Solar Drying of Sawn Timber in Kingston, Jamaica

Introduction

Traditionally, lumber is widely used in Jamaica and all over the Caribbean Region as material for furniture and craft items. The majority of small and medium sized firms, producing for the local market, can get the native lumber only unseasoned. In the Jamaican woodworking sector, extracting the moisture is often limited to a few days or weeks of exposing the moist boards to the open air (open air seasoning), especially if the products are meant for the local market. Not being able to afford the drying costs in oil fired kilns, or dehumidification kilns run by electricity (one m^3 of timber costs US$ 52), the end product's moisture content (17 to 21 %) achieved by open air seasoning is far above the necessary equilibrium moisture content (approx. 13 %).

Some woodworking companies in the Caribbean, especially larger ones which export their products, use oil fired kilns (boilers) to reach end moistures of approx. 8 to 12 %, thus ensuring suitability in terms of dimensional stability and proper functioning, once the product is exposed to drier climate, abroad or locally.

However, using expensive oil is out of question if appropriate wooden products are also to be made available for the low income sector, not to mention the environmental damage caused by the combustion of oil. Furthermore, the region is a net importer of petroleum with the resultant outflow of foreign exchange. Therefore, the solar drying system described here was developed to provide a viable and affordable alternative to the conventional oil fired drying systems.

An entire solar concept

An experience exchange with the technical arm of the Caribbean Development Bank, was followed by the planning and subsequent construction of a solar heated kiln, in conjunction with a solar pre-drier. An NGO owned woodworking company, manufacturing craft items and office furniture, was the project partner.

Since the size for the kiln had to stay within certain limits (efficiency and space), the pre-drier was planned to increase the capacity of the kiln, by bringing the moisture content of the sawn timber down from green (60 %) to approx. 30 to 25 %, before it is placed in the kiln. A positive effect of this is the lower drying temperature of the pre-drier, such that the timber is dried very smoothly in the first step of the drying process, resulting in high drying quality.

Acceptance and awareness raising

The dissemination of solar energy use in Jamaica is still in its initial stage, compared with its potential. Solar water heaters, experimental photovoltaic equipment and drying facilities in the agricultural sector, have the capacity to boost this alternative technology. In general, however, solar energy equipment is considered inferior.

In order to get sufficient commitment from the project staff, as well as to introduce this specific technology to the local woodworking sector and to some research institutions, several seminars were offered at the start of the project. The principles of timber drying, the physical relations between air temperature, air humidity, equilibrium moisture content, the establishing of drying schedules and the presentation of different drying technologies, were part of these seminars.

Together with the project staff, three woodworking companies, running their own kilns (oil fired and dehumidification kilns) were visited. The research centre of the University of Technology at Kingston showed its interest by sending an engineer during the planning and construction phase to prepare their own documentations.

Figure 1 The solar kiln under construction, shortly before finishing installation of the glass frames

Figure 2 View of the solar kiln, which is just being closed for drying a new charge of timber

The solar kiln

The kiln was planned to dry a total of approx. 12 m^3 per month of the following tropical timber species:

- Hibiskus elathus (Blue Mahoe)
- Cordia gerascenthus (Spanish Elm)
- Cedrela odorata (Cedar)

The determining factor for the size of the kiln is the absorber area (below the roof). For instance, to dry 12 m^3 of Blue Mahoe coming from the pre-drier with a moisture content of 30 % down to 11 or 12 %, means to extract 1,188 kg of water. Since this has to happen exclusively with solar energy, we have to look at the available insolation in Jamaica. From 09:00 to 17:00 hours an average value of 5.5 kWh/m^2 was measured. With 25 days/month available for drying, a total of 137 kWh/m^2 per month can be used, and with proper thermal insulation of the kiln and an air temperature not exceeding 60° to 65°C, an empirical value of 40 % of energy usage can be achieved. The net amount available is therefore :

$0.4 \times 137 = 54{,}8$ kWh/m^2 per month.

The required heat energy to evaporate 1 kg of bound water is about 1.3 kWh (= 4,680 kJ). For 1,188 kg of water to evaporate per month, an energy amount of 1,545 kWh is necessary. Hence the size of the absorber area required to harvest the incoming radiation is 29 m^2 (resulting from 1,545 kwh/month divided by 54.8 kWh/m^2 per month).

Since the glass roof of the kiln is much bigger than the absorber area, the greenhouse effect provides an additional amount of energy.

