CHEMICAL ENGINEERING TRANSACTIONS Volume 17, 2009
Editor Sauro Pierucci
 ISBN 978-88-95608-01-3 ISSN 1974-9791
DOI: 10.3303/CET0917058

Building of a Sustainable Ecological Village in the Amazon - Related Projects and Activities

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The location and implementation of a Green Materials and Processes Program centered in environmental themes~~,~~ at Universidade Federal do Amazonas (UFAM) , has gained momentum with the "First Amazonian Meeting of Green Materials and Processes", held on August 18-20, 2008, in Manaus, Amazonas, at Universidade Federal do Amazonas. This motivation was mainly the result of a project of a multi-family house village~~,~~ utilizing green building processes and comprising rain water utilization and ecological sewage treatment. Besides traditional construction materials (cement, sand, clay, wood, and ceramic tiles), bamboo based wall panels were used. Wall panel structures were prefabricated with a wood frame, whole bamboo culms placed as studs and bamboo strips on the outside. Wood and treated bamboo elements were dried in a solar drying kiln. Concrete blocks were used for foundation placing the wall panel at 20 cm above ground level. Plastic sewage pipes were installed below ground. After wall framing and bracing, roof framing took place using wood elements covered by clay tiles. Water and electrical pipes and fixtures were installed in the wall framing of the building according to plans. Earth of high clay content from the construction site was mixed with bamboo chips, and filled into the wall gaps. This *bamboo-clay* mixture produced a lighter and more stable filling than regular clay soil abundant in the region. After drying, usual plaster was applied to protect the wall. An industrial residue (hydrated lime of carburet) was used to paint the walls. This prototype ecological village comprised of eight houses was constructed at Adolpho Ducke Forest Reserve, in Manaus. The group being consolidated is involved in establishing a Doctorate Program at UFAM, and initiating research in areas such as high performance green composites (Professor Anil Netravali), modification of cellulose surface by plasma and layer by layer deposition (Professor Juan P Hinestroza), preparation and

Please cite this article as: Sa Ribeiro M.G., Toledo Filho R., De Vasconcelos R.P., Vieira R.K., Vieira A.K., Bittencourt E. and Sa Ribeiro R.A., (2009), Bulding of a sustainable ecological village in the amazon - related projects and activities, Chemical Engineering Transactions, 17, 343-348 DOI: 10.3303/CET0917058

utilization of cellulose nanofibrils (Professor Orlando Rojas), and concrete-cellulose fibers (Professor Romildo D. Toledo Filho).

1. Introduction

The housing project (SáRibeiro M and SáRibeiro, R.A., 2008) encompasses a multi-family house village (8 units of 42.92 m^2 each) with a total housing area of 342.70 m^2 to be used and monitored by the scientific community working at Adolpho Ducke Forest Reserve. The concepts are of low-cost housing of social interest (Janssen, 1995) and green construction (SáRibeiro et al., 2006). Rainwater captivation, storage, and utilization for sanitary basins, garden irrigation, laundry, car and pavement washing, guarantee potable water reservation for human consumption. Water economic 6-L flush sanitary basins are used in the village. The sewage disposal system uses ecological treatment plants to treat the domestic effluents of the village. The system employs the natural conditions of the site for nutrients and energy, such as gravity (potential energy), solar and biochemistry with a sequential microbiological decomposition by repeated transition of physiochemical conditions and absorption of nutrients by microorganisms and semi-aquatic plants. The main materials used to build the village were: cement, sand, clay (from the site), wood (from forest management), ceramic tiles, bamboo based wall panels (filled with *bamboo-clay* mixture), and industrial residue paint.

1.1 The Project

The village planning uses an existing opening on the main office entrance of the Forest Reserve. The conceptual planning is illustrated in Figure 1. Dual geminated houses were conceptualized for extended economy of the construction cost, as shown in Figure 2, and Figure 3 (Façade). Two-bedroom houses were planned for up to five inhabitants, according to local needs.

