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Characterization of the Mechanical Properties of Concrete with Addition of Bamboo Fiber - Porto Nacional/TO

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***Abstract*— The search for materials which do not unduly the environment by reducing the cost of production is increasing throughout the world. In the construction sector, concrete is the most consumed material in the world. Its production with bamboo fiber addition can contribute to minimize environmental impacts and production costs by reducing the extraction of natural resources. This study aimed to investigate the mechanical properties of bamboo located in the region of Porto Nacional - TO, Brazil and its application as a binder (Portland cement) in the production of concrete. The research aimed at results that allowed to verify the behavior of the concrete in relation to its uniaxial compressive strength at 28 days of the specimens produced with the addition of bamboo fibers, replacing the cement binder. Bamboo fibers and aggregates were characterized and evaluated according to the material and defined by the trait (1: 1.68: 2.68: 0.482), with replacement percentages set at 3%, 4% and 5%. Therefore, through the tests that were performed, the possibility of replacing the Portland cement binder with natural polymeric bamboo fibers was verified, which proved to be viable and quite advantageous not only for the environmental and economic, but also in the material strength gain.*
Keywords*— Concrete, Bamboo fibers, Mechanical properties, Resistance.

I. INTRODUCTION

Concrete, a structural material widely used worldwide, has been the subject of continuous research (SALVADOR; FERNANDES; DE FIGUEIREDO, 2015), due to its wide importance and application in the field of construction (BARBOZA; DE ALMEIDA FILHO, 2018; BITTENCOURT, 2009). With the growth of urbanization and industrialization, the demand for concrete is increasing day by day. Therefore, raw materials and natural resources are required in large quantities for concrete production worldwide (S, 2017). According to Zein (2017) cement is the main constituent of concrete.

In the civil construction sector, applications and productions of cement, is seen as one of the processes more aggressive to the environment (FERNANDES, SERPA, 2017). It is estimated that only the cement industry is responsible for about 7% of the entire CO_2 generated throughout the world, for a ton of cement produced are released a ton of co_2 in the atmosphere, and to produce 1 ton of ligand, are required 2.8 tonnes of raw materials (APRIANTI et al., 2015; wholesale; Forest, 2018). This information shows how important it is to reduce the consumption of Portland cement due to the environmental problems caused by their production (MORAES et al., 2015).

In Brazil, civil construction, besides consuming about 80% of all-natural resources available in the environment, is also responsible for consuming about 44% of all energy produced in the country (CORDEIRO et al., 2017).

The search for new alternatives that will contribute to the efficiency of the Concrete in its production, today, has been growing significantly (CAMPOS, 2015). Several studies have focused on finding an alternative that can be used as material for replacement of cement (S, 2017), thus various categories of fibers are used as reinforcement in concrete, being the main, steel fibers, polymeric fibers and natural fibers (AMARAL JÚNIOR; SILVA; MORAVIA, 2017).

Recently, the natural fibers have been highlighted in studies such as the additions more used to improve certain characteristics of concrete, primarily to reduce the effects of cracking in your state hardened (FIGUEIREDO, 2017). In addition, were developed various research programs of the use of bamboo and natural fibers (sisal, coconut, carbonized rice, sugar cane bagasse, lump of açai, piassava, bamboo pulp, among others) for the production

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of concrete, so as to provide improvements related to durability and mechanical resistance of the materials (GERALDO, 2017; FIGUEIREDO, 2017), also, are characterized as materials with low environmental impact to be employed in buildings (GERALDO, 2017).

Therefore, bamboo is a plant raw material that has efficient mechanical properties and great potential to be explored by civil engineering (BRAGA FILHO et al., 2010). In addition to adding great ecological benefits, it absorbs CO_2 from the atmosphere, generates less environmental impact and reduces the final cost of the work, thus becoming a renewable resource in civil construction compared to conventional inputs (GHAVAMI; MARINHO, 2005; SILVA et al., 2015).

Therefore, in order to reduce energy expenditure and increase sustainability in civil construction by reducing the extraction of natural aggregates and constituting a plausible and viable option in the production of concrete in the region of Porto Nacional - TO, an experimental study was conducted with the objective to evaluate the influence of the addition partial (3%, 4% and 5%) of polymeric fibers of bamboo on mechanical properties of concrete, being possible to analyze their influence on the resistance to the uniaxial compression test, in order to assess its feasibility for use in constructions sites.

II. METHODOLOGY

Initially, for this study the polymeric fibers of bamboo were produced for partial addition of cement (binder) in the production of concrete. The acquisition of material (culms of bamboo), were collected in the urban area of the municipality of Porto Nacional - TO.

