Analysis of the hydraulic characteristics of bamboo tubes, using the brazilian bamboo - species Bambusa vulgaris var. vittata

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***Abstract*— With the growing repercussion of the impact of the use of plastic, there was the need for replacement of this material in several sectors of the economy. Among these is the civil construction industry, which has been innovating the types of materials used in conventional construction methods. Aiming at these adaptations, this study proposes to analyze the feasibility of using bamboo as a hydraulic conductor, justifying its application, especially in the communities of the interior of the state of Amazonas, where the arrival of inputs is hindered by long distances and deficient means of transportation. Bamboo samples were extracted and submitted to laboratory tests where a hydraulic system was assembled in order to determine the flow and pressure loss of the bamboo. The system relied on the use of PVC pipes and connections. To read the pressure drop and the flow rate, hoses and a hydrometer were used, respectively, where at one end there was a pump responsible for the functioning of the system and at the other end, a water tank was closed, both belonging to the hydraulic laboratory of the Federal Institute of Amazonas. The data collected in the test were analyzed and used in the Hazen-Williams equation that resulted in the coefficient of roughness C which, for the bamboo, the value obtained was 103.15. Through the study developed, it is possible to design and apply bamboo pipes according to the ABNT NBR-5626 criteria.*

***Keywords*— Bamboo, Bambusa vulgaris var. vittata, hydraulic, hydrosanitary installations, pressure drop.**

I. INTRODUCTION

It has long been observed that the issue of sustainability is discussed in Brazil and, in this context, the need arose to study alternative methods and materials that would cause less impact on the environment. In this context, we highlight civil construction as a technical area concerned with the development of the study of natural resources and renewable sources, using unconventional and recyclable raw materials, enabling economy and modernizing the constructive processes already known.

A good alternative is the use of vegetal origin materials such as bamboo - light, resistant, rigid and versatile vegetal [14]. Thanks to its easy adaptation in most of the Brazilian territory, its rapid growth and the possibility of cultivating it in areas unfit for agriculture, protecting the soil from erosion, bamboo would be an alternative for its use, either in irrigation and drainage water supply or in wastewater supply [8]. Because it presents advantages such as accelerated growth, ease of planting and handling, and accessible acquisition value, bamboo can be used to replace PVC pipes used in hydrosanitary installations.

In Brazil, the most common exotic species are Bambusa vulgaris, Bambusa vulgaris var. vittata, Bambusa tuldoides and Dendrocalamus giganteus, all Asian origin brought by Portuguese colonizers and, later, the genus Phyllostachys [11]. We highlight the species found in abundance in the state of Amazonas is *Bambusa vulgaris var. vittata* known as bamboo-imperial or bamboo-Brazilian, which has the hardness and resistance as physical characteristics.

The study of the hydraulic behavior of bamboo in the Amazon region is lacking in information, therefore the objective of this study is to analyze the pressure loss, flow and roughness coefficient of bamboo-imperial pipes - *Bambusa vulgaris var. vittata* - using the Hazen-Williams equation and obtaining the data through laboratory tests in order to verify its hydraulic performance in comparison to PVC pipes.

II. METHODOLOGY

The research was of the experimental field type and quantitative approach in order to obtain the results and answers about the problematization presented in this work.

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The study was divided into three stages. The first is based on the definition of bibliographic research through primary sources, as well as technical reports, dissertations and published articles. The second is to select bamboo samples for the study, defining a pattern of choice and determining, through laboratory tests, the pressure drop and roughness established by the Hazen-Williams equation. After data analysis, the last step was to compare the data obtained from bamboo with the pertinent data to the PVC pipes, represented by graphs and tables.

2.1 Place of research and laboratory tests

The laboratory tests were carried out at the Hydraulics Laboratory of the Federal Institute of Education, Science and Technology of Amazonas - IFAM, where the assembly of the system and the tests to determine the pressure loss and flow of bamboo pipes were performed.

2.2 Bamboo Extraction Site

The sample of bamboos was taken from a predominantly residential region of the eastern zone of the city of Manaus.

2.3 Sample extraction and cleaning of nodes

The extraction of bamboo was performed with the aid of an axe, in which four samples of bamboo were cut above the first thatched, as shown in figure 1. Due to the objective of this study to propose the use of bamboo as a conductor for building systems, it was then decided to use diameters approximately 40 mm, a diameter widely used in water-sanitary installations.

As the body of the bamboo is born with a larger diameter and as it grows it becomes thinner, when extracting the bamboo it was opted to use the upper stalks because they are close to the diameter planned for the system. This decision affected the length that became 1.5 m, diverging from the desired length of 3.0 m.

