CONSENSATION AND DECAY PREVENTION UNDER BASEMENTLESS HOUSES

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CONDENSATION AND DECAY PREVENTION
UNDER BASEMENTLESS HOUSES

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Summary

Observations and measurements support the hypothesis that sufficient moisture to sustain growth of decay fungi in the end and header joists of basementless houses may arise solely from condensation of water vapor coming from damp soil. The condensation occurs during those portions of the year when the wood temperature may be below the dewpoint. In field tests, this condensation was prevented by the use of a soil cover.

Introduction

The advent of the small, tightly constructed house brought with it problems of excessive moisture in walls and attics leading to paint failure, decay, and other troubles. Many investigations (3)2 have shown that a chief cause of this excess moisture is condensation of water vapor in

1Maintained at Madison, Wis., in cooperation with the University of Wisconsin.
2Underlined numbers in parentheses refer to Literature Cited at the end of this report.
the atmosphere. Condensation is a phenomenon that takes place in response to definite physical laws. Air contains moisture in the form of water vapor, an invisible gas. When the air contains all the water vapor it can hold at a given temperature, it is said to be saturated. Any cooling of the saturated air below this temperature, the dewpoint, will condense out some of the vapor. Similarly, when the temperature of any wooden structural member of a house, in response to outdoor temperature particularly, is below the dewpoint temperature of the water vapor surrounding it, condensation takes place on these members. Absorption of the water by the wood may then lead to paint failures, decay, and other troubles.

The chief danger from excessive amounts of moisture in wood is the occurrence of decay caused by fungi. Wood-destroying fungi are plants, but unlike the ordinary plants they lack chlorophyll and are unable to manufacture their own food. The microscopic "roots" of these fungus plants, known as hyphae, attack the wood elements and extract nourishment from them. The wood gradually loses its strength and eventually becomes the softened and often brown, cracked, or powdery material recognized as rotted wood.

The decay-producing fungi grow most rapidly at temperatures of 70° to 85° F., but some growth may take place between the extremes of 40° to 100° F. Free water in the cell cavities of the wood is also essential for fungus growth, which means that wood with a moisture content lower than about 20 percent, ovendry basis, will not decay. Keeping wood dry, therefore, is a practical method of controlling decay.

In the living quarters of the house, water vapor is continually being added to the atmosphere from the activities of washing, cooking, heating, and even from the respiration of the occupants. Investigations (3) have shown that the application of vapor barriers to the warm side of walls and ceilings and the use of adequate ventilation will prevent condensation and thus eliminate troubles arising from excessive moisture.

In the crawl space under a basementless house, the moist soil has generally been considered a source of water vapor. Data presented in this report show that condensation of the water vapor from the soil alone is sufficient to raise the moisture content of subfloor structures to a level that will support growth of decay organisms. It was also demonstrated by these tests that the use of a soil cover (comparable to the use of a vapor barrier in the walls and ceiling of a house) can prevent this condition. The value of soil cover has been strikingly demonstrated by Diller (1), and widespread use has been made of this device. His early trials of soil cover resulted from suggestions made by T. C. Scheffer of the Division of Forest Disease Research at the Forest Products Laboratory in the course of general discussions of the subject.
All of these investigations were carried on in private houses in the Lake States Region with the consent and cooperation of the owners and occupants, and while some limitations resulted, it is due to the assistance of these people that so much information was obtained. Corroborative evidence in the form of observations and additional measurements were obtained during this study, but only the minimum data needed to support the case will be presented here.

How Crawl Space Wood Members Become Wet

This part of the study was made in a house in Madison, Wisconsin. The house was of frame construction on a concrete foundation with a floor area of about 900 square feet. The crawl space was provided with 5 vents having a total of 148 square inches, which represents 18 percent of the approved 2 plus 1/3 formula. The vents remained open during the winter of 1943-44, when the first observations were made. They were closed in October 1944 when the second series of observations was started, and they were kept closed until June 6, 1945. The study was restricted to an area under the utility room which could be reached through a trap door. The soil under the house was usually wet to the point of being sticky but not muddy or soft. It was never frozen during the winter, as was the outside soil, and it was capable of giving off water vapor all the time.