The bamboo fibers used in the concrete mass were produced through a manual shredding process. For the extraction and production process, the stems were initially cut, and the knots removed from the bamboo. After they were washed and dried at an ambient temperature of (±40 °C), then the stems were cut in strips in a horizontal direction to make the production of polymeric fibers. The fibers were cut with lengths of five (5) cm, as shown in Fig. 1.

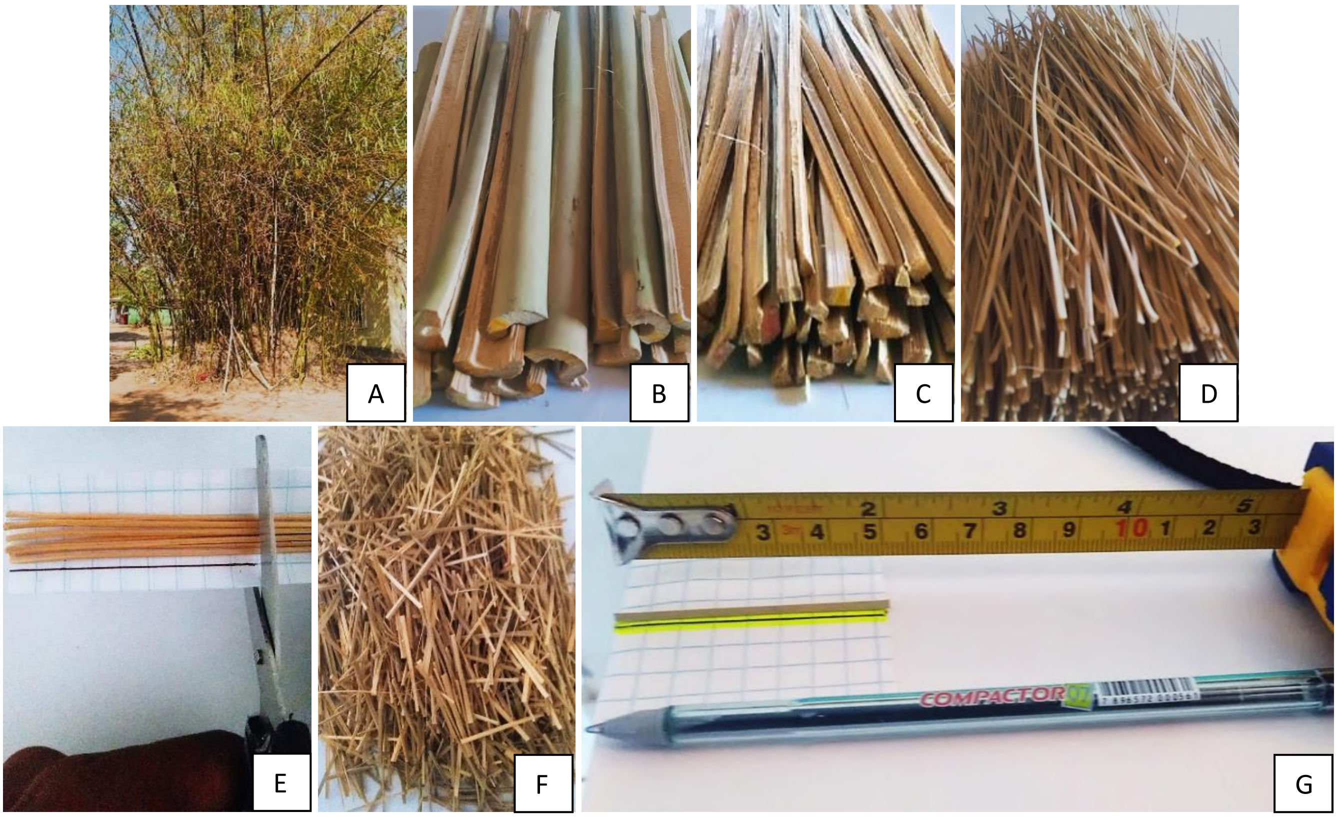

Fig.1: Extraction and cutting of fibers, (A) Bambuzal, (B) (C) and (D) Extraction and manual production, (E) Cutting of fibers on graded paper, (F) Cut polymeric fibers, (G) Fiber Length.

It is worth mentioning that the fibers of bamboo were placed submerged during 24 hours in water, for analysis and verification of the quantity of water absorbed by the fibers. The absorption of water is the value in percentage, of the weight of water absorbed by the body after immersion (BARBAR, 2017), this percentage is calculated and expressed by equation 1.

