MEASUREMENTS OF MOISTURE IN CRAWLSPACES RETROFITTED FOR ENERGY CONSERVATION

by

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ABSTRACT

This paper presents wood moisture measurements from 15 crawlspaces in a Toms River, NJ development. Six of the crawlspaces had their masonry block walls insulated with one-inch-thick extruded polystyrene panels. At the same time the floors were covered with polyethylene sheets to reduce moisture transport from the wet ground below these houses. In three of the retrofitted houses, the vents in the crawlspace were sealed while in the other three, vents were left open. The remaining houses did not receive any crawlspace retrofits and had open vents. Periodic visits were made to measure air humidity and wood moisture in these crawlspaces over the course of a year. Seasonal variations of wood moisture content were noted with higher values occurring in the summer months.

For the insulated crawlspaces, there is little difference in wood moisture content between crawlspaces with vents open and those with vents closed; moisture content stays well within safe limits in both cases. In three of the six untreated crawlspaces, however, the average wood moisture content exceeds 20% for at least a part of the year, with very high levels at some locations. Our results indicate that if the ground has been covered with a vapor retarder, leaving crawlspace vents open is not necessary to contain moisture within safe levels. In the future, building codes should require vapor retarders on crawlspace dirt floors, and eliminate the requirement for ventilation in those regions of the country where this approach poses no moisture threat to the wood building materials.

INTRODUCTION

Ventilation of crawlspaces through passive vents has been the traditional way for preventing moisture buildup. However, recent attempts to reduce heat loss through crawlspaces have called for adding insulation either on the floor above the crawlspaces or on the outside walls. The latter is easier to install and thermally more effective in that it traps heat from crawlspace ducting,[1] however, ventilating a crawlspace greatly reduces the energy savings from added wall insulation.[2] On the other hand, if the vents are sealed to increase energy savings, increased moisture buildup in the crawlspace leading to condensation damage could negate the benefits of the energy savings. The experiment described here was designed to determine the effect of ventilation on crawlspace wood moisture content following energy saving retrofits. Seasonal variations in wood moisture content were used to compare crawlspaces with wall insulation (with vents open and closed) and crawlspaces without wall insulation (with vents open). The houses for our study are located where the water table is high, thus moisture problems are more likely.

THE EXPERIMENT

The houses involved in this experiment are part of a retirement community near Toms River, New Jersey. The community is approximately eight miles from the ocean in an area known as the Pine Barrens which character- istically has sandy soil with a high water table. The one-story houses have approximately 900 square feet of living area and were built using wood frame construction, over a crawlspace with a dirt floor. Many of the crawlspaces were frequently wet indicating a very high water table at this site.

The houses in this experiment were part of a larger effort called the Modular Retrofit Experiment (MRE)[3] which was designed to test the effectiveness of instrumented energy audits and retrofit strategies on a wide range of housing styles. The retrofits consisted of a variety of conservation measures addressing the thermal envelope as well as furnace tune-ups and the installation of low flow showerheads. The experiments evaluated the level of effort, actual energy savings, and the cost effectiveness of the analysis/retrofit techniques known as "house doctoring".[4]

The MRE study consisted of seven modules, of 18 homes each, located in New Jersey and New York. Each module consisted of a six-house control group where no retrofits or measurements were taken; a six-house "house doctor" group, and a six-house "major retrofit" group which received the house doctor treatment plus additional wall and attic insulation (where needed). The module located in Toms River was the site of the houses in the experiment reported here. In this module, the houses in the major retrofit group received additional attic insulation and the crawlspaces were retrofitted as follows: the ground was covered with six-mil polyethylene film, which ran up the walls of the crawlspace about a foot; one-inch-thick extruded polystyrene insulation (R-5) was glued to the inside of the crawlspace walls, over the polyethylene film.

There were a total of 15 houses in the experiment. Six of the houses were in the major retrofit group and the remaining homes were in the "house doctor only" group which did not receive any crawlspace retrofits in the MRE. In reality, some "house doctor only" houses also had crawlspace wall insulation and polyethylene film on the ground, arranged by the homeowners themselves, independent of the MRE. These retrofits were taken into account in categorizing the houses according to the condition of the crawl space.

One additional retrofit originally included in the major retrofit group was the sealing of the crawlspace vents with tightly fitted and caulked polystyrene insulation. By covering the ground with polyethylene film we felt that the major moisture source had been eliminated so that the crawl space vents were no longer necessary to control moisture buildup. To test this hypothesis, the sealed vents in three of the six houses were reopened.

