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Evaluation of The Influence of Rice Husk Bio-oil Use, as an Addition for Structural Concrete

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Abstract**—***This work seeks to evaluate the influences of the addition of rice husk bio-oil in the concrete mixture for structural purposes. In the first stage of the research, through the pyrolysis process, the fraction of bio-oil was obtained and in a second moment, its addition to the cement paste and the concrete mixture. With the use of oil obtained from rice husk, it was aimed to analyze the effects generated in cement paste and concrete in the fresh and hardened states, consequently seeking to evaluate the potential of the liquid as a surfactant addition to concretes. The study embraces the analysis of the physical and mechanical properties of the concrete mixt with the addition of the bio-oil. The results indicate that these properties undergo changes, which may enable the use of its by-product.*

Keywords**— *bio-oil, rice hulls, rice husk, concrete.***

I. INTRODUCTION

Contrary to what is imagined, additions to composite materials mixtures, for structural goals, are quite old. It was already used by the Romans long before Portland cement, which is the most common type of concrete, nowadays [1].

Recently, the incorporation of residues in cement mixtures has growing significantly in research, in the field of civil engineering, due to presenting technical advantages and social benefits related to the reuse of organic materials available in the nature. Contributing with the sustainability [2].

Some alternatives are being studied by researchers, such as the use of residual biomass from the agriculture in the production of concrete.

The biomass of rice husk, the subject of this research, already has functionality in several industrial sectors, such as its use in biomass power plants, due to its high heat capacity and as a mineral addition to concrete, and its high silica content.

The by-product resulting from the grain processing corresponds to approximately 20% of rice total weight, meaning that the production of this cereal generates a large amount of waste [3] [4].

The use of rice husk as a source of silica and oil production has been widely discussed in scientific studies. Such product is one of the main readily available biomass resources, being an ideal fuel for electricity generation, activated carbon production and silica production, widely used as mineral addition for structural concrete [5] [6].

The yield of each by-product obtained in the hull pyrolysis process, depends on the biomass characteristics, besides the main parameters of the process, such as reaction temperature, heating rate, residence time and particle size of the biomass [7].

[8] showed, in his master's thesis, about rapid pyrolysis of rice hulls, that the bio-oil generated in the process proved to be rich in oxygenated compounds (phenols, ketones and carboxylic acids), the main components of plasticizer additives according to [9], thus there is an indicator that bio-oil may have a similar effect on concrete and cement paste.

In this context, the general objective of this study is to evaluate and to compare, the physical-mechanical properties of the cement and concrete mixed with the addition of rice hulls bio-oil.

II. METHODOLOGY

The activities for the development of this study were divided into two stages: Production of bio-oil and its application in concrete and cement paste.

2.1 Pyrolysis of rice husk.

For starting the pyrolysis it was necessary to make briquettes, cylindrical biomass, as shown in Fig. 1

Fig.1: Wet and processed rice husk briquettes.

The process consists in the fractionation of 200g of rice husk in a low-speed blender and its subsequent sieving in a standard 1.18mm mesh sieve. 100ml of water was added to the pass-through material and the hydrated biomass was pressed into a 20cm long and 32mm diameter tube. We used a low-speed blender to decrease the granulometry of the material, then sieve it with a 1.18mm sieve from the normal series. We produced 3 briquettes with that amount and the rest was discarded.

Subsequently, the hydrated biomass was pressed into a cylindrical pipe 20cm long and 32mm in diameter. The briquettes were dried in a heating chamber for 24 hours.

The adopted intermediate pyrolysis process, characterized by [10], occurs between 500 °C and 650 °C with a heating rate varying between 1 °C/min and 10 °C/min and residence time of 5 min and 15 min. Consequently, the pressure stays at 0.1 MPa during the process. Typically, the yields of products in this modality are between 40-60% bio-oil, 20-30% non-condensable gases and 15-25% biochar.

The thermal conversion of the biomass was made in a 100cm long, stainless steel fixed bed reactor with a 10cm outside diameter, operated in batch mode, with water vapor as the carrier gas, as shown in Fig. 2

Fig.2: Fixed bed reactor in stainless steel body.

For mass and yield balance purposes, after the reaction and cooling of the pyrolysis unit, the coal, gas and oil fractions obtained were weighed.

2.2 Dosage and addition of bio-oil to concrete

In this stage, concrete was produced with a referenced mix proportioned by the Brazilian Portland Cement Association (ABCP) method and the addition of the bio-oil.

This method consists of collecting data in the laboratory of the materials used in the production of concrete, they are: fineness modulus (FM), maximum characteristic length (MCL), humidity (h%), specific mass (γ) and unit (δ). From the data obtained, tables and graphs were used to support obtaining the appropriate proportions for the mix.

The fck (Feature Compression Know at 28 days) of 30 MPa was defined for an aggressiveness class II [11], moderate aggressiveness class and low risk of deterioration of the structure. Another characteristic adopted was a concrete slump equal to 50 ± 10mm.

Based on the concrete mix, the consumption of the necessary inputs for making 24 specimens for each bio-oil content was calculated, in the percentages of 0.5 and 1.0% of addition in relation to the cement mass of the mix.

III. RESULTS AND DISCUSSION

3.1 Preliminary Bio-oil Evaluation

In this research, it was used results of bio-oil characterizations made recently and similarly, for the development of the bio-oil for this research.

The data referring to the physical and chemical properties of rice husk oil can give strong indications about the quality, toxicity and stability of the product, as stated in [8]. According to the author, chromatographic and spectrographic methods are the main instruments for the characterization.

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For [12] both the pyrolysis temperature and the properties of the raw material used, strongly influence in the properties of the liquid obtained.