After 24 hours of soaking, the bamboo fibers were removed for the weighing process and the absorbed water content calculated. The bamboo fibers absorbed 16.06% of water, ranging from 0.965 g to 0.810 g immersion, difference of 28.66 g compared to dry weight, i.e., twice the weight of its natural mass of 19.87 g. To be a plant material, bamboo absorbs water with ease, recent research shows that the material continues to absorb water after 24 h, reaching more than 30% of absorption (GERALDO, 2017). The Fig. 2, demonstrates the process of porosity of the material.

$$A(A)\% = \frac{[Pa - Pab]}{Pa} x100 \quad (1)$$

- ***(A%)*** *= Water absorption in percentage;*
- ***Pa*** *= Weight of Water;*
- ***Pab*** *= Weight of Water absorptio.*

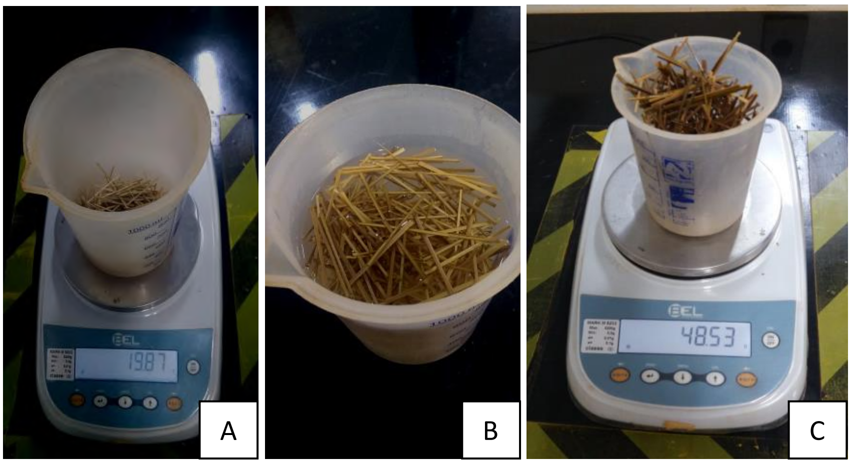

Fig.2: Determination of water content absorbed by bamboo fibers, (A) Weight in dry natural state, (B) Immersion in water, (C) Weight of fibers (post) immersion.

When absorbing water, bamboo vegetable fibers undergo dimensional variations, their dimensions increase when they absorb and decrease when they lose it (GERALDO, 2017), so the dry base and wet base content can vary from 4.85% to 4.65 %. This happens because the specific mass of the bamboo culm walls is lower than water, ranging from 0.8 kg / dm³ to 0.95 kg / dm³, in the most suitable species for construction (GERALDO, 2017), the water content in wet basis can be calculated by equation 2.

$$\%Bu = \left[\frac{Pa}{Pa + Pfs}\right] x100 \quad (2)$$

- ***Pa*** *= Weight of water;*
- ***Pfs*** *= Weight of dry fiber;*
- ***%Bu*** *= Percentage of moisture content on a wet basis.*

The production of concrete consists of the composition of cement, aggregates and properly dosed water (RIBEIRO, 2013). For this study, the following materials were used:

- Small aggregate (Coarse Sand);
- Large aggregate (Gravel 1);
- Portland cement composed with slag CPII F 32 TO;
- Water supplied by the supply company;
- Bamboo fibers.

The natural aggregate was collected on the Tocantins river, near the city of Palmas, Tocantins State, Brazil, and sorted by similarity of size ABNT NBR NM 7211:2005. Portland cement CPII F 32 TO was used as a binder to obtain the concrete, according to ABNT NBR 5736: 1991 specifications. All raw materials used in the manufacture of the bodies of evidence, were weighed using a digital balance. The table 1 and 2 shows the proportions of materials consumed for each type of concrete studied and the levels of additions of dashes represented in percentage.

For the concrete trace, the following formulation was used: 1: 1.68 (cement: sand), 1: 2.68 (cement: crushed stone) and 1: 0.482 (cement: water) (ANTONIO et al., 2019), as there was a slight change from the amount of water (± 600 ml). The table 3 shows the compositions characteristics of determination of trace of concrete with and without the addition of fibers of bamboo. Note - if the only change that occurred was between the cement and the addition of fibers.