In all fifteen houses, wood moisture content at various locations in the support beams, floor joists, and rim joists were measured with a detector that measures the electrical resistance across two nail-like pins hammered into the wood. A constant voltage is applied across the pins, which are separated by about 1.5 inches, and the electrical resistance is measured. The resistance goes down exponentially as the wood moisture content goes up. The range of resistance falls roughly between 10^3 and 10^{12} ohms. In addition, crawlspace air humidity was measured using a sling psychrometer. In the process of our measurements we also recorded the presence of any large water puddles or breaks in the plastic sheets. Measurements were made over a year-long period, every month for the first three months and every other month thereafter. There were a total of seven trips each to 13 houses while the two remaining houses only received six visits due to scheduling problems.

RESULTS

The seasonal variation in wood moisture content, aggregated in various ways is presented in Figures 1-8. The moisture content in all the houses shows the same seasonal trend. Wood moisture content peaks around day 200 (July 19, 1983) with a broad minimum around day 400 (Feb. 4, 1984), i.e., the peak is reached in the summer and the minimum in the winter. The fact that the wood moisture content is higher in the summer goes against the commonly held belief that the summer is a time when the properly ventilated crawlspace dries out. Attics by contrast experience higher moisture levels in the winter and dry out in the spring.[5]

Figures 1 and 2 show that the house-to-house variation in wood moisture content is small for crawlspaces with wall insulation (both vents open and vents closed). There is much greater variation among houses in the "no-wall insulation, vents open" group (Fig. 3). This group includes houses that were insulated by the occupants. Unlike the houses in the other groups, some of these unretrofitted houses had wood moisture levels above 20%, a value corresponding roughly to the threshold for wood decay. Our detailed measurements, not presented here, show that in parts of the crawlspaces of these houses, the wood moisture content was much higher than the location-averaged values presented in Figure 3.

Averaging the moisture content, not only by location in the crawlspace (as in Figures 1-3), but also across houses within each group, Figure 4 shows that the average moisture content of crawlspaces with wall insulation and with vents open is slightly higher than with vents closed but the uninsulated crawlspaces (with vents open) had much higher wood moisture content. The four to six percentage points higher average wood moisture for this group is substantial compared to the 20 percent condendation damage level.

A few of the "no wall insulation vents open" houses had some polyethylene sheeting covering the ground, but it did not constitute an effective covering. All of the crawlspaces with wall insulation had well installed polyethylene film over the entire ground and partway up the walls. If we group the houses by the presence or absence of floor covering we note the moisture content is substantially higher without the floor covering (Fig. 5). Since the presence of floor covering accompanied the wall insulation and is therefore strongly correlated with it, it is not possible to separate their individual effects from our data. It appears, however, that the reduced moisture migration through the walls, covered by extruded polystyrene, and through the ground, covered by polyethylene, was a substantial factor in reducing the moisture content of wood in retrofitted crawlspaces.

The effect of vent opening on moisture content of crawlspaces with wall insulation can be seen in Figure 4. The group of retrofitted houses with vents sealed, i.e. with the least amount of ventilation air, actually has the lowest moisture content. This is physically reasonable since warm, moist air from the outside flowing into a cooler crawlspace in the summer results in an increase in the air relative humidity and wood moisture content. It is interesting to note that, prior to the retrofits and in unretrofitted houses, homeowners often took care to open the crawlspace entrance hatches in the summer believing that the increased ventilation would dry out the moisture which built up over the winter when the vents were closed.

Wood moisture data aggregated across houses by structural elements within the crawlspace (floor joist, support beams, rim joist) for each of the three groups are presented in Figures 6-8. Insulated crawlspaces with vents closed show little spatial dependence (Figure 6). For the insulated crawlspaces with vents open, the highest moisture content is recorded in the support beams (Figure 7) while the "no wall insulation vents open" case shows highest values in the floor joists (Figure 8). In both cases, the rim joist shows the lowest moisture content. These results suggest that with ventilated crawlspaces, moisture levels are expected to be higher in the interior of the crawlspace and not at its perimeter.

CONCLUSIONS

One important conclusion from our results is the need for vapor retarders on exposed soil floors and possibly on cinder block foundation walls, for controlling moisture problems. Once moisture flows into the crawlspace have been reduced in this way, the addition of wall insulation and closing crawlspace vents create no moisture problems. The reduction in ventilation enables the energy savings from the wall insulation to be enhanced.