Bio-oil, also called pyrolysis oil, is a liquid mixture of dark brown color and contains several organic compounds, such as: acids, alcohols, ketones, aldehydes, phenols, ethers, esters, sugars, furans and alkenes; in addition to nitrogenated compounds and various oxygenated compounds, as shown in Fig. 3 [13]

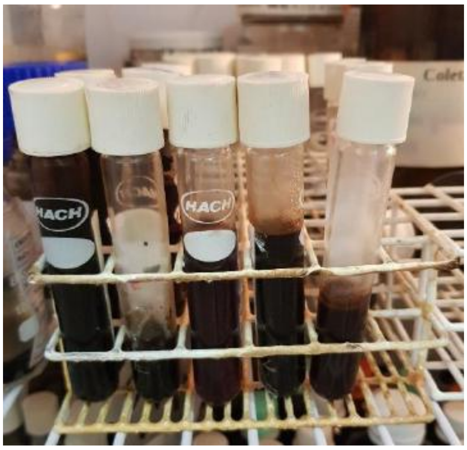

Fig.3: Bio-oil obtained from pyrolysis.

3.2 Concrete in fresh state (Slump-test)

For the slump-test, significant changes were observed, since they exceeded the admitted variation defined in calculation by the ABCP/ACI method (Portland Cement Brazilian Association/American Concrete Institute), (50 ± 10mm).

There was an increase of 9% and 23%, with the addition of bio-oil with proportion of 0.5% and 1.0% respectively. The Table 1 below shows the values obtained in the laboratory for the reference mixture and the respective additions.

Table 1. Results of Slump-test of cone trunk.

% Addition	W/C Ratio	Slump (mm)	Increase
0.00%	0.52	50	0.00%
0.50%	0.52	55	9%
1.00%	0.52	65	23%

3.3 Initial and Final Setting Time

Observing the setting time obtained via determination assay [14], there was an increase in the initial and final setting time. The table 2 below shows the values obtained.

Table 2. Setting time obtained via determination assay.

% Addition	W/C Ratio	Initial Setting Time	Final Setting Time
0.00%	0.30	2h45min	3h36min
0.50%	0.30	2h46min	3h56min
1.00%	0.30	3h10min	4h28min

It is possible to note that, both initial and final setting time of the sample, with the addition of 0.5% of the oil, increased on average 22.5min compared to the reference. The initial and final setting for the mixture with the highest percentage, increased 25 and 52 minutes respectively in relation to the reference mixture.

Fulfilling the requirements established in [15], with initial of setting $\Delta t \geq 90$ minutes and final of setting $\Delta t \leq 360$ minutes, the bio-oil is characterized as a plasticizing retardant additive.

The analyses of the chemical composition of the bio-oil show that the present compounds have carbon chains with hydroxyls (hydroxylated carboxylic acids), which according to studies developed by [16], affect the chemical reactions between cement compounds and water, delaying the setting. Still according to the author, the hydroxyl linked to the carbonic chain makes the medium more acidic, causing a delay in the setting without relation to plasticity.

3.4 Concrete in Hardened State

In the concrete axial compression strength test, 6 specimens of each sample were used for the ages of 7, 14, 28 and 90 days, in a total of 24 specimens tested. The results are shown in Table 3.

Table 3. Results of axial compression strength.

Average Compressive Strength (MPa)			
Age (days)	Ref.	0,5%	1,0%
7	25,0	23,9	19,4
14	30,1	27,4	22,78
28	30,9	29,2	25,5
90	31,5	29,1	28,5

It was observed that the concrete with additive (bio-oil), did not exceed the reference concrete (without additive) in its resistance to compression at any age. However, it is known that the presence of hydroxyls and some acids in the compounds already detected in the bio-oil, can initially be attributed to this decrease in resistance gain in the early ages, knowing that acidic average cause the delay in hydration and cement setting time.

The average compressive strengths of the specimens with addition of 0.5%, at 7 and 28 days, reached more than 90% of the average compressive strength of the specimens prepared without addition, respecting the requirements of [17]. At 7 days the reach was 95.60%, and at 28 days the reach was 94.49%

When performing the analysis of variance (ANOVA), it was possible to identify, statistically that, there was a difference between the samples and by Tukey's test it was possible to identify where this variation occurred

For the age of 7 days, the variation factor obtained, number $F_{calculated}$, was equal to 10.29, in other words, there was a difference between the samples since the F_{tabled} was 6.36, with a 99% confidence level. The two mixtures with bio-oil influenced the results in the order of 57.84% in relation to the mixture without addition, however, between them there was no variation.

For 28 days a $F_{calculated}$ number obtained was equal to 4.497, a very close value to the F_{tabled}, thus, showing that the variations decreased, with variation only between the sample dosed with 1.0% in relation to the reference concrete. The influence of bio-oil, for this age, was 37.48%.

IV. CONCLUSION

The analysis of data obtained from the compressive strength test, initial and final of setting time, can confirm the interference of the use of bio-oil as an addition to concrete. All results show significant changes in the setting time and compressive strength when compared to the reference concrete.

In the hardened state the specimens with bio-oil, despite not showing resistance gain in relation to the reference concrete (without bio-oil), it cannot be discarded, even if not very relevant, the resistance gain in advanced ages.

The results indicated that the addition of bio-oil showed improvements in the concrete in the fresh state, with an increase of 23% in the slump with 1.0% of bio-oil in relation to the weight of the cement, collaborating to justify the hypothesis that the bio-oil has a characteristic of a plasticizer additive.

Although the static analysis demonstrates that there were significant changes in the concrete with the addition of bio-oil. This is a preliminary study for a potential plasticizer additive and set retarder, with the need of others analysis and tests, especially with regard to the behavior in the microstructure of the concrete.

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