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Drying by Solar Radiation in Puerto Rico

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In Puerto Rico, and in the tropics in general, there are very few dry kilns. Often lumber is processed at a moisture content higher than 30 percent, resulting in problems during manufacturing, finishing, and in use. Research on solar drying at the U. S. Forest Products Laboratory led to the construction of the first solar dryer in the tropics in Puerto Rico, and the results have been promising. The use of solar heat may, because of its low cost, provide a readily acceptable solution to the lumber drying problems of this region.

THE WOODWORKING INDUSTRIES OF Puerto Rico are dependent upon imported lumber, most of which is not air dry when it reaches the island. None of the local furniture or millwork plants possess adequate facilities for drying lumber, either an air-drying yard or a dry kiln. Even storage space is inadequate, so the common practice is to store lumber in solid piles out-of-doors with no protection from damp local climate. Lumber from such piles usually enters the production line with no attention to moisture content. This practice occasionally causes difficulties when manufactured items are placed in service.

The local lack of concern with dryness of lumber has resulted in only minor problems until recently. The low shrinkage coefficients and the grain characteristics of mahogany (*Swietenia macrophylla* King), the most commonly used wood, prevent many of the defects which might otherwise be anticipated. Furthermore, the local climate, with no requirement of interior heat, maintains a relatively uniform, high, equilibrium moisture content. However, this same climatic characteristic is unfavorable to air drying and makes unattainable by this technique a moisture content sufficiently low for marketing locally manufactured products under the drier use conditions prevailing in most of the continental United States.

Recent experiments at the Forest Products Laboratory at Madison, Wisconsin, suggested that solar energy might be an effective and inexpensive basis for drying lumber in Puerto Rico. At Madison, a solar dryer had been designed and tested with results that indicated the possibility of commercial use of this method in areas receiving high solar radiation. As a consequence, the Institute of Tropical Forestry set up a cooperative research program with the E. I. DuPont de Nemours and Company, and the Forest Products Laboratory. DuPont was interested in obtaining exposure data on a new type of transparent plastic film used in the construction of the drier.

The Solar Dryer

A pilot dryer with a capacity of 2,000 board feet was constructed at a cost of approximately $2,000 at a location subject to day-long sunlight on the grounds of the Institute at Rio Piedras, Puerto Rico (see the figure). The structure is 10 feet wide (north to south) by 14 feet, 8 inches long (east to west). The south wall is 9 feet 9 inches high and the north wall is 13 feet 4 inches, making the southward pitch angle of the roof about 16°, or approximately perpendicular to the mean position of the sun at noon in this latitude. The structure rests on a reinforced concrete slab, to which it is anchored by bolts through sill plates. The framework is 2- by 4-inch dimension stock. The north wall is sheathed with plywood. The roof and all other walls are sheathed, both outside and inside, with transparent plastic films, providing an insulating dead-air thickness of about 1½ inches. The west wall contains a pair of hinged doors of the same construction. Small louvered vents were set in the lower corners of the east and west walls.

Within the dryer is mounted a heat-absorbing surface consisting of a corrugated metal sheet, painted black, and set parallel to but about 12 inches beneath the roof. Near the peak of the roof are mounted four 16-inch fans perpendicular to but centered in line with this heat absorbing surface, and powered by a 1½ horsepower motor mounted outside the north wall. Baffles around the fans and beneath the heat-absorbing surface to the top of the lumber pile located centrally within the dryer force circulation of the internal air past the heat absorbing surface, downward, on the south side, through the lumber pile, and back upward on the north side into the fans. A slight pressure differential

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created on the two sides of the pile produces slow air movement through the vents.

The First Test

The first test was conducted with 5/4 mahogany of random widths, recently imported. A pile 4 feet wide and 14 courses high was placed on the center of the dryer (about 1,000 board feet). Boards were matched, end-to-end, in order to utilize the full length of the dryer. Vertically, the boards were separated by stickers 7/8 inch thick by 1½ inches in width, placed 24 inches apart. Pockets to hold four moisture-determination samples were left in the fifth and tenth courses on each side of the pile. These were 20-inch sections, crosscut from two different boards and endcoated before placement. At the same time a comparable pile of the same lumber, 19 courses high, was made on concrete blocks outside but near the dryer. This pile was roofed with corrugated metal and allowed to air-dry.

The period for this test was from October 26 to November 24, 1961. The vents in the dryer were left closed during the first day and left open halfway for the rest of the test period. The fans were normally operated beween 8 a.m. and 5 p.m. Temperature readings were made frequently within the dryer and outside of it on the north wall. Records of maximum and minimum temperatures and precipitation were available from standard instruments at a station less than 200 feet from the site. Relative humidity data were obtained from a station within 5 miles. Sample weighings were made almost every day. Moisture contents were determined by relating these to oven-dry weights obtained for each sample after the test period.