Although our measurements were made in the Mid-Atlantic climate with its warm moist summers, the results are likely to be relevant to other areas as well. Extrapolation of these results to more humid southern climates must, however, be preceded by additional measurements. The requirement for ventilating crawlspaces in the Northern states could be resulting in significant additional energy losses in the winter.

Our results have several implications towards the modification of building codes applicable to crawlspaces. First, the installation of well-installed vapor retarders on crawlspace dirt floors should be a requirement. Second, the requirement for crawlspace ventilation can be eliminated in the case that vapor retarders properly cover the floor and walls of a crawlspace. These two code changes should greatly reduce moisture problems while permitting larger energy savings in crawlspaces in Northern climates.

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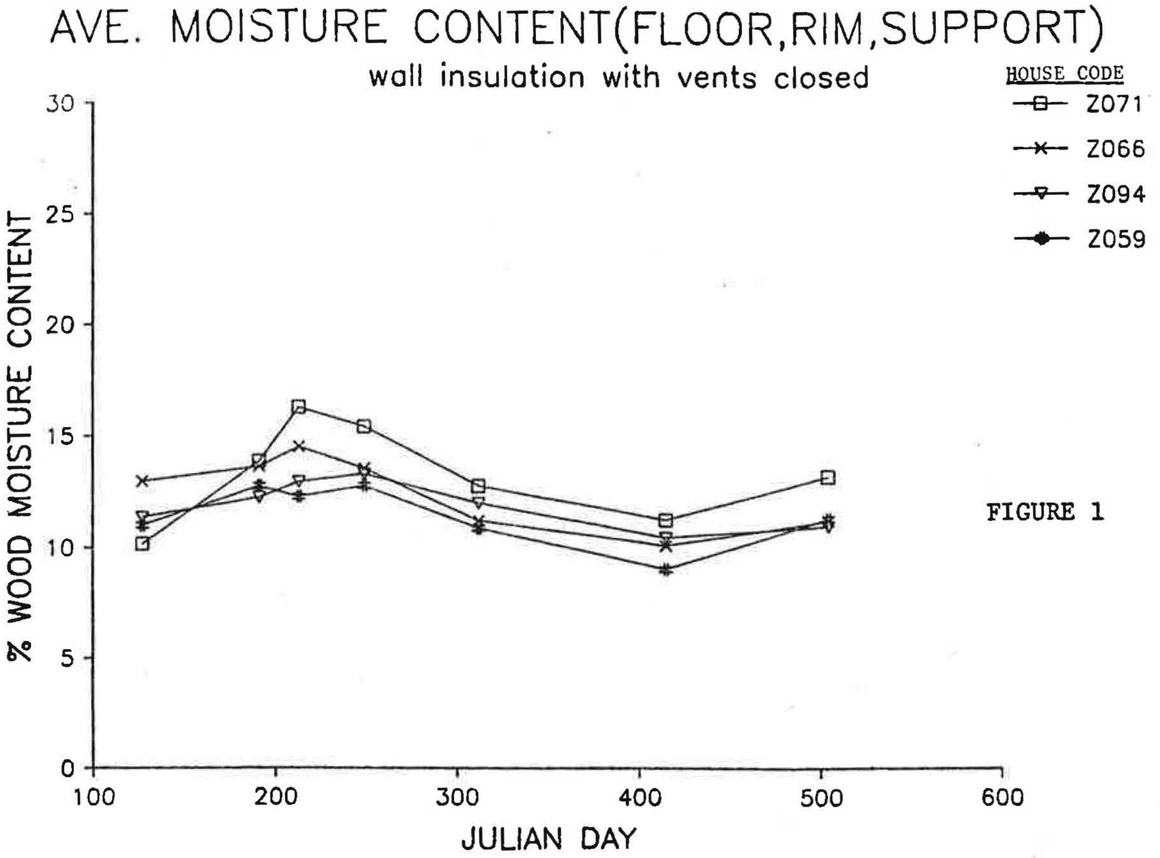


