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EFFECT OF BAMBOO (*BAMBUSA VULGARIS* (SCHRAD)) BASIC JOINT PRINCIPLES AND TECHNIQUES FOR IRRIGATION AND DRAINAGE NETWORK WATER SUPPLY SYSTEM IN AGRICULTURAL SYSTEMS.

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Abstract

Irrigation system of farming is one way of achieving food security for sustainable national development in any country but the challenges of utilizing a substitute material like culm of Bambusa vulgaris Schrad for the expensive aluminum and plastic pipes in irrigation water conveyance have yielded no fruitful result. Consequently, this study examines challenges of appropriate jointing techniques among other problems and investigates different jointing techniques for improved irrigation systems using bamboo culms: Tapered joint, Rubber tube joint, Flange joint, PVC external joint, PVC internal joint, Bamboo external joint, Bamboo internal joint, PVC Tee joint, Bamboo Tee joint and Rubber butt joint using two different locally made adhesives (Top bond and Cascamite) as sealants at the joints. Performance evaluation was carried out on the joints based on percentage water leakage, pressure drop due to joint and time spent in fabricating the joint. The results show that PVC External joint with Top bond as sealant was the most effective with 1.83% percentage leakage, 286.96N/ m^2 pressure drop and 42 minutes production time while Bamboo internal joint with Cascamite as sealant was the least effective having 6.85% percentage leakage, 473.33N/ m^2 pressure drop and 71 minutes production time. None of the joints evaluated gave zero leakage which is the ideal situation but the head drops obtained were minimal. PVC external joint with Top bond sealant was therefore recommended for Bamboo Bambusa vulgaris Schrad in forming network of irrigation system.

Keywords: Food security, joints, water conveyance, sealant and irrigation.

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Introduction

Bamboo is one of the oldest materials people have used to increase their comfort and well-being (Jayenneti and Follet, 1998). In today's world, bamboo plays an important role in the rural economics of the developing countries. Kumar, (1995) refers to bamboo as poverty alleviator and Quintans, (1998) called it miracle grass because of its usefulness. Bamboo is a wood-like plant, which constitutes the *Bambusoideae*, a sub-family of the grass family, the *Gramineae (*Kumar, 1995; Quintans, 1998; Oyebode and Ogedengbe, 2001*)*. Over 75 genera of bamboo with about 1250 species are growing in natural stands or plantations covering an area of more than 14 million hectare globally (Espiloy, 1991; Banik, and Fu. Maoyi, 1995; Onilude, 2005).

Bamboo is a very important raw material for several small to large-scale industries besides its use as a construction material, bamboo pipes are also used to tap water from streams and springs (Sanghvi, 1985; Ik worldwide, 2002). It has been estimated that 2.5 billion people depend on or use bamboo materials with a value of US$ 7 billion per annum (Liese, 1992; Salleh, 1995; Aminuddin, 1995). The plant according to Kumar, (1995) has more than 4000 traditional uses. In agriculture, bamboo is widely used for irrigation and drainage as water conveyance structure either above or below the ground surface when the diaphragms of the culms are removed (Kumar, 1995; Salleh, 1995; Quintans, 1998; Oyebode and Ogedengbe, 2001; Ik worldwide, 2002; Li, (2004). It is been used in some locality in Tanzania to supply rural water and for drip irrigation system (Ik worldwide, 2002; Sanghvi, 1985; Kick van den, 1981).

Bamboo has a long and well-established tradition as an engineering material throughout the world's tropical and sub-tropical regions. The tensile strength of bamboo is very high (Li, 2004). Bamboo has good mechanical properties (Lam Yanta, 1998). Most of the outstanding schemes of irrigation and drainage systems that are existing in various parts of the world make use of materials such as Steel pipes, Asbestos pipes, Polyethylene pipes (PVC) and many of the developing countries cannot afford the cost of importation of these materials and therefore the substitution by indigenous materials is increasingly justified (Lam Yanta, 1998; Oyebode and Ogedengbe, 2001).