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Table.1: proportions of consumable materials for each type of concrete

Concrete	Cement (g)	Sand (g)	Gravel (g)	Water (ml)	Fiber (g)
0%	22 000	56 960	58 960	11 200	0
3%	21 340	56 960	58 960	11 200	0,66
4%	21 120	56 960	58 960	11 200	0,88
5%	20 900	56 960	58 960	11 200	1,1

Table.2: levels of addition of Traces

Dash	Cement	Sand	Gravel
TC conventional	100%	100%	100%
TC3	97%	100%	100%
TC4	96%	100%	100%
TC5	95%	100%	100%

Table.3: Composition characteristics of determination of trace on the concrete.

Betonadas	Dash (Kg)	Rupture
0% (Fiber)	22.00: 50.40: 58.96:11.20	28 days
3% (Fiber) Bamboo	21.34: 50.40: 58.96:11.20	28 days
4% (Fiber) Bamboo	21.12: 50.40: 58.96:11.20	28 days
5% (Fiber) Bamboo	20.90: 50.40: 58.96:11.20	28 days

The concrete dosage was designed to obtain the 20MPa fck compressive strength, established by ABNT NBR 6118: 2003 at 28 days, using CPII F 32 cement, without the use of additives. After production and characterization of the materials, the bamboo fibers were partially added to the concrete. Concrete preparation was performed with the aid of a stationary concrete mixer. After the preparation of the molds, the traces were made using bamboo fibers with substitution contents of 0% (conventional concrete), 3%, 4% and 5%. in the binder (cement CPII F 32). Concrete production follows the specifications of ABNT NBR 7215: 1996, where dry materials were mixed in the order of coarse aggregate, fine aggregate and cement, then water was added, the bamboo fibers were the last components to be added to the mixture to form a paste consistent and homogeneous.

The consistency of the concrete of each composition was evaluated through the Slump test, according to the specifications ABNT NBR NM 67:1998. The mixture of concrete was placed in the trunk of metallic mold - cone in three layers, each layer also distributed received 25 blows manuals with the aid of a lawgiver, the mold was removed slowly in the vertical direction for checking the final reduction of concrete (difference between the height of the mold and the height of the mixture of concrete). The Fig. 3 shows the reduction in Slump test of the conventional mixture and compositions in fibers of bamboo.

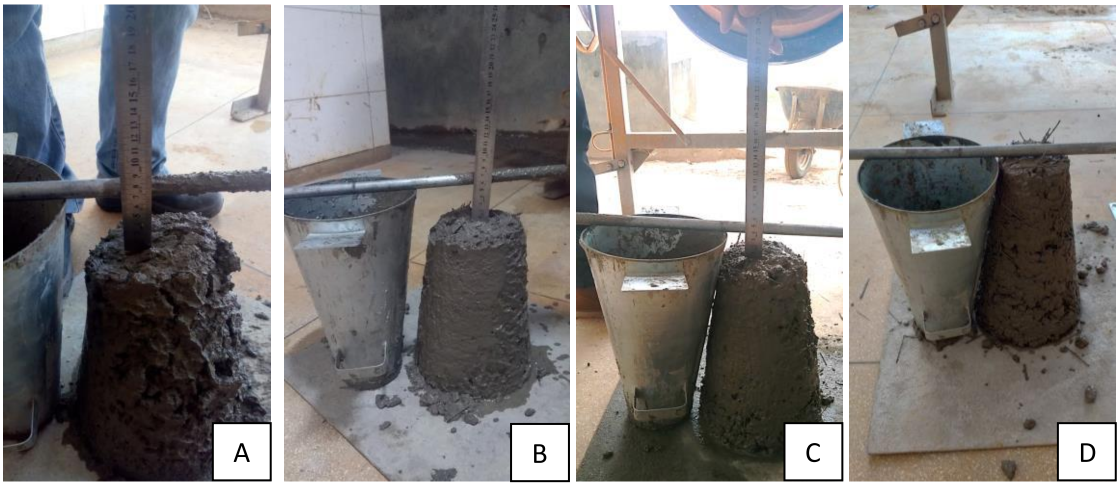

Fig.3: Cone Trunk Discharge Test, (A) Conventional Concrete, (B) Concrete with 3% Bamboo Fiber Addition, (C) Concrete with 4% Bamboo Fiber Addition, (D) Concrete with 5% added bamboo fibers.

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Once the proper consistency was reached, the molding process of the specimens was started, the concrete was placed in the molds with the aid of a trowel and the concrete compactor (AF 46 mm), to eliminate the voids of the mass, establishing its uniformity. Subsequently, 30 cylindrical specimens were made for each composition in the dimensions of Φ10x20cm. After 24 hours, the samples were removed from the cylinders, and placed in a tank of water saturated (hydration process) until they reach their ages (3, 7, 14, 21 and 28) days of curing, ABNT NBR 5738:2015, as shown in Fig. 4.