FIGURE 1

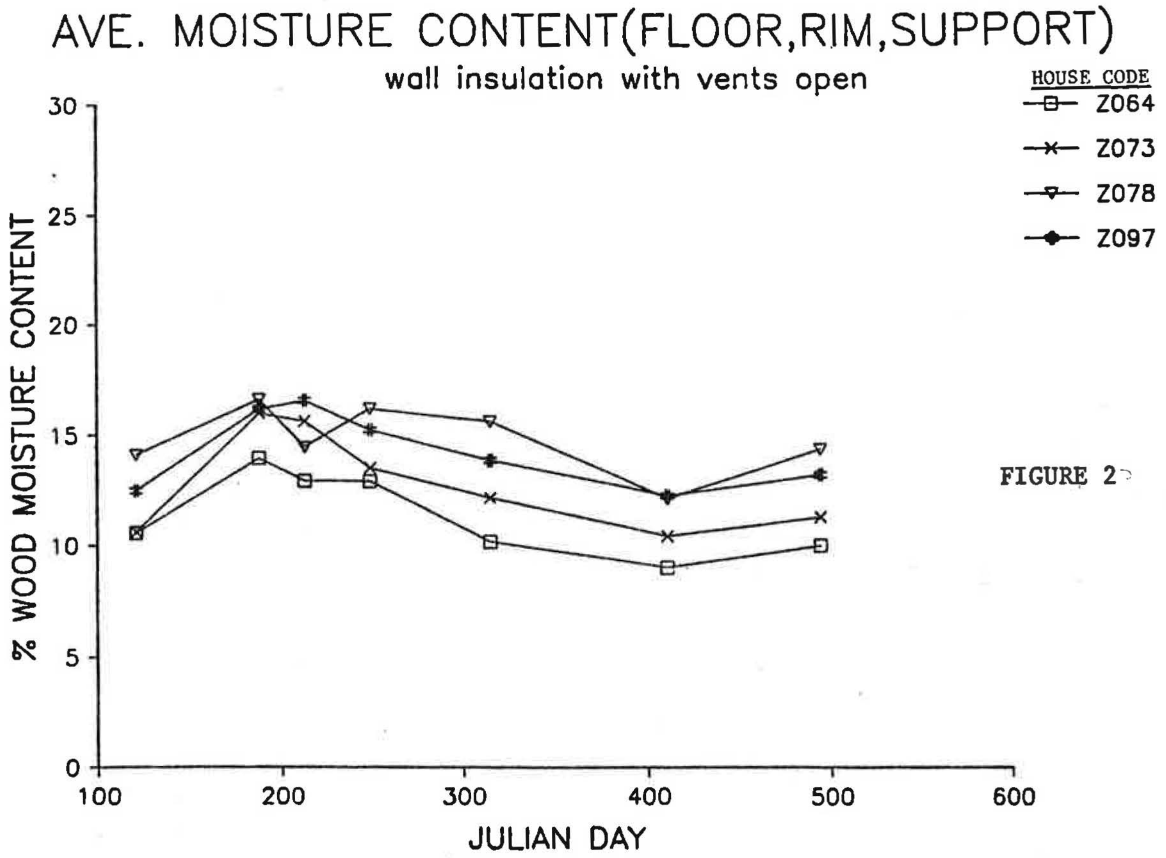


FIGURE 2