Bamboo in terms of cost, is relatively a very cheap material compared to other piping materials. At least one type of species is easily available in most developing countries of the world. The availability of bamboo is pronounced in Nigeria with concentration in South and Middle belt areas of the country (Onilude, 2005). There are about seven species of bamboo in Nigeria of which *Bambusa vulgaris Schrad* is the commonest. The use of substitute material like bamboo has to be encouraged to enable many peasant farmers carry out less expensive and less complicated constructions of water conveyance structures.

According to ***Amar,*** (2012), Bamboo have been used as conveyance systems throughout the hilly areas of the eastern region of Nepal. Water are piped over 100 meters to different household using local technology and local materials. However, the challenge of effective and durable joint techniques for bamboo has posed problems to its utilization as irrigation and drainage conveyance structure. Making joints in bamboo is rather difficult because bamboo by nature is hollow, tapered, have nodes at varying distances and is not perfectly circular (Janssen, 2000; Stephane, 2009). Therefore in the design of joint in bamboo pipe, one has to keep above-mentioned constraints in mind in other to achieve effective joints. However, Stephane, (2009) recommended completely **dry** bamboo to be used in any construction work. This will enable the bamboo diameter to shrink, so that when it is used as joints, it will not result in loose and weak joints after a few weeks of installations (Stephane, 2009). Bamboo like other piping materials has a combination of good and bad materials properties. In design of bamboo joints, full advantages of the material should be taken in other to enhance its full structural potentials (Janssen, 2000).

The use of bamboo as a substitute material is limited due to lack of knowledge on how well to make strong joints without leakages of water at the joint (Janssen, 2000). The study therefore was aimed at fabricating and evaluating new joints techniques and principles for Bamboo pipe as irrigation networks and rural water supply systems. Performance evaluation of these joints techniques and principles were based on percentage of water leakage, production time and pressure drop along the bamboo pipe due to the joint techniques.

Materials and Methods

The project was carried out at the Department of Agricultural and Environmental Engineering, University of Ibadan, Nigeria in 2006. Materials used for the fabrication of the joints were sourced locally based on their availability. These include Bamboo culm (*Bambusa vulgaris Schrad)*, two locally made adhesive materials (Cascamite and Top Bond), bicycle tubes, wood for the flange construction, PVC pipes, water tank, tape rules, 10 mm diameter transparent tube (Piezometric tubes), graduated plastic container, laboratory equipment such as electric weighing balance, stop clock, round bottom flask and other essentials bonding materials. Locally made available adhesives were used as joint sealants.

The techniques adopted by Lipangile and Landman, (1976) and Kick van den, (1981) was contrary as these researchers applied PVC paste called Tangit to make the bamboo joints water tight. Moreover, in other to obtain bamboo pipe of tangible length (4.0 m), the impeded internodes which grow naturally across the bamboo stem at interval of about 1 m were removed by drilling. The drilling was accomplished using hand auger known as Tanzania Auger (Drilling bit). This was attached to a steel bar, manually inserted into the bamboo tube from both the ends. The design and fabricating processes of the Tanzania Auger were described by (Oyebode and Ogedengbe, 2001; Ogedengbe, 2014).

The auger coupled with a long steel rod was twisted inside the Bamboo culm at both ends so as to remove the septa and form a Bamboo pipes. Bamboo of right **diameter and wall thickness** must be used fabrication of the joints (Stephane, 2009). The solid nodes or septa of the bamboo which is necessary to be removed in order to form a pipe were removed with the aid of fabricated pointed steel rod, known as Tanzania Auger (Drilling bit). \

Preparation of the adhesives

Two different locally made adhesive bonds were used as sealant at the joints. The adhesives were used to strengthen and prevent leakages at the joints. Different techniques were adopted for the preparation of these adhesives because of their nature. For the Top Bond adhesive, fine particles sawn dust were mixed with it in the ratio of 5 to 2 (Top Bond to fine particles sawn dust) by volume. The mixture formed thicker sticky paste which solidified within one hour after application to the joints. In case of Cascamite adhesive, it was prepared by mixing the Cascamite (powdery in nature) with water in the ratio 3 to 1 by volume respectively to form a sticky paste which also solidified within one and half hours after application depend on the dryness of the weather or prevailing climatic conditions.