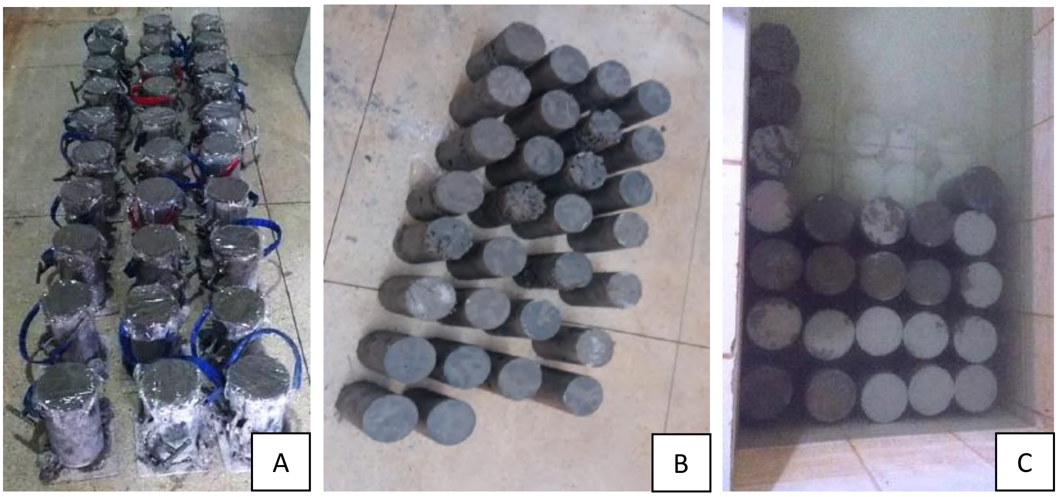

Fig.4: (A) forming the bodies of evidence, (B) Withdrawal of bodies of evidence, (C) hydration and healing of the bodies of evidence.

The samples of the formulated compositions, that is, with and without the addition of bamboo fibers, had their uniaxial compressive strength evaluated. The axial compression test consists of determining the maximum breaking load supported by the specimen.

The uniaxial compression resistance of the concrete was determined via the compression test in accordance with the specifications ABNT NBR 7215:1996. To this end, six (6) samples were tested for each formulation and age (3, 7, 14, 21 and 28) days of curing, totaling in the end one hundred and twenty (120) bodies of evidence, subsequently allocated to each one, strictly centralized in the bottom plate hydraulic press mechanical (EMIC DL 3000), illustrated in Fig. 5, breakage and resistance determination were performed automatically.

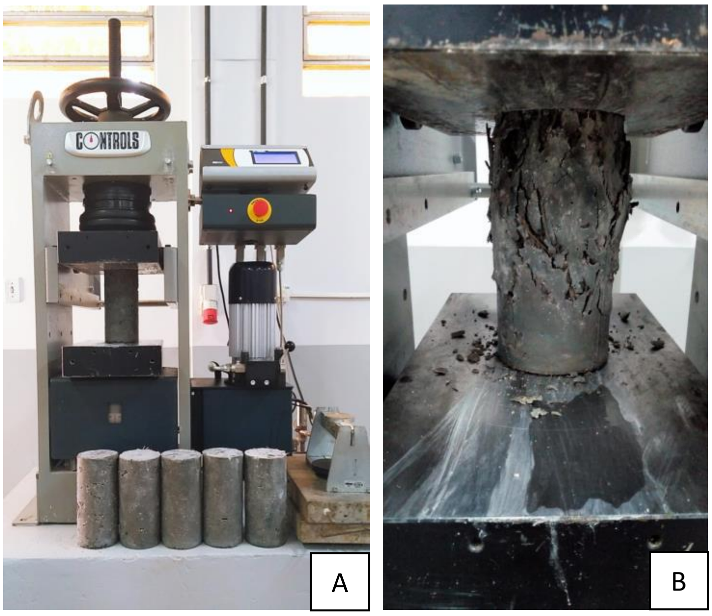

Fig.5: (A) Test of resistance to compression, (B)Uniaxial compression.

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III. RESULTS AND DISCURSSIONS

The test of abatement of the concrete with additions of bamboo fibers of 3% and 4% obtained satisfactory results of 55 mm and 40 mm in comparison to the conventional rebate of 0% of 65 mm, it is noteworthy that bamboo fibers absorbed about (± 16%) of water during the production process of concrete, the addition of 5% presented a rebate, not satisfactory, with dry consistency and little homogenization, the table 4 presents the values of rebate of dashes.