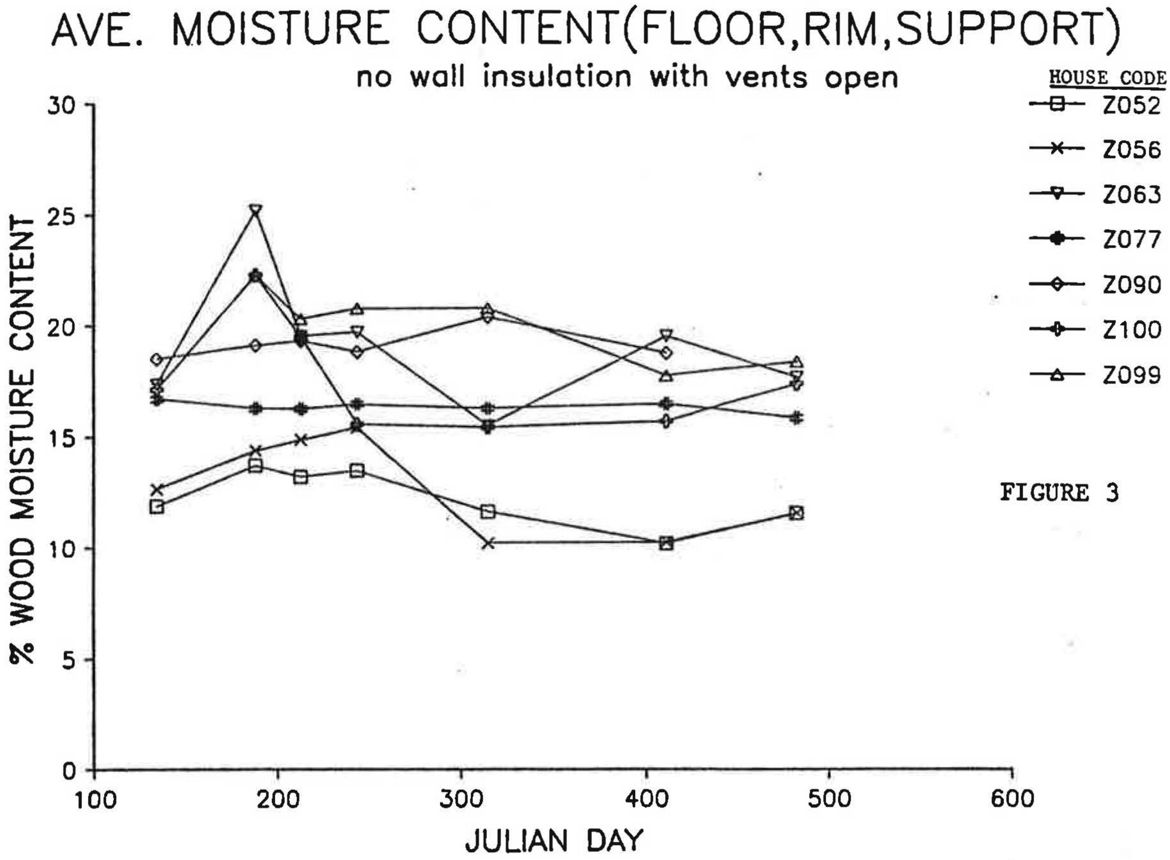


FIGURE 3