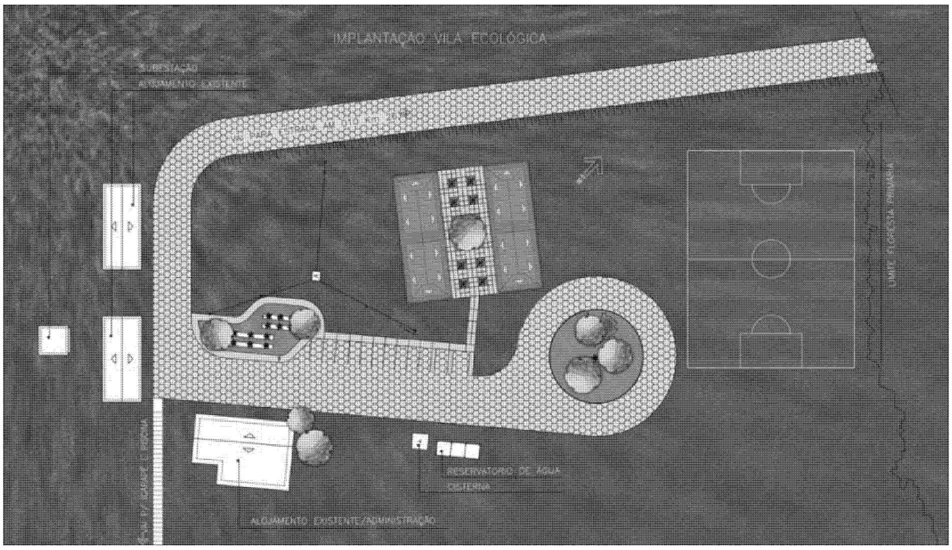

Figure 1 – *General Plan*

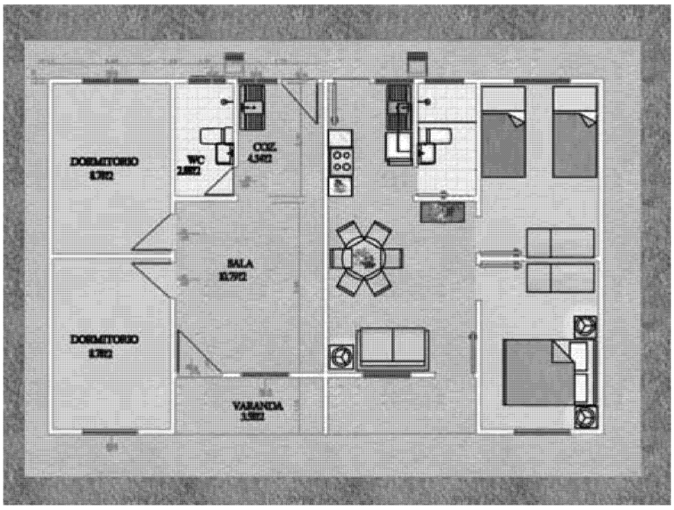

Figure 2 – *Layout of the house units*

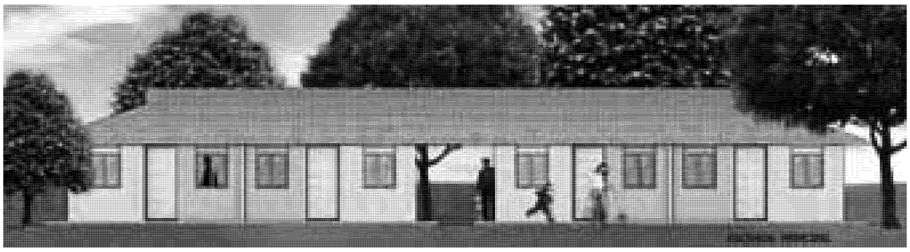

Figure 3 -*Façade*

1.2 Selected details of the Project

Prefabricated Wall Panels - The wood frame holding the bamboo elements are medium density sawn and planed hardwoods from local managed forest and dried to 18% EMC (equilibrium moisture content of wood in Manaus). It was collected 320 bamboo culms (9 m long) of *Bambusa vulgaris* (abundant in Manaus), 4-years old average, to fabricate the wall panels and windows for the village. The whole bamboo culms were treated by the Modified Boucherie Method, using a non-toxic preservative solution under pressure, as described by (Liese and Kumar,2003). The bamboo strips were treated by immersion in non-toxic preservative solution. Wood and treated bamboo elements were dried to the equilibrium moisture content in a solar drying kiln.

Prefabricated Trusses - Structural wood trusses were prefabricated prior to installation on site. Medium density planed hardwood pieces at 18% MC (dried in a solar drying kiln) with sections 5 x 7.5 cm (webs) and 5 x 10 cm (top and bottom chords) compose the trusses. Sixteen trusses were fabricated with 20° slope and 7.48 m length. For simplified transport and handling, half-trusses were fabricated to be united on site. The half-trusses were mounted with nailed connections. The two halves of each truss are united by nailed zinc metal plates from construction waste.