Table.4: Trace Drop Values

Características	**Dashes**			
Contents	0%	3%	4%	5%
Rebate (mm)	65	55	45	-

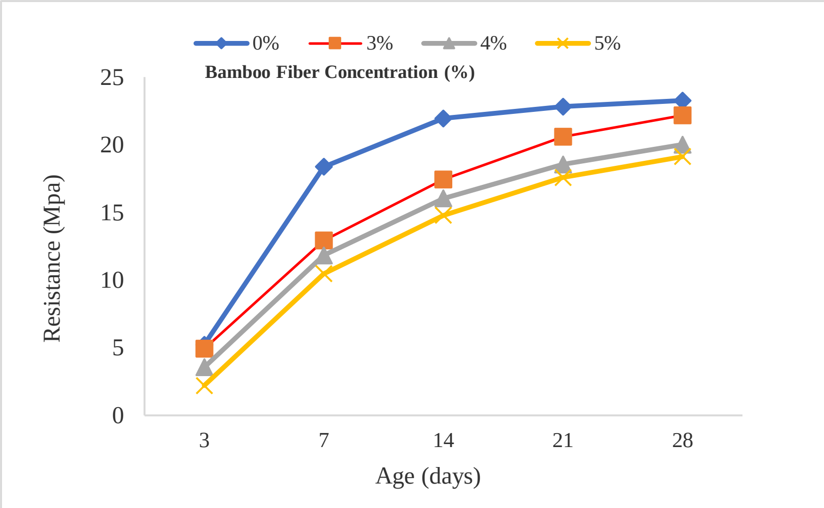

Fig.6: Graph of compressive strength gains after 3, 7, 14, 21 and 28 days with addition of 5 cm bamboo fiber concentration.

Fig. 6, demonstrates the compressive strengths achieved from (3 to 28) days, respectively, to determine the uniaxial compressive strength. It can be observed that the lowest value of compressive strength occurred in the composition of 5% of bamboo fibers at 28 days and the highest value occurred in concrete with the addition of 3% of bamboo fibers. Therefore, the obtained values demonstrate resistance gain gradually between the tests.

It was also observed that there was a significant decrease in the compressive strengths of both ages, between the conventional concrete (0% addition) and the concrete with the addition of cement by the bamboo fiber during the 3 days of hydration and cure, demonstrating that the composition of 3% was the most approached the resistance value of the conventional concrete, as shown in Fig. 7.

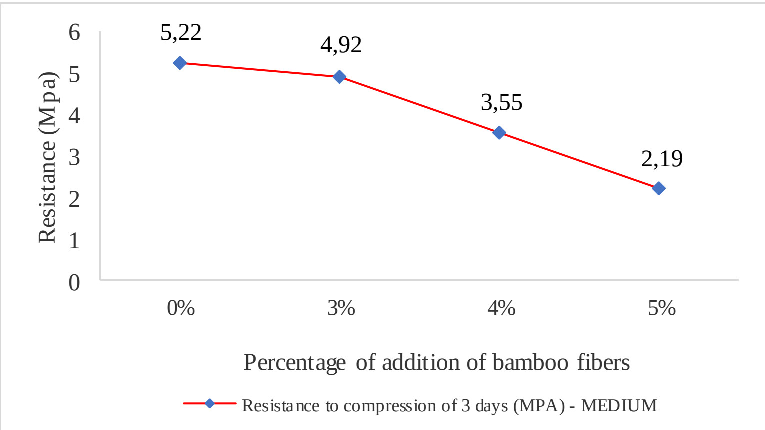

Fig.7: Graph of resistance to compression for 3 days.

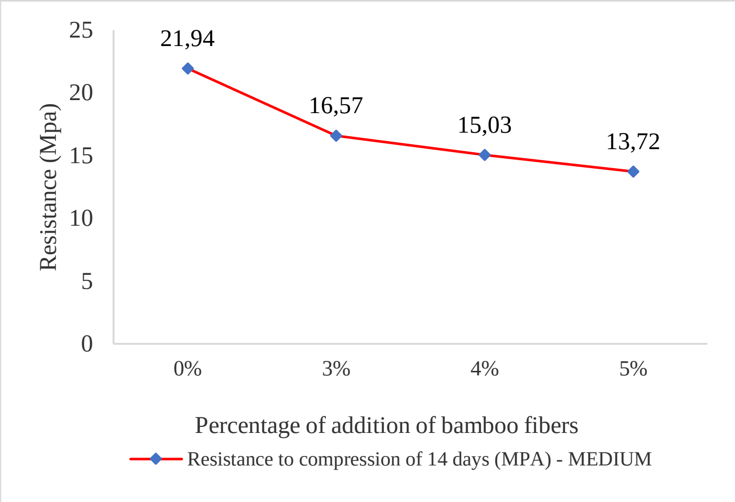

Fig.8: Graph of resistance to compression for 14 days.