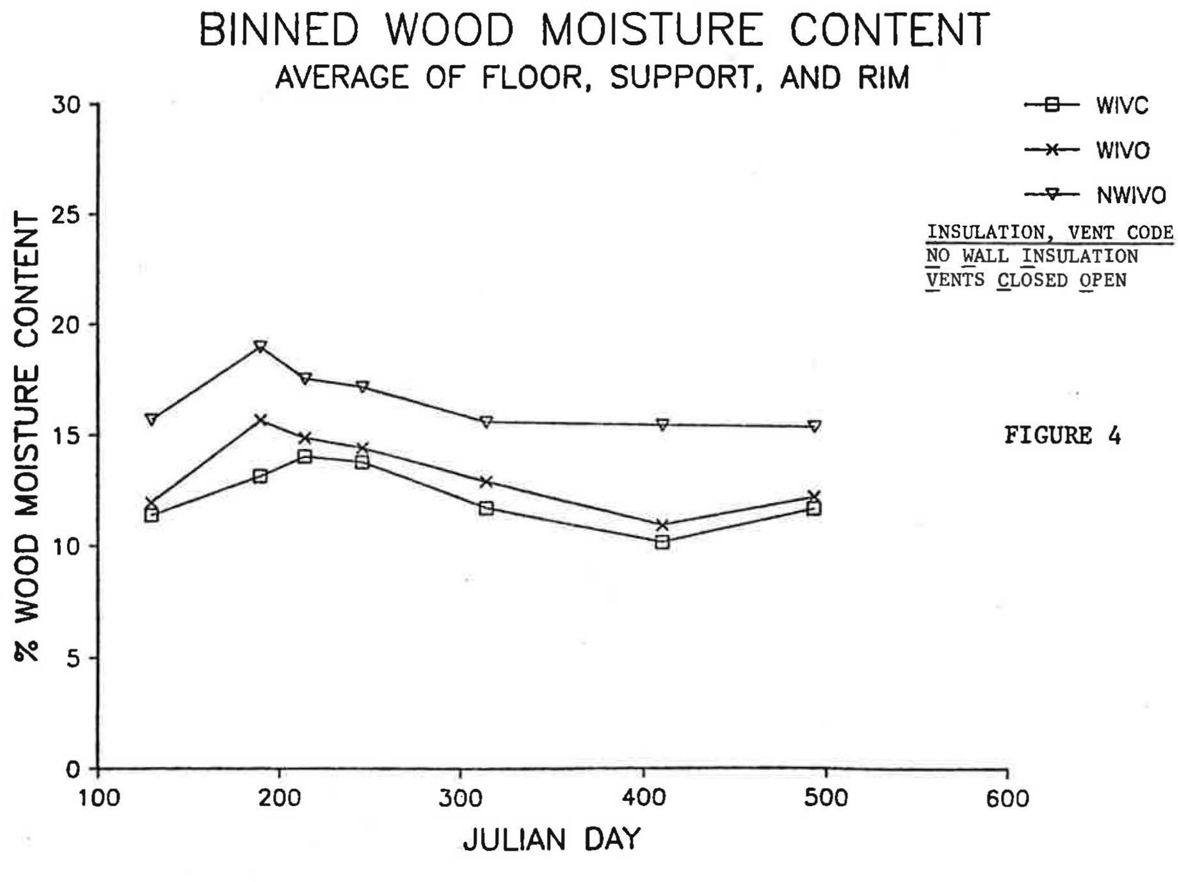
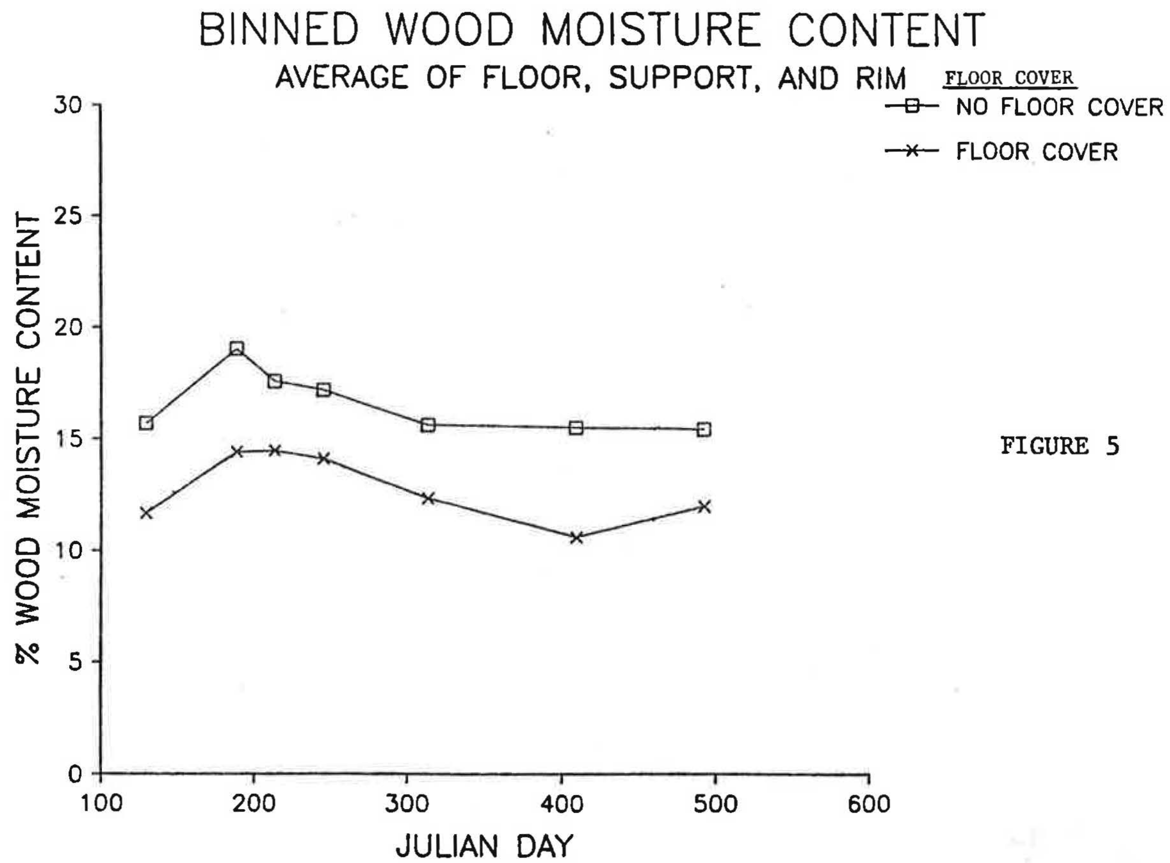