Kiln construction

All the materials used in the construction were purchased in Jamaica, a considerable amount of which was even manufactured locally. Only the ventilators, glass sheets and the absorber sheets were imported. The timber used for construction was exclusively vulmanized pine.

The kiln comprises three independent compartments (instead of one big chamber) for greater flexibility in drying different timber species and quantities. The inner and outer walls consist of 6 inch (15 cm) thick concrete hollow blocks, rendered with mortar and painted with black oil paint. Since the walls have a black outer surface, they absorb a lot of heat. Thus the temperature difference between the outer and inner surface of the kiln gets smaller, leading to a lower temperature gradient and subsequently less energy loss. All the walls rest on a foundation with steel reinforcement, since the area experiences heavy storms and occasional earthquakes.

Two swing doors for each compartment allow easy loading and unloading of the kiln. Like the panels above them, the doors are sandwich constructions, consisting of foil coated insulation foam, water resistant plywood and thin galvanized metal sheets as the outer layer.

Six 0.75 kW axial-ventilators, two for each compartment, provide adequate air circulation (3 to 5 m/s). They are easily accessible for maintanance from a small walkway at the back of the kiln and can be started from there as well. It also provides access to the absorber area for cleaning.

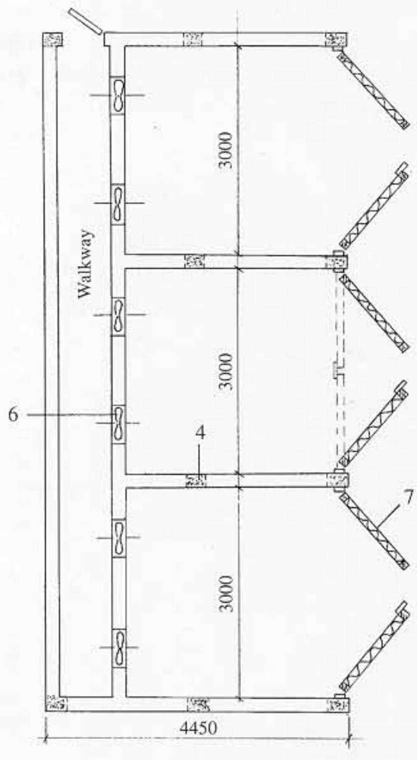
The absorber and roof

The absorber consists of corrugated, black oil-painted aluminium sheets. Screwed onto wooden frames and resting on top of side rails, they are very light and easy to remove for repainting. The corrugated shape of the absorber guarantees an optimal heat transfer from absorber to air by causing a turbulent airflow.

The roof of the kiln has an inclination of 21° to allow perpendicular insolation. The roof structure, which carries 16 glass frame units, is supported by three horizontal hollow section beams (4 x 4 inch, or 10 x 10 cm), which rest on concrete columns inserted in the walls. Nine wooden rafters (16 x 2 inch, or 40 x 5 cm) run across these three beams, forming 16 fields for the glass frames, which are assembled independently to allow easy and fast replacement of individual glass sheets.

For the frames, which carry two layers of perspex glass (8 x 4 feet, or 244 x 122 cm), vulmanized pine was used. With increasing wind speed, it becomes more important to use two layers of glass instead of one, because the energy loss through convection due to wind is higher when using only one layer of glass, than the additional loss caused by reflection of the second glass layer. The outer glass is 1/4 inch (6 mm), the inner one 1/8 inch (3 mm) thick, because the airspace in between the two layers, and not the thickness of the inner glass, is crucial for proper insulation.

Perspex glass (Polymethylmethacrylate) was used instead of wired glass, which has longer lasting light permeability, but is