It was postulated that if condensation were responsible for the wetting of the wood, then the temperature at the surface of the wood should generally be below the dewpoint when the moisture content of the wood was high. On the other hand, with low moisture content in the wood, the temperature at the wood surface would generally be above the dewpoint. Of course, some of the high moisture content would result from retention of previously condensed water vapor. Perfect correlation, therefore, is not to be expected.

The following measurements were necessary for the investigation of this hypothesis: (1) Moisture content of the wood; (2) Temperature of the wood at the surface; and (3) Dewpoint temperature. The dewpoint was a computed value determined from the air temperature and the relative humidity of the crawl space.

2This formula calls for 2 square feet of vent area per 100 lineal feet of building perimeter, plus one-third of 1 percent of the crawl-space ground area after allowance for air-flow obstructions (2).

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Methods of Obtaining Data

1. Moisture content.--The moisture content of the wood was obtained by means of a resistance-type moisture meter. Permanent contacts were established at stations in the header joists, end joists, floor joists, and subfloor. The contacts or electrodes were made of 1/4-inch fiber rod drilled to accommodate a No. 14 brass escutcheon pin 1-1/4 inches long. The length of the fiber rod was such that the pin protruded 1/4 inch (fig. 1). At each station, a pair of electrodes, spaced 1-1/4 inches apart along the grain direction of the wood, were driven so that the conducting part extended 1/4 inch into the wood. The electrodes were sealed to the wood with melted grafting wax. Leads of No. 23 S.C.E. copper wire were run from the contacts to the access door, and the meter was connected at that point when weekly readings were taken. The meter readings were corrected for wood temperature in accordance with the directions furnished by the manufacturer.

2. Temperature at the surface.--The temperature of the wood was obtained by means of copper-constantan thermocouples and a potentiometer. Thermocouples were placed under a sliver on the surface of the wood and secured with a drop of melted grafting wax. Separate leads to the access door were used for each thermocouple.

3. Dewpoint temperature.--The dewpoint temperatures were computed from the air temperature and the relative humidity. The air temperature was obtained from a thermocouple inserted in a foil tube suspended in the center of the crawl space. The prevailing relative humidity was measured by the equilibrium moisture content of a joist at a station in the center of the crawl space. The meter reading at this joist was corrected for temperature as described above. The moisture content of air-dry wood is determined largely by the relative humidity of the air, and the general relation has been defined graphically (4).

It is obvious that equipment for obtaining continuous readings would have been desirable, but even the weekly measurements made as described above proved to yield worthwhile data.

Results and Discussion

The results of this study have been summarized in table 1. A graph illustrating the sequence of typical readings at the start and conclusion of a winter season is shown in figure 2.

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1 The header joists are those members resting entirely on the sill and into which the floor joists frame. The end joists also rest entirely on the sill and are parallel to the floor joists. Both members, therefore, are at the periphery of the building.
With the exception of the data for Station II, it is obvious that within
the limitations of our weekly readings, conditions suitable for conden-
sation existed in the crawl space during the time that wood moisture was
building up and being maintained at a high level. On the other hand,
when wood moisture content was low there were only a few times when our
data indicated that condensation should be taking place.

The poor agreement of Station II requires some explanation. This station
was located on a joist about 6 inches away from the header joist. As the
data indicate, this station would not be expected to receive much moisture
through condensation. This was actually true; the chief source of mois-
ture here was observed to be the absorption of condensate that had formed
on and flowed or dripped from such nearby colder surfaces as the header
joist and subfloor. However, there were several times during the coldest
weather when this station was itself below the dewpoint, and the moisture
content was increased by condensation.

There is some question of the accuracy of the moisture meter at the high
moisture contents. It was not feasible, of course, to remove cores from
the substructure members to determine moisture content on an ovendry
basis. In a very few cases, small blocks clamped to the header joist
with foil interspersed were used for the determination of moisture by
ovendrying and were in good agreement with the meter. However, disre-
garding absolute moisture values, it was clear that wood moisture in-
creased with the onset of cold weather, dewpoint temperatures, and con-
densation, and decreased when these conditions no longer existed.