Preparation of the Bamboo Joints

Ten different joint techniques were developed based on materials incorporated within to form the joint. Materials used include Bamboo culm with adhesive; PVC pipe with adhesive; bicycle tubes with adhesive; and wood flange with rubber sealant. These joints are: Bamboo external union joint, Bamboo internal union joint, PVC external union joint, PVC internal union joint, Tapered joint, Rubber tube union joint, Flange joint, PVC Tee joint, Bamboo Tee joint and Rubber butt joint. In fabricating the joints, matured bamboo culms were cut into samples of 2 m length with a cross cut saw machine and the edges were smoothened. Each joint technique has two set of samples because of the two different adhesives that was added as sealant.

Experimental Set Up

The detail set- up of the experiment consists of a water tank for storing water, 3.5 Kw pumping machine for pumping water to the bamboo pipe line at the entry point via a hose. Another 120 liters container was placed at the exit for collecting discharged water. The set-up also included four piezometric tubes of diameter 7mm each and 160 cm length. Tape rules were attached to the piezometric tubes hanged upright for easy reading and recording of the water level in the tubes.

For the easy determination of pressure drop and percentage leakage, the bamboo pipes were connected in series and placed on 1 m vertically erected bamboo supports which serve as seat for the jointed bamboo pipe sample that were tested. The length of bamboo pipes for each test run was 9 m consisting of two bamboo pipes 4.5 m. One end of the 9 m pipe network was free to discharge water while the other end connected to the hose from the pump. The joints were connected to the bamboo pipes and evaluated one after the other. Holes for the insertion of the piezometric tubes were made on the jointed bamboo pipe before and after the joint in vertically upward position to ensure correct measurement of the head loss **(**White, 2003; Munson, *et al.*, 1998; Streeter, *et al.*, 1998). The holes were sealed with an adhesive to ensure no water leakage. A small container (10 liters) was placed at the joint to collect any drop of water resulting from leakage. Stop-watch was used in taking the volume of water discharged and water leakage per specified time (5 minutes).

Furthermore, the pump intake was connected to the elevated water tank to ensure water flows into the pump by gravity to prevent cavitation. Water was pumped into the pipes at regulated pressure of 100 Kpa and required data were taken. The different joint samples fabricated were coupled and tests were carried out on them. Pressure drop and percentage leakages were determined.

Determination of pressure drop (? P)

The pressure drop due to joint was determined using Munson, *et al.*, (1998) equation. The head loss was determined by careful reading the level of water in the graduated measuring tape attached to piezometric tubes and values obtained were incorporated into this equation.

$$\Delta P = \rho g h \qquad \ldots\ldots (1)$$

Where: ? P is pressure drop (Nm^{-2}), g is the acceleration due to gravity (9.81 gm^{-2}), h is the head loss of water (m) and

$$Percentage\ leakage = \frac{Volume\ of\ water\ that\ leaked\ out\ (ml)}{Volume\ of\ water\ discharged\ (ml)} \times 100 \qquad \ldots\ldots (2)$$

2.6 Determination of production time:

The time spent in producing each joint from the assembly parts together, sealing with adhesives and drying were noted with the aid of stop watch. Time spent on each was recorded.

2.7 Data Analysis: Data obtained were analyzed statistically using analysis of variance (ANOVA) and means were separated using least significant difference test (LSD) specifically for this study purpose.