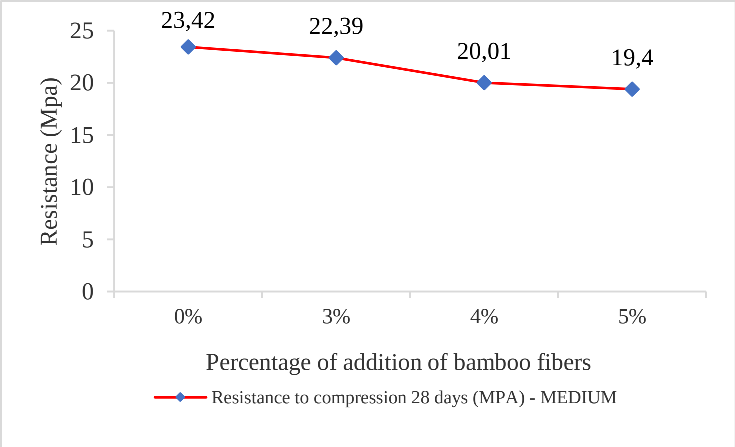

Fig.9: Graph of resistance to compression for 28 days.

In Fig. 8, shows that there was a minimal difference of resistance to compression between both compositions of bamboo fibers during the ages of 14 days, in relation to the concrete control.

Note that only the concrete from 5% was below the desired strength of 20 Mpa, shown in Fig. 9, the concrete with 3% and 4% of addition of fibers of bamboo to 28 days showed a tendency of significant increase of resistance with 22.39 Mpa and 20.01 Mpa respectively, next to conventional concrete (0%), with resistance of 23.42 Mpa.

Souza et al., (2014) in his research with the addition of fibers of bamboo analyzed results obtained between the compositions of 2% and 5% with the use of additives and obtained a gain of 34.04 Mpa resistors and 24.77 Mpa for 28 days. It is worth mentioning that all materials used in this study was composed of natural raw materials without the use of additive and showed a gain of resistance satisfactory.

Given the observed analyzes, it can be noted that both the conventional concrete (0%) and the concrete of 3% and 4% had satisfactory results in the tests performed, the concrete of 5% obtained results below the proposed goal, established by ABNT NBR 6118: 2003.

These results indicate the possibility of adding 3% of Portland cement by fibers of bamboo, without prejudice of resistance to compression. According to Souza et al., (2014) the use of natural fibers to the formulation of concrete is technically feasible for civil construction.

IV. CONCLUSION

The concrete is a material that gets high resistance to compression. The conventional concrete had resistance to compression of 23.42 Mpa for 28 days, by comparing, only concrete with a 5% addition content suffered a reduction in compressive strength, staying with 19.40 Mpa, in which becomes negligible. Already the additions of 3% and 4% resulted in a gain of resistance, getting close to the conventional concrete, with respectively, 22.39 Mpa and 20.01 Mpa.

Therefore, the replacement of Portland cement by 3% and 4% addition of bamboo polymeric fibers did not affect statistically the compressive strength of the concrete in relation to the studied trait. The traces of 3% and 4% evaluated were adequate, however the rebate of 5% was not satisfactory, resulting in a lower resistance to conventional trait in parameter of water absorption by immersion, differing from the other traits.

Thus, with the considerations made and the results obtained, the work successfully achieved its objective, showing if feasible and with the possibility of increasing sustainability in constructions.