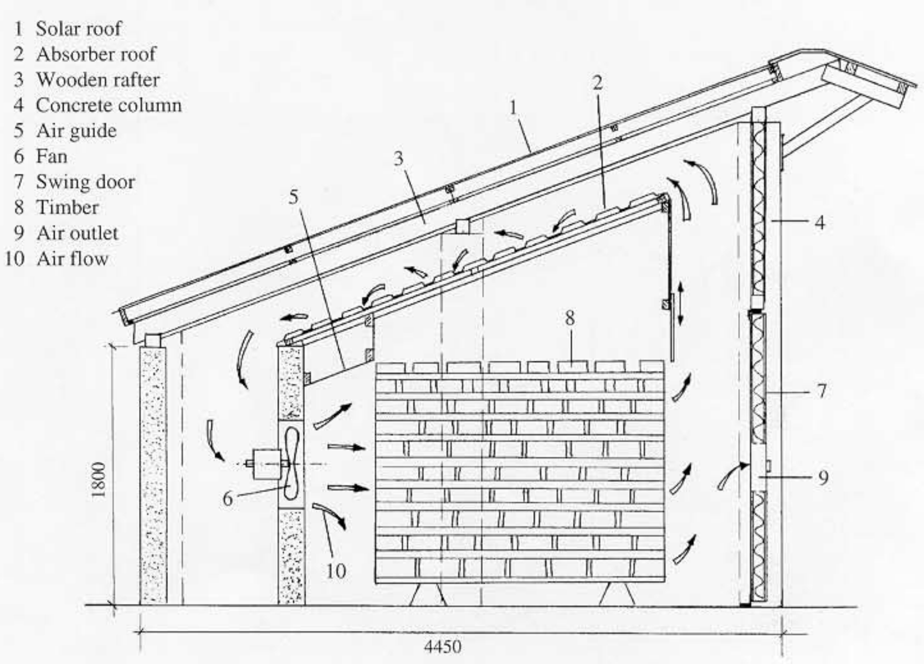


Figure 3 Plan and section of the solar kiln (not to scale)

Figure 4 An open compartment of the solar kiln. The timber stack is placed on the blocks to allow air circulation below.

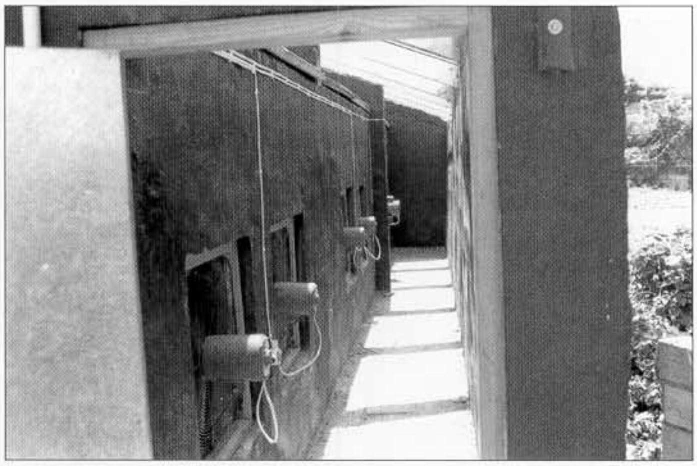


Figure 5 The walkway behind the compartments, providing access to the fans and absorber roof for maintenance.

60 % more expensive and much heavier than perspex. A further problem was that stones were occasionally thrown onto the kiln site from a neighbouring school yard.

Time schedule

Most of the time, just one person worked on the kiln construction. Only at certain times two or three other operators from the production plant came to help. This is why the kiln took more than 8 months to build, whereby the manufacturing, assembling and installing of the glass frames and doors took the most time. During all this time, lumber had to be dried by renting the capacity of another company's drying facility. It seems worth considering hiring additional manpower, in order to reduce construction time and the costs of drying elsewhere.

Performance data

Air temperatures in the kiln can reach up to 65°C on sunny days. There has been no visible damage of the dried timber due to fast drying. However, using elaborated drying charts for the respective species, it is ocassionally necessary to raise the air moisture within certain phases of the drying process to lower the drying speed. For this, a portable moisture meter was used, together with electric distance sensors for measuring the wood moisture and equilibrium moisture of the 1 inch (25 mm) boards.

Inserted into the doors are little sliding shutters, which can be opened or closed gradually to control the climate of the kiln, as well as to increase the air humidity rapidly during certain phases of the drying process, by spraying water with a water hose. However, interference is rarely required, since the temperature only rises up to a maximum of 65°C, compared with temperatures of 90°C and higher in conventional oil fired driers.

The ventilators normally run from 09:00 to 17:00 hours. About ten minutes before the fans are switched off in the evening, the outlets are opened to release the humid air, so that during the night the moisture from the centre of the wood can come to the surface. In the morning, the kiln is started with closed shutters to start the drying process with relatively high air humidity.

Hibiscus elatus, coming from the pre-drier with about 28 % moisture content, reached an end moisture content of 12% within 14 to 16 days. Cedrela odorata (Cedar) was dried from 31 % down to 11 % in 12 days.