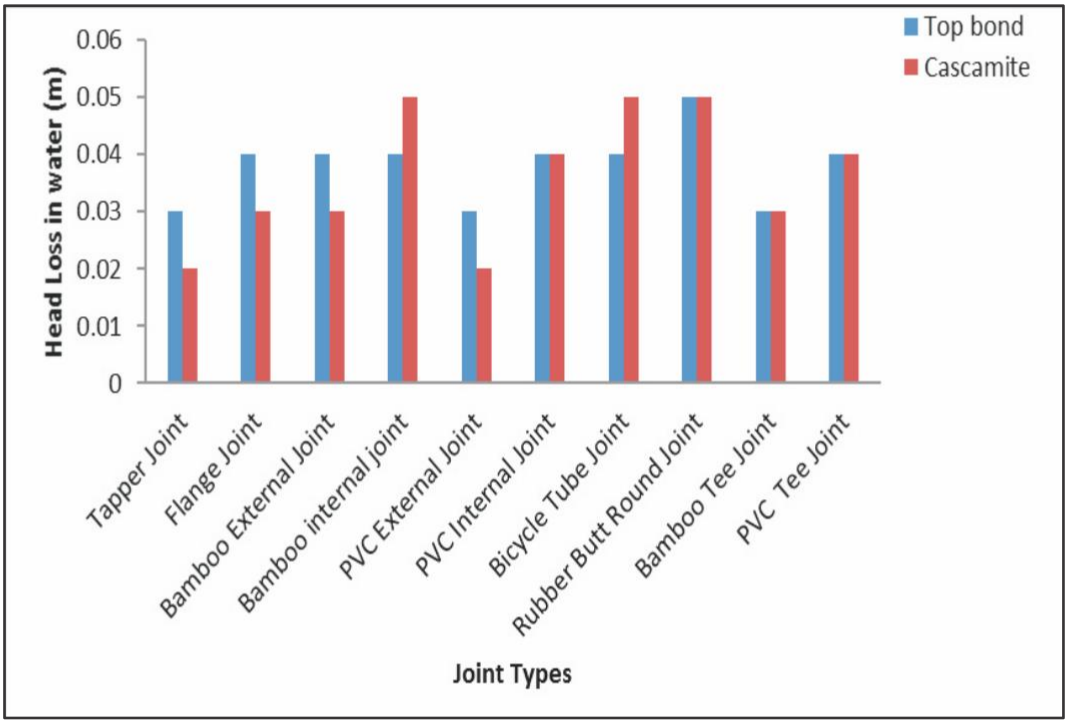

Figure 1: Head of water Vs different Joint Techniques with sealants

Table 1 and 2 below show the average values obtained for pressure drop, percentage leakage and production time with Top bond and Cascamite adhesive respectively. There were significant differences in the parameters mentioned above. From the Table 1, average pressure drop values ranged from 286.96 Nm-2 (PVC External Joint) to 473.49 Nm-2 (Rubber Butt Joint) while in table 2, the average pressure drop values ranged from 231.43 Nm-2 (Tapered Joint) to 476.29 Nm-2 (Rubber Butt Joint). From this evaluation, maximum pressure drop value was recorded in Rubber Butt Joint (476.29 Nm-2) made with Top bond adhesive while least value was obtained in Tapered Joint (231.43 Nm-2) made with Top bond adhesive.

Also in table 1 with joints made of Cascamite adhesive, the average percentage leakage values varied from 1.83 % (PVC External Joint) to 6.66 % (Bamboo External Joint) while in table 2 with joints made of Top bond adhesive, the values ranged from 2.07 % (PVC External Joint) to 6.85 % (Bamboo Internal Joint). The highest percentage leakage value was obtained in Bamboo Internal Joint (6.85 %) made with Top bond adhesive while the least value was recorded in PVC External Joint (1.83 %) made with Cascamite adhesive.

The average production time recorded in joints made of Cascamite adhesive as shown in table 1, ranged from 20 minutes (Rubber Butt Joint) to 67 minutes (Flanged Joint) while in table 2, with joints made of Top bond adhesive, average production time values varied from 41 minutes (Rubber Butt Joint) to 91 minutes (Flange Joint). The results from table 1 and 2 above show that the time spent on Flange Joint (91 minutes) made with Top bond adhesive was the highest while least time was spent on Rubber Butt Joint (20 minutes) made with Cascamite adhesive.

Table 1: Average pressure drop, percentages leakages and production time of Joint techniques made Cascamite sealant.