FIGURE 4



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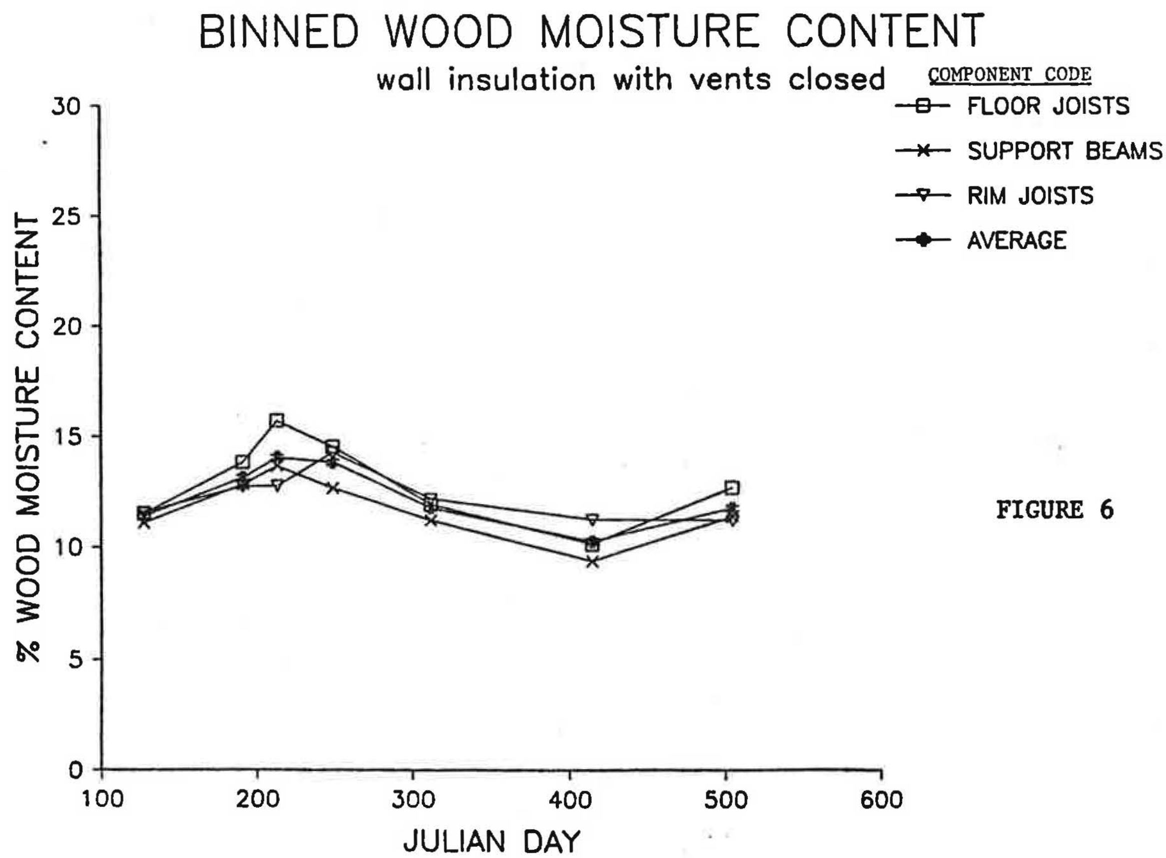

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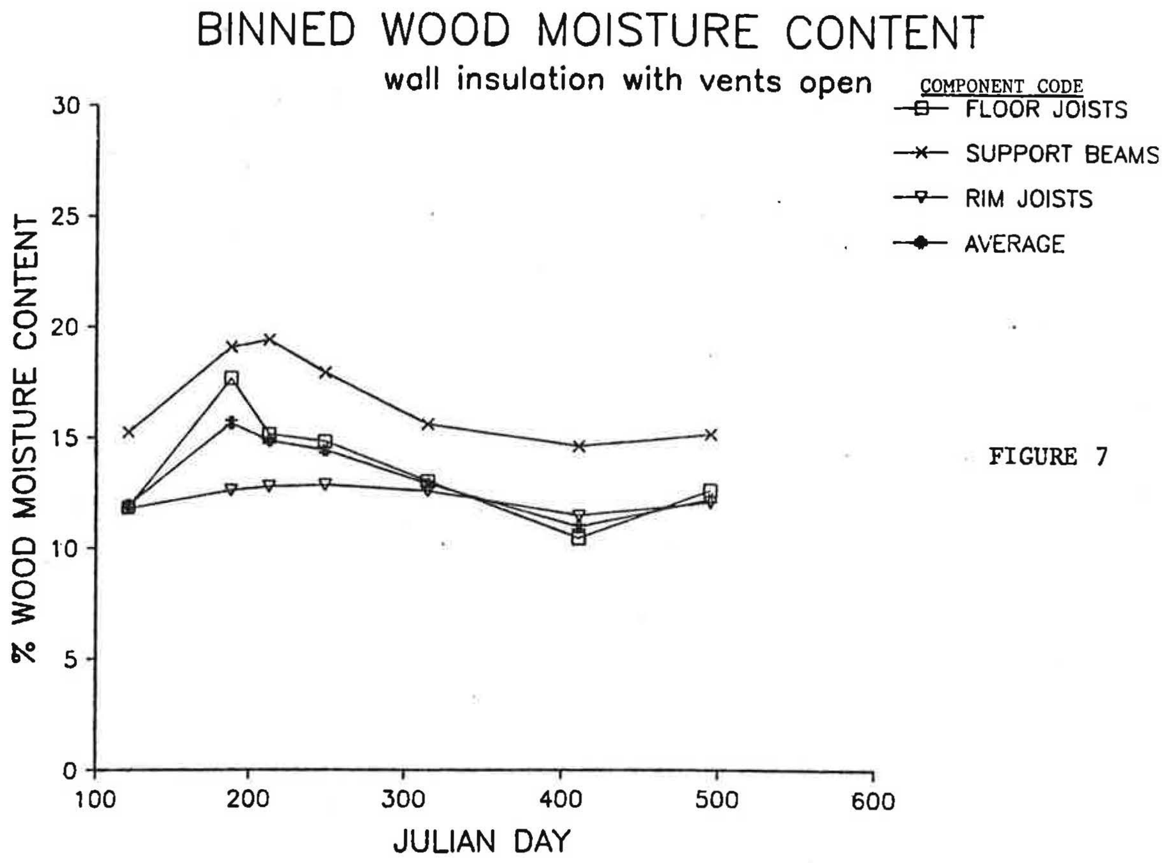

