Roof Structure for the Amazon region
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ABSTRACT

A new concept of wooden roof structure with an attached ceiling is idealized for construction in tropical climates. A scissors truss system is used for roof structure dictated by architectural considerations. The roof structure was developed using computer aided design in order to achieve an optimized construction system. This prototype project uses 3 trusses spaced 2.75m over a 5-m span, with a 5/7 slope, and a 60-cm overhang. The top chord and web members consist of 5x15 cm mixed hardwood species at 18% moisture content. The roofing material is composed of 5x10 cm wood joists spaced 50 cm on center, 1x8 cm T&G wood panel ceiling, asphalt sheet, 1.5x3 cm wood strips spaced 30 cm on center, and clay tiles. The use of a wood panel ceiling, besides its aesthetic appearance, is ecologically and economically correct by diminishing the amount of wood used in roof structures when compared to conventional systems in Brazil. This design also, inhibits the occupancy by undesirable bats under the roof, because there is little gap between roof and ceiling. This prototype project was built two years ago in the Amazon tropical rainforest, under extraneous adverse weather conditions: six months of severe rainfall and six months of severe heat and sparse rainfall. Monitoring the structural and material behavior for the past two years it is evident the applicability of this construction system for adverse environmental conditions of high heat and humidity together.

INTRODUCTION

The Amazon Basin represents the largest reserve of tropical forest in the world. The Brazilian Amazon contains 280 million hectares (692 million acres) of tropical forest which represents 30% of the timber supply in the world. The timber volume in the Brazilian Amazon is estimated at 50 billion m³ of which 18 billion m³ is known commercial timber.

In spite of its potential, the Amazon forest is very much underutilized. It supplies only 3% of the international tropical wood market and 10% of the internal Brazilian market. Forest harvesting is more intense in the varzeas (rich humic lowlands formed during the low water period, and that are normally inundated during the rainy season - December through May), where harvest is considerably easier and water transportation is the cheapest way of furnishing raw material to the wood industry. The forest of terra-firme (land that is not inundated by the flooding rivers) requires much higher harvesting costs (machinery, road construction). Most of the timber is utilized as sawn wood. Over 2500 wood species have been identified in the Brazilian Amazon forest. Among these, only about 400 species have been studied and just a few selected species are harvested. Timber harvesting is highly selective due to the heterogeneous composition (over 100 tree species in a single hectare) of the forest.

Wood is largely used for roof structures in the Amazon region. Almost every single residential house uses wood on its roof structure. A conventional roof system widely used in the region consists of wooden truss elements topped by wood joists, rafters and strips, and clay tiles or asbestos tiles. Some of these systems use a flat T&G wood panel ceiling or a reinforced concrete slab. No thermal insulation is conventionally used.

OBJECTIVES

A new concept of wooden roof structure with an attached ceiling is idealized for construction in tropical climates. A scissors truss system is used for roof structure dictated by architectural considerations. The scissors truss can be efficiently designed for clear spans up to 24 m (AITC 1986). An attempt is made to compare cost efficiency of the proposed roof system and the conventional one.

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DESIGN

The roof structure was developed using computer aided design (AutoCAD R14) in order to achieve an optimized construction system. Figures 1 and 2 depict the proposed and the conventional roof systems. This prototype project (Figure 1) uses 3 scissors trusses spaced 2.75 m over a 5-m span, with a 5/7 slope, and a 60-cm overhang. The top chord and web members consist of 5x15 cm mixed hardwood species (angelim vermelho, louro gamela, angelim pedra) at 18% moisture content and 800 kg/m³ average density. The truss elements are connected by bolted metal plate connections (steel side plates 3.175 mm thick) (Figure 3). The roofing material is composed of 5x10 cm wood joists spaced 50 cm on center, 1x8 cm T&G wood panel ceiling, asphalt sheet, 1.5x3 cm wood strips spaced 30 cm on center, and colonial clay tiles. Although these clay tiles weigh 56 kg/m² (549 N/m²), they are readily available at reasonable low costs, and they have good thermal insulation.

Figure 1. Plan and cross-sectional views and details of roof prototype project; and plan view of conventional roof
The design of the roof structure and connections complies with both the Brazilian NBR-7190 (ABNT 1997) and the American NDS (AF&PA 1997) Standards. The designed total roof loads (dead and live) for the proposed system were equal to 1545 N/m², while for the conventional system they were equal to 1637 N/m². Thus, the proposed roof system presents 6% reduction in roof loading. The idealized roof system uses 0.04 m³ of wood (truss elements, joists, strips, attached ceiling panel) per m² of roof. The conventional roof system uses 0.07 m³ of wood (truss elements, joists, purlins, strips, ceiling panel, ceiling purlins) per m² of roof. Therefore, the idealized roof system uses 43% less wood than the conventional system.

**CONSTRUCTION**

The construction site chosen is on the outskirts of Manaus by the Amazon tropical forest. The complete roof construction was done by a crew of 3 carpenters working 7 hours a day during 20 days. Construction took place during June 1997.
under daily temperatures over 30°C, relative humidity above 80%, and sparse rainfall. The wood pieces were air dried to 18% moisture content.

Based on detailed CAD drawings, all 5x10 cm joists, 1x3 cm wood strips, and 5x15 cm truss elements were cut to size. Templates were used to drill holes in the truss elements to be connected by bolts and metal plates. All wood elements were surface treated with diesel oil. This is an inexpensive and effective treatment against termite attack. The trusses were built on the ground and erected in place. The joists were then nailed to the top chords of the trusses. It was then installed the t&g wood panel on top of the joists. The asphalt sheet was laid on top of the wood panel. Wood strips were installed on top of the asphalt sheet to accommodate the clay tiles.

Figure 4 shows a general view of the constructed roof. A close up view of the roof structure and the attached wood panel ceiling is depicted in Figure 5.

Figure 4. View of the constructed roof

RESULTS AND CONCLUSIONS

This prototype project was built over two years ago in the Amazon tropical rainforest, under extraneous adverse weather conditions: six months of severe rainfall and six months of severe heat and sparse rainfall. Monitoring the structural and material behavior for the past two years it is evident the applicability of this construction system for adverse environmental conditions of high heat and humidity together. The use of a wood panel ceiling, besides its aesthetic appearance, is ecologically and economically correct by diminishing the amount of wood used in roof structures when compared to conventional systems in Brazil. This idealized roof system for the Amazon region represents a reduction of 43% on the amount of wood used on similar conventional system. Furthermore, it reduces by 6% the total roof loads. These reductions on the amount of wood used and on the total roof loads represent substantial savings in energy and
construction time, and demand much less tree cutting. Since the bat community plays an important role on the ecological Amazonian system, a peaceful living with humans is desired. In this sense, this design also, inhibits the occupancy by undesirable bats under the roof, because there is little gap between roof and ceiling.

Figure 5. Close up view of roof structure and wood ceiling

REFERENCES