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BUILDING OF A SUSTAINABLE ECOLOGICAL VILLAGE IN THE AMAZON - RELATED PROJECTS AND PERSPECTIVES

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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 UFAM. This motivation was mainly the result of a project of a multi-family house village utilizing green building processes 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, and 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.

1. INTRODUCTION

The location and implementation of a Green Materials and Processes Program centered in environmental themes at Universidade Federal do Amazonas gained momentum with the “First Amazonian Meeting of Green Materials and Processes”, held on August 18-20, 2008, in Manaus, Amazonas, at UFAM. This initiative was preceded by a project of a multi-family house village utilizing green building processes 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, and 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.

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According to Sá Ribeito, M. G., and Sá Ribeiro, R.A. (2009) "The housing deficit in Brazil is over 7.9 million residential units. In the North region this deficit represents 850,355 units, from which 212,487 are for the Amazonas State alone The modular ecological house composed of bamboo can contribute to lower the housing construction cost , potentially diminishing the housing deficit. Among the innovations introduced in the project were:

1) Development of a sustainable green construction process.
2) Development of a system for rainwater collection, storage, and utilization
3) Development of an ecological treatment sewage disposal system, with reuse of treated water
4) Development of a green roof.

As precedent of this project , Sá Ribeiro, M. G., and Sá Ribeiro, R.A. (2009) mention the CasaEcoProt Project – An ecological prototype house (Figure 1) built for monitoring and tests at Bosque da Ciência, in Manaus, Sá Ribeiro et al. (2006), and the Bamboo-Wall Project –and the development of Wall panels composed of bamboo (as illustrated in Figure 2 and Figure 3), for housing in the Amazonia, Sá Ribeiro et al. (2004).

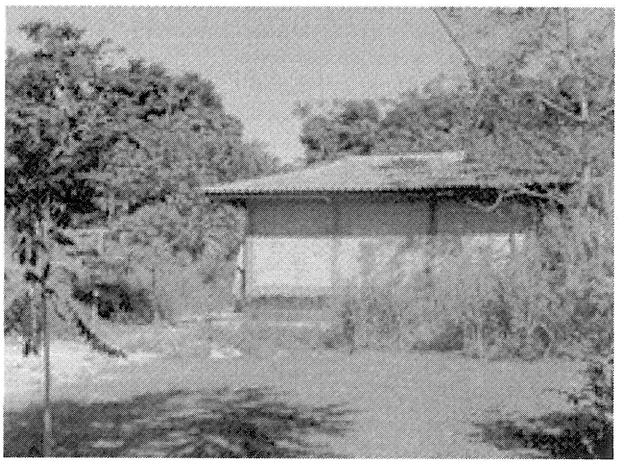


Figure 1 Ecological prototype house at Bosque da Ciência, Manaus , Sá Ribeiro et al (2006).

Figure 2 Wall panel with infill of bamboo-clay and finished with plaster SáRibeiro et al (2004).

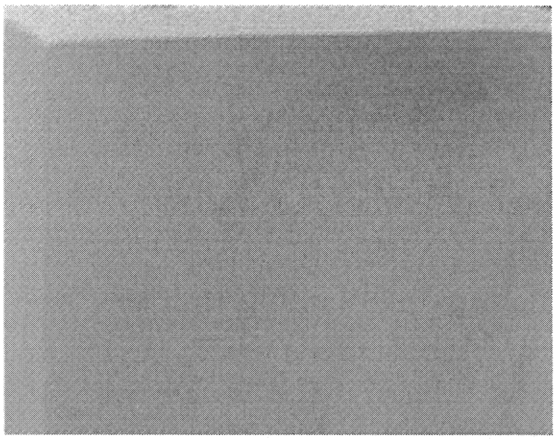


Figure 3 Wall panel with infill of bamboo-clay finished with plaster Sá Ribeiro et al (2004).

2. THE PROJECT

Location: The Eco-Village is located at Adolpho Ducke Forest Reserve (2°57'21"S, 59°55'20"W) on the North-East of Manaus, as depicted in Figure 4. This Forest Reserve has an area of 100 km^2 (10,000 hectares), Sá Ribeiro, M G, and Sá Ribeiro , R. A. (2008) .