The pre-drier

This "roof pre-heater" ensures a continuing supply of pre-dried timber with moisture contents of 30 % or lower for the kiln. At project start, the entire lumberyard was already covered with zink sheets at a height of 3.5 m. Thus, an area of 80 m^2 just had to be selected and painted on top with black oil paint. A false ceiling of 3/8 inch water resistant plywood was fitted 28 cm underneath the zink. A horizontal collector duct and two vertical ducts bring the hot air down to two 1 hp fans, each fitted with a diffuser, directing the air to the lumberpile.

Once the timber arrives at the company's lumberyard, it is immediately piled up in the pre-drier area, or, if occupied, somewhere else in the covered lumberyard. Each layer of timber is separated by sticks to allow air to circulate between them. With the black painted roof, the air reaches temperatures of 40° to 45°C on a clear sunny day with an insolation of 21 MJ per m^2. The ventilators run from 07:00 to 18:00 hours.

Figure 6 The solar pre-drier within a timber shed, showing the suspended ceiling, collector duct and two vertical ducts

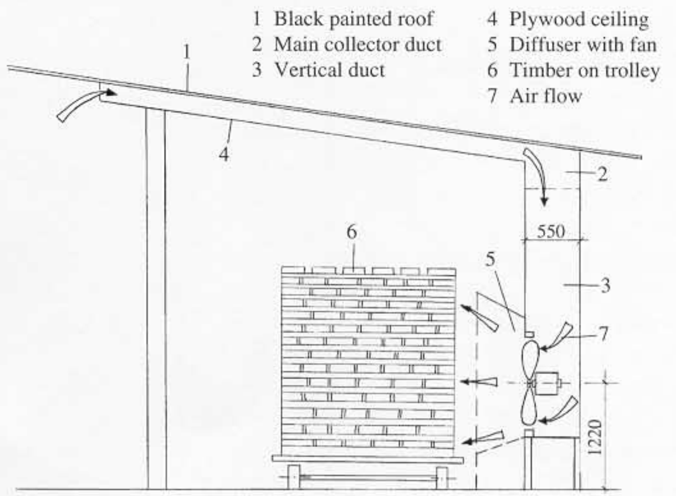


Figure 7 Section of the solar pre-drier, showing how the warm air is circulated to the timber stack

Economic considerations

The following economic comparison of the solar kiln with a conventional kiln, evaluated in Jamaica, only shows the costs which differ for both options. Investment for ventilators of the kiln and the basic building for instance, are not mentioned, since they neutralize each other.

	Solar kiln	*Conventional kiln*
Additional cost of the kiln's solar roof (duration of life: 6 years)	5,100 US$	
Absorber cost (duration of life: 15 years)	685 US$	
Total cost of the pre-drier (duration of life: 15 years)	3,400 US$	
Cost of electricity for longer fan operation (including kiln and pre-drier fans)	4.5 US$ per m^3	
Annual drying quantity	165 m^3	165 m^3
Cost of oil fired 100 kW boiler (including installation of steam pipes) (duration of life: 15 years)		12,500 US$
Cost of oil to dry 1 m^3 moist timber		29 US$
Total cost within 6 years	13,640 US$	41,210 US$
Total cost within 12 years	23,195 US$	69,920 US$

Advantages of the solar kiln:

- significantly lower expenditure
- mild drying
- environmentally friendly
- easy to maintain

Advantages of the oil fired kiln:

- easy increase of drying capacity, drying operation possible 24 hrs/day
- lower wood moisture content attainable (7 to 8 %)
- independent from weather
- lower capital tie-up due to faster availability of dried lumber (no slow pre-drying necessary).

Final contemplation

The economic considerations of this case study as well as the understanding of the necessity of drying timber before entering the manufacturing process, present the solar drying system as a viable alternative to conventional systems, especially for small and medium sized companies, which manufacture exclusively for the local market. By utilizing the abundantly available solar energy, which is free, renewable and non-polluting, they can achieve an emormous improvement of the durability of their products.

Even for larger and exporting firms, drying with solar energy can be of potential interest. By combining solar pre-drying with oil fired systems, an essential part of the enormous cost for fuel can be saved. However, a great deal of information and demonstration work needs to be undertaken to spread the know-how and overcome the obstacles of further dissemination.

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