After the extraction, the removal of the nodes was performed manually with the aid of an iron bar with sharp edges. Then, the excess of internal diaphragm of the bamboo was removed, presenting a treatment like what would be done in the interior of the Amazon, as shown in Fig. 2.


Fig.1: Bamboo extraction. Figure 2: Bamboo interior after cleaning the knots Bamboo interior after cleaning the knots. Source: Author.

2.4 Diameter Determination

With the samples present in the laboratory, the second stage of the research to determine the diameter was initiated. The chosen method was to fill the bamboo with water and pour it into a beaker. Through the liquid level it was possible to read the volume (mL). After collecting the volumes for all samples, the values obtained in the equation presented below were applied, allowing to know the mean internal diameter of each one;

$$(1)\,Dm = \frac{\sqrt{(4 \times VOL)}}{\sqrt{(\pi \times L)}}$$

Dm = average inner diameter of bamboo tube [m];

Vol = Inner Volume of Bamboo Tube [m3];

L = Bamboo Tube Length [m].

2.5 Determination of pressure drop

2.5.1 Materials Used

In order to determine the flow rate and the pressure drop, a system was created which had the following materials available:

Water meter ¾";

Water tank 410 L and pump belonging to Hidro Didactic machine;

Threadable plastic hose adapter ½";

Hose ½" 10 m;

4 bamboo samples 1.5 m with external Ø ≈ 40 mm;

PVC tube Ø 40 mm;

2 Flexive Hose 10 cm Ø = 2";

2 Clamp Ø = 2";

Register;

4 Tee with reduction 40x25 mm;

4 Bushing of 25x20 mm;

4 Threadable gloves of 20x ½";

2 Threadable gloves of 25x ¾";

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2 bushings of 40x25 mm;
5 knees Ø 40 mm;
Thread sealing tape;
Preparing solution;
Plastic adhesive for PVC.

2.5.2 System assembly

The process of assembling the system began with the welding of PVC pipes and fittings. At first the section of the tube to be welded was sanded, then the prepared solution was passed, and the plastic adhesive was applied finishing the welding, according to Fig. 3, 4 and 5.

Fig.3: Plastic preparation and adhesive solution for PVC. Source: author.

Fig.4: Application of the solution. Source: author.

Fig.5: Adhesive application. Source: author.

After assembly of the assembly frame, the bamboo sample was fitted with a flexible sleeve and clamps for attachment. With the sample inserted, the tests were started after connecting the system to the pump. The compound worked as follows: the pump threw water into the system, which rose through the first hose (ha) determining the first water column and so on. Through the difference between the water columns, it was determined the pressure loss of the bamboo (ha-hb) and the pvc (hc-hd) for the presented conditions. Then, the water flow followed in the direction of the hydrometer, promoting the reading of the flow and, later, led to the water tank that closed the system. The same process was repeated for all samples. For each sample, the AB and BA directions were analyzed for better visualization of the bamboo behavior, as shown in the following results.

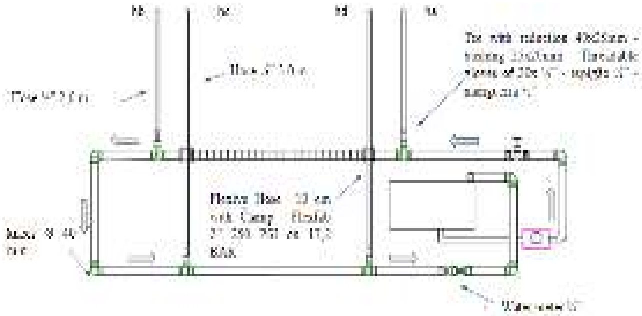

Fig.6: Scheme of the system detailing the connections used (the arrows indicate the flow of water). Source: author.

Fig.7: Real image of the test system, showing the machine used in the IFAM laboratory.

2.6 Bamboo roughness

With the values obtained - diameter, pressure loss and flow - it was possible to calculate the roughness coefficient of the bamboo using the Hazen-Williams equation;

$$(2)\, hfbamboo = \frac{10{,}646 \times L \times Q^{1{,}85}}{C^{1{,}85} \times Dm^{4{,}87}}$$

hf bamboo = Pressure drop in bamboo tube [m];
L = Tube length [m];
Q = Flow rate [m3/s];
Dm = Average bamboo tube inside diameter [m];

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C = Coefficient of roughness.

III. RESULTS AND DISCUSSIONS

At the end of the trial, the data were collected and subsequently treated. As previously mentioned, the samples were tested in AB and BA directions for better visualization of the bamboo behavior. The following tables show the results obtained in the field. The value for the coefficient (C) was obtained in calculation using the Hazen-Williams equation.