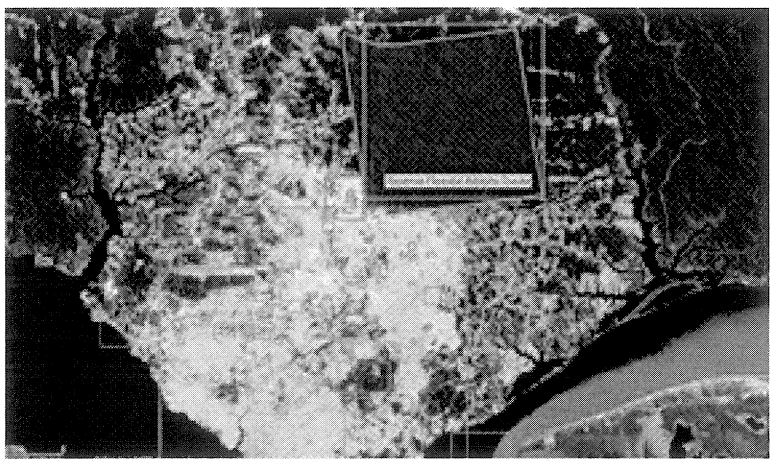


Figure 4 Village location at the forest reserve Adolpho Ducke, Manaus - Amazon.

The village planning uses an existing opening on the main office entrance of the Forest Reserve. The conceptual planning is illustrated in Figure 5. Dual geminated houses were conceptualized for extended economy of the construction cost, as shown in Figure 6, and Figure 7 (Façade)..

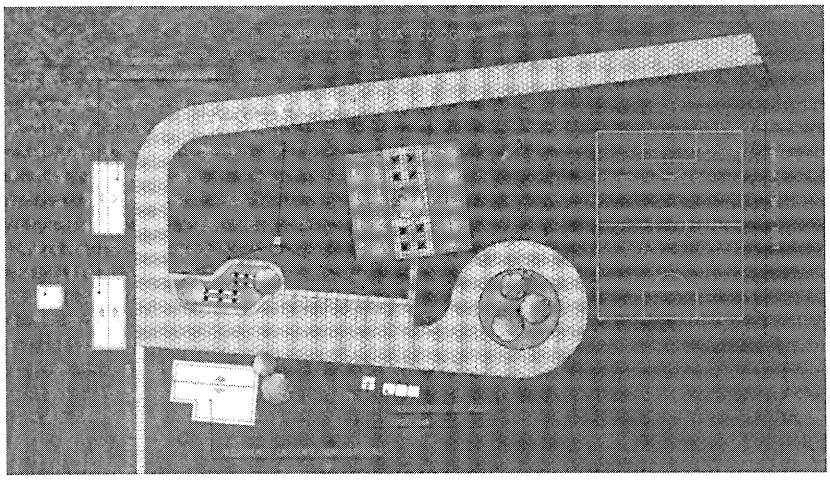


Figure 5 – General Plan.