REFERENCES

[1] ABNT-NBR-NM-67, Rio de Janeiro 1998. **Concrete - Determination of consistency by tapering the trunk**.
[2] ABNT-NBR-5736, Rio de Janeiro 1991. **Concrete - Portland pozzolanic cement**.
[3] ABNT-NBR-5738, Rio de Janeiro 2015. **Concrete - Procedure for molding and curing specimens**.
[4] ABNT-NBR-6118, Rio de Janeiro 2013. **Concrete - Design of concrete structures.**
[5] ABNT-NBR-7211, Rio de Janeiro 2005. **Aggregates - Aggregates for concrete**.
[6] ABNT-NBR-7215, Rio de Janeiro 1996. **Portland Cement - Determination of compressive strength**.
[7] AMARAL JÚNIOR, J. C. DO; SILVA, L. C. F .; MORAVIA, W. G. Experimental analysis of the addition of polymeric fibers in the mechanical properties of concrete. **Feature (Rio de Janeiro)**, v. 22, no. 1, p. 1–9, 2017.
[8] ANTONIO, F. et al. Glass foams produced from soda lime glass waste and rice husk ash applied as partial substitutes for concrete aggregates. **Process Safety and Environmental Protection**, v. 128, p. 77–84, 2019.
[9] APRIANTI, E. et al. Supplementary cementitious materials from agricultural wastes - A review. **Construction and Building Materials**, v. 74, p. 176–187, 2015.
[10] BARBAR, J. S. **Influence of the incorporated air content on the performance of concretes with different aggregate contents**. Sao Carlos: University of Sao Paulo, Jan 24. 2017.
[11] BARBOZA, L. DA S .; DE ALMEIDA FILHO, F. M. Self-compacting concrete with low cement consumption: Impact of reduced cement consumption on compressive strength. **Feature (Rio de Janeiro)**, v. 23, no. Oct. 3, 18 2018.
[12] BRAGA FILHO, A. C. et al. Structural behavior of concrete studs reinforced with studded bamboo slats. **Brazilian Journal of Agricultural and Environmental Engineering**, v. 14, no. 10, p. 1115–1122, Oct. 2010.
[13] LAMB, L. DE N. P. et al. Process evaluation of concrete mixtures with recycled coarse aggregates. **Built Environment**, v. 17, no. 3, p. 255–265, Jul. 2017
[14] CAMPOS, M. A. Use of alternative aggregates of porcelain electrical insulators in concrete. **Concrete and cement. Investigation and development**, v. 7, no. 1, p. 30–43, 2015.
[15] FERNANDES, G. A .; SERPA, N. S. C. Solid Waste in the Production of Concrete Artifacts. **Brasiliense Journal of Engineering and Applied Physics**, p. 61–67, jun. 2017
[16] FIGUEIREDO, A. D. Fiber Reinforced Concrete. **IBRACON Journal of Structures and Materials**, v. 5, no. 87, p. 1–116, 2017.
[17] GERALDO, C. I. **Building Materials and Science Sciences and Materials Engineering**. Ed. III. t. Rio de Janeiro: IBRACON, 2017.
[18] GHAVAMI, K .; MARINHO, A. B. Physical and mechanical properties of the whole stem of the bamboo of the species Guadua angustifolia. **Brazilian Journal of Agricultural and Environmental Engineering**, v. 9, no. 1, p. 107–114, Mar. 2005.
[19] GROSSO, M .; FLORESTA, A. Incorporation of uncrushed sugarcane bagasse ash into concrete at different strengths. **Acta Iguazu**, v. 5, p. 85–93, 2018.
[20] MALHOTRA, V M. **Role of supplementary cementing materials in reducing greenhouse gas emissions**. In: Gjorv E, Sakai K, editors. Concrete technology for sustainable development in the 21 st century. London: E&FN Spon, 2000. P. 226-35.
[21] MORAES, J. C. B. et al. Assessment of sugar cane straw ash (SCSA) as pozzolanic material in blended Portland cement: Microstructural characterization of pastes and mechanical strength of mortars. **Construction and Building Materials**, v. 94, p. 670–677, 2015.
[22] Ribeiro, Carmen Couto. **Building materials**. Carmen Couto Ribeiro, Joana Darc Silva Pinto, Tadeu Starling. 4. Ed. Ver. Belo Horizonte: Publisher UFMG, 2013.
[23] SALVADOR, R. P .; FERNANDES, J. F .; DE FIGUEIREDO, A. D. Evaluation of low-fiber reinforced concrete for structural purposes according to EN 14651-2007. **Materia Magazine**, v. 20, no. 4, p. 961–974, 2015.
[24] S, E. A. A huge number of waste material can be supplementary cementitious material (SCM) for concrete production and review part II. **Journal of Cleaner Production**, v. 142, p. 4178–4194, 2017.
[25] SILVA, E. et al. Technical analysis for the reuse of coconut fiber in construction industry. **Ambienc**e, v. 11, no. 3, p. 669–683, 2015.
[26] SOUZA, C. A. DE et al. Structural concrete with addition of vegetable fibers. **Constituent Magazine**, v. 06, no. 02, p. 14–19, 2014.
[27] Zein, FT, Zulfikar, (2017**). Pengaruh Penggunaan Retarder Pada Workability Beton Geopolymer**. Jurusan Teknik Sipil - Fakultas Teknik UM, Indonesia.