The Second Test

At the end of the first test a full charge of lumber, about 2,000 board feet of 4/4 mahogany, was placed in the dryer to determine results during a different weather period and with the dryer operated at capacity. The material was done as in the first test but no comparable air drying pile was made. With the exception of the height of the pile (40 courses), and the fact that the south vents were kept closed and the north vents wide open throughout the test, there were no differences in the techniques used in the two tests. This test took place between December 15, 1961 to January 8, 1962.

Observations

The First Test: The weather during the first test was normal as to temperature but excessive as to cloudiness and rainfall. The mean minimum and maximum outdoor temperatures during the period of this test were 68.6° and 85°F. Relative humidity of the air for this period averaged 91 percent at 2:00 a.m., 88 percent at 8:00 a.m., 68 percent at 2:00 p.m., and 82 percent at 8:00 p.m. During the 30 days of the test, rain fell on 24 days, with a total precipitation of 14.92 inches.

Temperatures inside the dryer averaged 28°F. higher than outside, with a maximum of 40°F. attained on two occasions. Near the end of the drying process, when little heat is required to evaporate moisture, an 8-day average afternoon temperature difference was 37°F. The highest temperature recorded within the dryer was 122°F.

The moisture content of the lumber in this test, at the time it was placed in the dryer, was 50 percent. The drying rate of the various samples was sufficiently similar to permit their combination in determining the average moisture contents. The moisture content of the solar-dried lumber dropped to the 12 percent point in 23 days, having lost 38 percent during this period. The air-dried lumber, on the other hand, retained 27 percent moisture at this time, having lost only 23 percent. In terms of moisture loss, the rate was nearly twice as rapid in the dryer. Moreover, the solar dryer had reduced the moisture content below that ever attainable by air drying in this climate. Actually the decline in the air-dried pile had slowed almost to a standstill near the end of this rainy period. Nevertheless in the dryer, moisture loss continued to a level of 8.5 percent after 29 days.

The Second Test: The second test was conducted during a period with similar temperature and humidity, but with much less rainfall than in the first test. The mean minimum and maximum outdoor temperatures during the period of this test were 66.1°F. and 84.3°F. Relative humidity of the air averaged 89 percent at 2:00 a.m., 89 percent at 8:00 a.m., 67 percent at 2:00 p.m., and 81 percent at 8:00 p.m. for this period. During the 25 days of this test rain fell on 18 days, with a total precipitation of 2.60 inches.

Concurrent afternoon temperature readings taken inside and outside the dryer during this test showed an average difference of 28°F., as in the previous test.

The moisture content of the lumber in this test at the time it was placed in the dryer was 32 percent. It reached the 12 percent point in 13 days, having lost 20 percent during this time.

Comparing these two tests, it is seen that the decline from 32 percent to 12 percent took 19 days in the first test, but only 13 days in the second. This difference was in spite of the smaller volume of lumber and the higher temperatures prevailing during the first test. The difference in drying rate may be partly due to the difference in the thickness of the material (5/4 versus 4/4), but the main reason is probably the contrast in rainfall and outdoor humidity during the two periods. During the period required for drying from 32 to 12 percent in the first test, rain fell on 16 of the 19 days, a total of 13.22 inches, and the mean 2 p.m. relative humidity was 73 percent. For the 13 corresponding days of the second test rain fell on 10 days, a total of only 0.51 inch, and the mean 2 p.m. relative humidity was only 63 percent.

End Splitting: Prior to the tests most of the boards contained minor end checks and end splits. Each of these was marked prior to drying so that any increase in length during the drying would be evident. The data collected are not susceptible to mathematical analysis, but it was clearly evident that no serious end splitting developed within the dryer. The air-dried lumber, even though not completely dried during the test, showed a greater tendency to end split than that within the dryer.

Drying Costs: No attempt was made to obtain detailed drying costs in this study, since the dryer, if successful, will presumably sell itself primarily as a basis of the major saving in drying time and corresponding reduction in working capital tied up in yard inventory. The tests suggest that the solar dryer can reduce the moisture content of lumber to 12 percent in less than half of the time required to air dry lumber to the local equilibrium moisture content of about 15 percent. The cost of operating the dryer was limited to that of operating a 1½ horsepower motor 8 hours per day.

Conclusions

Elapsed times for drying 5/4 and 4/4 mahogany lumber in a solar dryer of the type tested, and under the warm humid conditions prevailing during the Puerto Rican winter are much shorter than those required for air drying. Lumber dried by solar heat can be reduced to a lower moisture content than it can by air drying. More extensive testing of this type of equipment in different seasons of the year, with different sizes of material and species of lumber, and in other climates of high insolation would be warranted.