Joint Techniques with Cascamite Sealant	Pressure drop (Nm^{-2})	Percentage leakages (%)	Production Time (Minutes)
Tapper Joint	231.43a	6.18e	58.00b
Flange Joint	335.96c	2.39b	91.00e
Bamboo External Union Joint	295.36b	5.57d	72.00cd
Bamboo Internal Union Joint	473.33e	6.85g	71.00cd
PVC External Union Joint	243.23a	2.07a	69.00c
PVC Internal Union Joint	380.41d	6.02e	65.00c
Bicycle Tube Union Joint	459.93e	2.45b	52.00b
Rubber Butt Round Joint	476.29e	3.70c	41.00a
Bamboo Tee Joint	330.27c	6.48f	82.00d
PVC Tee Joint	351.54cd	6.83g	68.00c

Mean with the same alphabet in the same column are not significantly different at P 0.05 using (DMRT) Duncan Multiple Rate Test

Table 2: Average pressure drop, percentages leakages and production time of Joint techniques made Top Bond sealant

Joint Techniques with Top Bond Sealant	Pressure drop (Nm^{-2})	Percentage leakages (%)	Production Time (Minutes)
Tapper Joint	273.41a	5.42e	31.00b
Flange Joint	401.41c	2.51b	67.00f
Bamboo External Union Joint	371.17c	6.66f	44.00c
Bamboo internal Union Joint	426.74cd	5.38e	38.00b
PVC External Union Joint	86.92a	1.83a	42.00c
PVC Internal Union Joint	362.15bc	5.39e	46.00d
Bicycle Tube Union Joint	396.51c	2.13b	34.00b
Rubber Butt Round Joint	473.49d	3.70c	20.00a
Bamboo Tee Joint	304.95ab	6.27f	51.00e
PVC Tee Joint	404.72c	5.25e	45.00d

Mean with the same alphabet in the same column are not significantly different at P 0.05 using (DMRT) Duncan Multiple Rate Test

Results and Discussion

Figure 1 shows the head of water versus different joint techniques with sealants, Bamboo internal joint and Bicycle tube joint with cascamite sealant recorded the highest head loss (m) followed by the Rubber tube round joint sealed with top bond and cascamite respectively. Least value of head loss (m) was however recorded in both Tapper joint and PVC external joint sealed with cascamite sealant. This could be as a result of condition inside of a joint pipe which has a great effect on the head loss of the flow of liquid (Streeter, *et al.*, (1998).

Considering the results from the table 1 and 2, it can be deduced that PVC External joint sealed with Top bond adhesive with average pressure drop of 286.96 Nm-2, average percentage leakage of 1.83 % and average production time of 42.00 minutes was therefore considered the most effective of the joints. Also, Bamboo Internal Joint with Cascamite as sealant was the least effective having 6.85% percentage leakage, 473.33Nm-2 pressure drop and 71 minutes production time. Pressures obtained in these joints must not be excessive as development of the pressure head will bring important cost consideration because as pressure increases leakages increases too. \

The results obtained was in accordance with findings of Munson, et al., (1998) which showed that pressure loss in fittings especially joints and valves are common parameters affecting pressure drop in piping systems and this need to be incorporated in the design system.

Conclusion and Recommendation

The results of the performance evaluation on the joints techniques have proved to be a promising. The replacement of highly expensive materials such as Steel pipes, Asbestos pipes, Polyethylene / Plastic pipes with locally available bamboo pipe will results in boosting the local economy considerable saving of foreign Exchange.

Therefore, PVC External Joint with Top bond sealant was considered most effective joint having pressure drop of 286.96 Nm-2, Percentage leakage of 2.07% and Production time of 42 minutes while Bamboo Internal Joint with Cascamite as sealant was the least effective having 6.85% percentage leakage, 473.33Nm-2 pressure drop and 71 minutes production time.

It is therefore recommended that more research works should be encouraged on the utilization of Bamboo as irrigation pipe network and overcoming the bamboo decays as a result of its exposure to the weather and the scouring effect of the flowing water. Bamboo being biological material is unique as piping material. The variations in culm thickness and culm diameters couple with the large cavity between solid cross walls (diaphragm) need to be overcome in future researches. However, no jointing techniques gave zero leakage which is the ideal situation but the head drop due to any of them was minimal. A lower pressure drop indicated little disturbance to the flow of water. This would lead to better water conveyance and increase efficiency of pipe network. While any leakage is a function of tightness of the pipes and binding strength of the sealant used. More work can be done in varying the sealants in other to produce best joint in bamboo.

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