Table 1. Field data for direction AB. C value obtained through equation (2).

Sample	Dm(mm)	Q (m³/s)	Hf (m)	C
01	32	0,00052	0,09	73,6
02	29	0,00052	0,12	81,6
03	34	0,00052	0,047	89,1
04	32	0,00040	0,021	124,3

Table 2. Field data for direction BA. C value obtained through equation (2).

Sample	Dm(mm)	Q (m³/s)	Hf (m)	C
01	32	0,00052	0,05	101,1
02	29	0,00052	0,103	89,1
03	34	0,00052	0,015	165,2
04	32	0,00040	0,03	102,5

From the co-effectors, a mean coefficient Cm was extracted in order to compare the performance of the bamboo and the PVC tube for the conditions analyzed.

Table 3. Mean coefficient of bamboo samples for AB and BA directions.

CmAB	CmBA	C PVC
92,15	114,48	140

With the values of Cm it was possible to relate the pressure loss to different flow values as presented in the tables and graphs below.

Table 4. Comparison of pressure drop between PVC and bamboo - AB.

Q (m³/s)	JPVC (m/m)	JBamboo (m/m)
0,00015	0,0025	0,0059
0,00021	0,0047	0,0111
0,00029	0,0086	0,0201
0,00033	0,0109	0,0256
0,00038	0,0142	0,0332
0,00042	0,0171	0,0400
0,00045	0,0194	0,0454
0,00050	0,0236	0,0552
0,00052	0,0254	0,0593

Table 5. Comparison of pressure drop between PVC and bamboo – BA.

Q (m³/s)	JPVC (m/m)	JBamboo (m/m)
0,00015	0,0025	0,0040
0,00021	0,0047	0,0074
0,00029	0,0086	0,0135
0,00033	0,0109	0,0171
0,00038	0,0142	0,0222
0,00042	0,0171	0,0267
0,00045	0,0194	0,0304
0,00050	0,0236	0,0369
0,00052	0,0254	0,0397

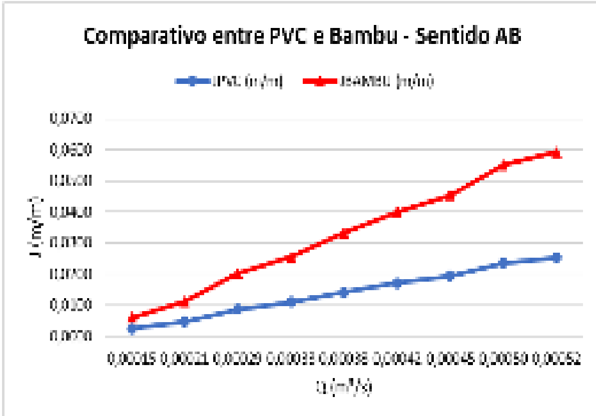

Fig.8. Comparison of pressure drop in direction AB.

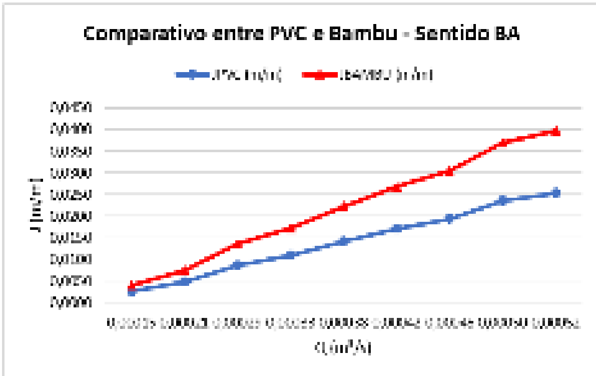

Fig.9. Comparison of pressure drop in direction BA.

IV. CONCLUSION

By means of the results presented, it is possible to conclude that the mean of the coefficient C, considering the value found for CmAB and CmBA, is equivalent to 103.315 which represents 73.80% of the PVC coefficient. This result, when compared to the C of the PVC tube, proved to be lower and can be justified by the initial treatment performed in the cleaning of the nodes, which was done manually and rustically, simulating the procedure to be performed in riverside communities of the Amazon. With the determination of the coefficient of roughness C for the bamboo, it is possible to verify the design of pipes using this material by the criteria of NBR-5626, with respect to the loss of load.

From this scenario, the study serves as a reference for future studies both in the application of bamboo as a hydraulic conductor in a real situation and in the analysis of the hydraulic characteristics for another bamboo species, in comparison with the bamboo species 'vulgaris' vittata.

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