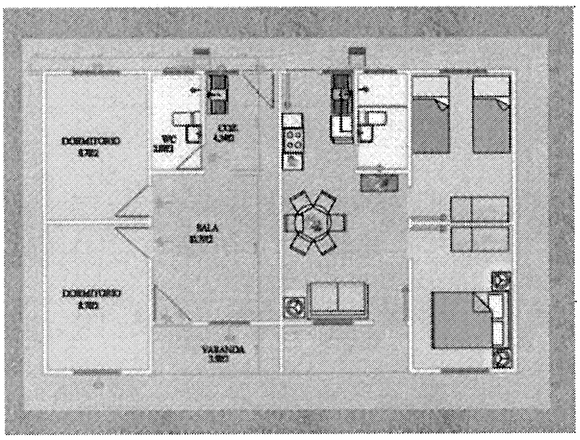


Figure 6 – Layout of the house units

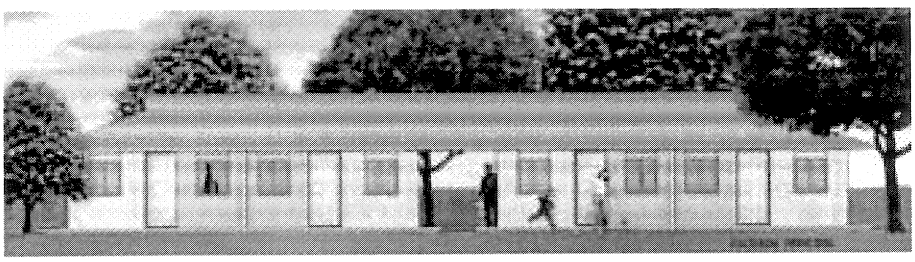


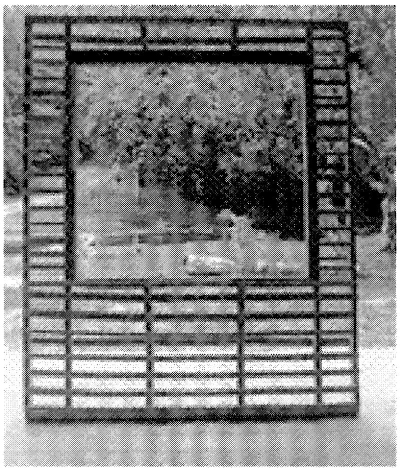
Figure 7 –Façade drawing of the ecovillage

Each house unit was initially planned for 5 inhabitants

2.1 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. See assemblies in Figure 8.



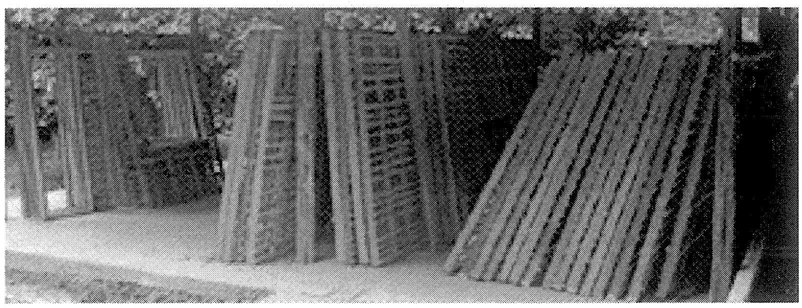


Figure 8 . Pre-fabricated wall panels

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. (Figure 9)

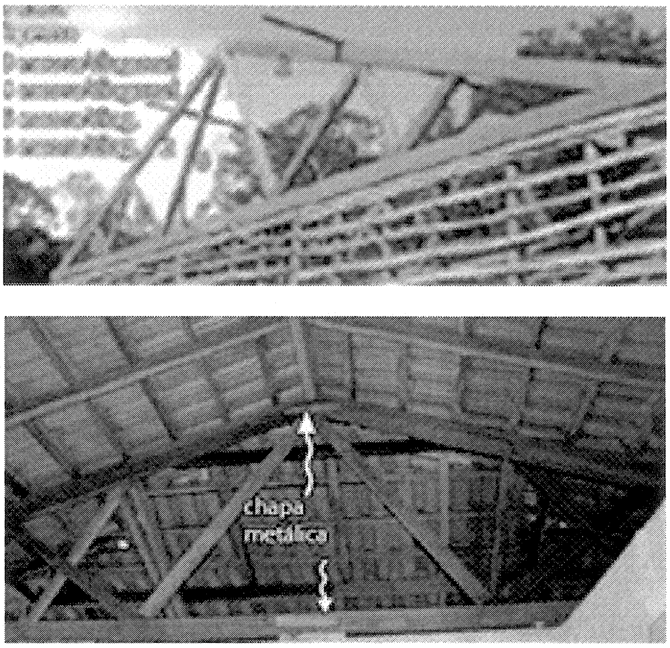


Figure 9 .Pre–fabricated wood trusses

Roof

Roof trusses are installed over the wall panels, (Figure 10). Roof structural wood elements are installed over the trusses, and defining the overhang, utilizing wood treated against insect attack) .Figure 11 shows ceramic tiles covering the roof.