Foundation system - A linear foundation system is chosen based on analysis of the soil and construction cost. Concrete block foundation is devised. The advantages are: no formwork is required; utilize easily handled small units; less erection time than for site cast concrete. Foundation ditches of 30 x 40 cm are excavated and levelled. Concrete U-blocks 19 x 19 x 39 cm are laid on the ditches and linked with mortar. Anchor bolts (10 mm diameter, 80 cm length) are placed according to project definition. The concrete U-blocks are filled to the top with concrete. One line of structural concrete blocks 19 x 19 x 39 cm is laid over the filled concrete U-blocks and linked with mortar. Holes containing the anchor bolts are filled with concrete. Wall base concrete blocks 9 x 19 x 39 cm are laid over the structural concrete blocks and linked with mortar. The foundation is completely sealed up to the wall base, in order to prevent soil ascending moisture. The base pavement is filled and compacted with soil from foundation excavation.

Ecological sewer treatment plants - The sewage disposal system for the Eco-Village is composed of three ETEEs (ecological sewage treatment plants). Two ETEEs are used to treat the effluents of four houses from the Village Block-1 One larger ETEE is used to treat the effluents of other four houses from the Village Block-2. The houses are also built with a system of captivation, storage, and utilization of rainwater.

Sustainable construction system promotes responsible intervention to the environment, satisfying the basic needs for housing, and preserving the natural resources for the future generations. This ecological prototype village encompasses sustainable water management, utilizing a simplified system which allows reduction in drinking water consumption by caption, storage and use of rainwater. It also uses ecological sewage treatment plants running with no conventional energy and with very low cost of operation and maintenance. This ecological sustainable housing proposal is keen on energy savings, reutilization of rainwater, use of natural light and ventilation, use of local materials, and reduction on the use of material fabricated by polluting technologies A detailed description of the project and construction techniques is given elsewhere (SáRibeiro, M. and SáRibeiro, R.A., 2008).

1.3 Related Projects and Activities

The Ecovillage project is presently~~,~~ in a process of integration with other projects of interest in raw materials available in the Amazon region, motivating the formation of a group of researchers from different Brazilian institutions and from abroad. The main objective is to work with natural materials from Amazonia, including materials for construction application. The projects will cover from fundamental to applied character. Furthermore, a new Doctorate Program is in the process of consolidation at UFAM, an institution strategically located in Manaus, and devoted to the development of sustainable technologies. Some projects are already underway, such as the one that studies the properties of composites of long fibers of sisal with concrete, coordinated by Romildo D. Toledo Filho (Toledo Filho et al., 1999).~~,~~ This project studies the properties and mechanical characterization of cement-based thin-walled laminates reinforced with sisal long Sisal fibers, obtaining very interesting properties. Three point bending tests were carried out to evaluate the influence of addition of fiber (3%), the number of layers of reinforcement (2 and 3 layers), fiber orientation (0 and 90°), and molding pressure (0 and 2 MPa), on the flexural behavior of the laminate. The results indicate that the fiber addition increased the toughness and post-cracking flexural strength of all composites studied. The laminate reinforced with 3% of sisal fiber arranged in three parallel layers and molded at a compression pressure of 2 MPa presented the best mechanical behavior. Projects presently being consolidated at UFAM, are in areas of study such as development of production, characterization, and applications of cellulose nanofibrils with Professors Lucian A Lucia and Orlando Rojas (Lucia and Orlando, 2007), surface functionalization and layer by layer modification of natural fibers, with Juan P Hinestroza, (Hyde et al., 2007), and in "green" composites, including high performance natural composites, with Anil Netravali (Netravali et al., 2007).

2. Conclusion

The sustainable construction system briefly described here promotes responsible intervention to the environment, satisfying the basic needs for housing, and preserving the natural resources for the future generations. This ecological prototype village encompasses sustainable water management, utilizing a simplified system which allows reduction in drinking water consumption by caption, storage and use of rainwater. It also uses ecological sewage treatment plants running with no conventional energy and with very low cost of operation and maintenance. This ecological sustainable housing proposal is keen on energy savings, reutilization of rainwater, use of natural light and ventilation, use of local materials, and reduction on the use of material fabricated by polluting technologies. This ecological housing project was the major catalyst for the proposal of formation of an international group of researchers and educators to work on immediate social-economical and ecological needs, but also on fundamental topics and associated basic science. The center of this future activity is the Universidade Federal do Amazonas em Manaus, Amazonia, Brazil.

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