FIGURE 7

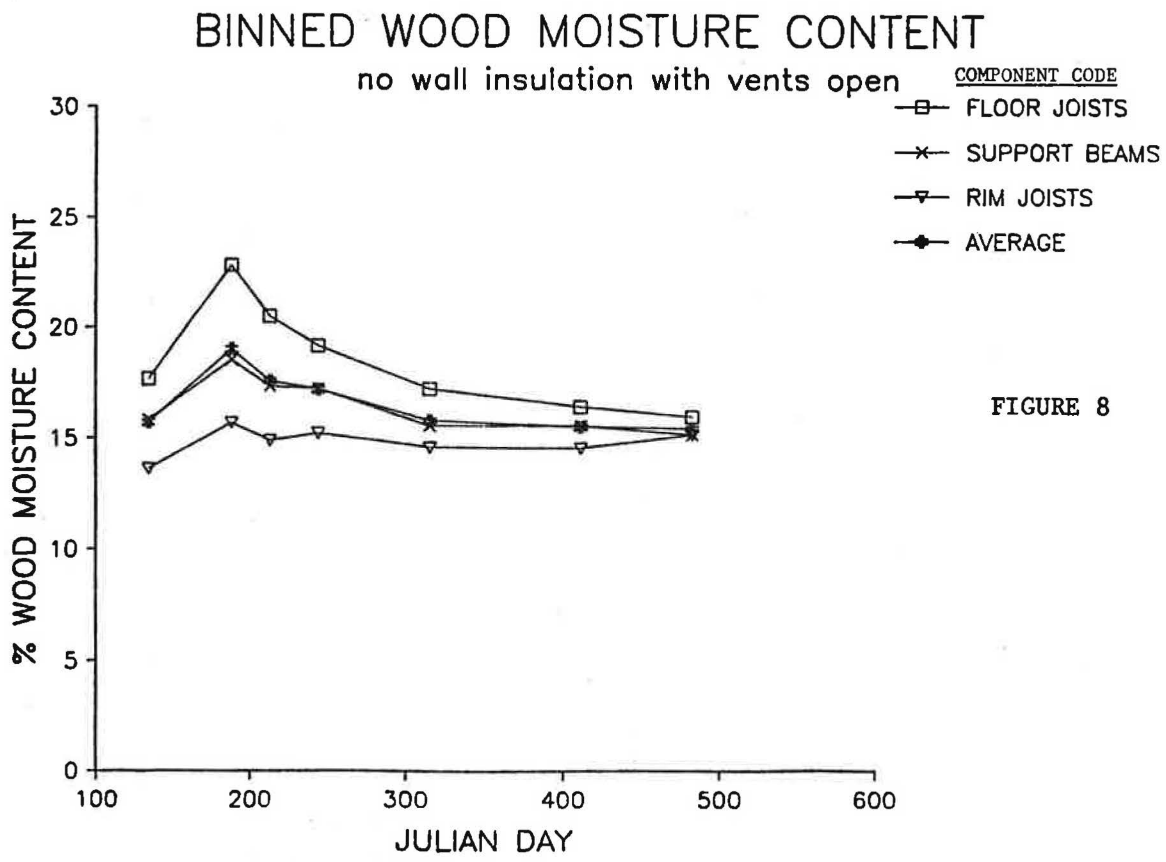

FIGURE 8