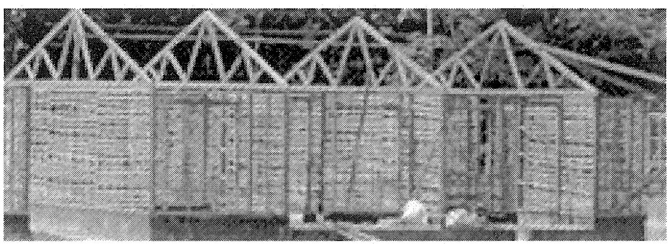


Figure 10 . Roof trusses

Figure 11. Roof with clay tiles

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 (Figure 12). The foundation is completely sealed up to the wall base. 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. These processes are shown 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 (Figure 13). Then concrete is poured in the basement floor.

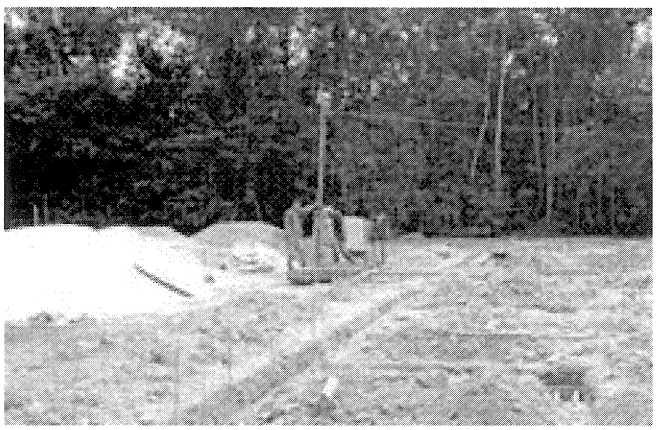


Figure 12. Foundation work

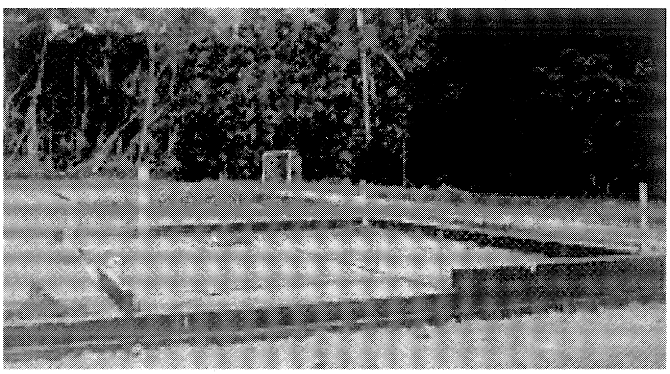


Figure 13. Foundation sealing and earth pavement

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 and SáRibeiro, 2008)

2.2 Related Research Activities and Perspectives

The Ecovillage project is presently in a process of integration with other projects of interest of search and study of 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 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.

A large variety of fibrous materials remain to be studied in the Amazon region, and the possibilities for applications to produce construction materials with relatively known fibers from the region are wide , as reviewed by Singh and Gupta (2005). As far as energetic independence goes, small scale biodiesel production (Sarantopoulos et al., 2009), is under consideration utilizing selected perennial crops. A source of oil under study is Jartropa Curcas (Berchmans and, Hirata . 2008) , an interesting source as potential animal feed and fertilizer (Sharma and Singh, 2009), with a perspective as source of proteins for human consumption, if starting from a non-toxic variety. In the sustainable energy utilization aspect, alternatives such as solar, inclusive for ice making and air conditioning (Dieng and Wang, 2001) , are under consideration.

Photovoltaic technology is another very interesting option , consisting in an energy source where impressive developments in materials and production processes have been made (Goetzberge et al, 2003) , resulting in significant reduced costs. Projects presently being consolidated at UFAM are in areas of study such as production, characterization, and applications of cellulose nanofibrils with Professors Lucian A Lucia and Orlando Rojas (Lucia and Rojas, 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).

There are wide possibilities for use of alternative energies, like photovoltaic, and low solar energy , among others leading to energy independence from long range electrical distribution systems

3. CONCLUSION

The sustainability inspired construction system briefly described here aims at promoting responsible coexistence with the environment in the Amazon region , 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. Energetic independence is a goal : renewable energy, wind, photovoltaic's, solar, are alternatives to be explored for the Villages, including greenhouse cooling for growing vegetables. 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 with the basic science to deal with the complex question of sustainability. The center of this future activity is the Universidade Federal do Amazonas, in Manaus, Amazon , Brazil.

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