The outdoor temperatures shown in figure 2 were obtained from the Madison
office of the U. S. Weather Bureau. The values shown are the averages
for the week preceding the observation. Outdoor temperatures, of course,
are related to the phenomenon of condensation, but the values necessary
to cool the header and end joists below the dewpoint vary considerably
throughout any given house. These variations may be due to the type of
materials and construction used, which may influence the insulation
factor, or to the presence of heating pipes in the crawl space. High
concrete foundation walls, for example, tend to condense water vapor and
absorb the condensate or let it drip back into the soil. Surface mois-
ture contents of wood members began to build up above 30 percent when
outdoor temperatures were near 40° F. and below. When outdoor tempera-
tures ranged from 41° to 51° F. and above, moisture contents were again
consistently below 30 percent.

The range of temperatures attained by the wood members may be of interest.
At one station, as many as 20 readings of 50° F. and more were recorded
when the moisture content was above fiber saturation. The maximum tem-
perature noted under this condition was 68° F. While these values are
considerably below those for optimum growth of wood-destroying fungi, it
is known that some growth will occur at these temperatures.

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As final evidence, it can be reported that advanced decay was found in the east and north joists in 1952, the house then being 12 years old. This decay was not noted on a previous inspection in 1948.

Prevention of Condensation Moisture on Crawl Space Wood Members

Studies of the prevention of excessive moisture in substructure members were made in houses located in suburban Chicago. A high water table in the area resulted in almost constantly damp soil in the crawl spaces. Decay was found in the header joists of several houses.

The method selected for the prevention of condensation moisture was the use of a soil cover of a vapor barrier type of material (4). Initially, a number of comparable, adjacent houses were selected as test houses (with cover) and as control houses (without cover). However, it was soon apparent that differences between houses would interfere with the success of the test, and two houses were chosen in which the soil cover was manipulated during the winter months so that the same house served as control and test subject. Asphalt roll roofing weighing 45 pounds per 108 square feet was used as the soil cover.

These houses were provided with vents of 11 and 40 percent capacity, respectively, (see footnote 3), but planned ventilation was eliminated during the test by closing all the ventilators. However, there was always a slight interchange of air due to faulty vents, cracks between foundation and sill, and other leakage.

The test was designed simply to measure the moisture content of the wood when the soil was covered or uncovered.

Method of Obtaining Data

The moisture content of the wood in the header and end joists was obtained by means of the moisture meter. Permanent contacts of the type described earlier were installed. During the last part of the study, the temperatures of the header joists were taken by means of a bimetallic thermometer. These temperatures were used in correcting the moisture content as read by the meter (figs. 3 and 4). Supplementary information included air temperature of the crawl space measured as above, relative humidity as measured by a hand-aspirated psychrometer, dewpoint computation, outdoor temperatures recorded at the nearest station of the U. S. Weather Bureau, and observations on condensation.
Results and Discussion

The results of this study are presented in figures 3 and 4. These graphs represent the response of wood moisture to manipulation of soil cover. The degree of control possible is clearly illustrated, even when only a partial cover is used.

It will be noted that, at the beginning of the test, high moisture content values occurred in the wood when the average outdoor temperatures ranged from 26° to 31° F. Similar conditions occurred during the test, and there were weekly intervals from December 20, 1950 to March 6, 1951 during the time the soil was covered when the average outdoor temperature was as low as 9° F. The average for this period was about 25° F. Therefore, these graphs demonstrate that, with all other factors comparable, the use of soil cover prevented any condensation and build-up of excessive moisture in the wood.

Some evidence not shown by a graph includes the "feel" of dryness in the crawl space when the soil was covered and the shrinkage of the subfloor and finish floor. Active fungus growth also ceased to spread over the surface through lack of moisture.

The control achieved with the soil partly covered indicates that a smoothly laid and overlapped cover is not necessary for the success of the system here. Why this is so, in contrast to the carefully installed vapor barrier required for walls and ceilings, is not entirely clear. Of course, there is less opportunity for air movement under the soil cover than there is in wall spaces. The temperature differences of the crawl space are also less, and consequently high vapor pressure is not built up. Thus, the flow of vapor from cracks or gaps in the soil cover probably is restricted largely to that diffused from the soil near such gaps, and, furthermore, the vapor movement does not have such a large motive force. Perhaps the small amount of vapor given off by the partially exposed soil is carried away by air leakage. It is also probable that the great mass of wood substructure acts as a reservoir for a considerable amount of water vapor, absorbing or dissipating it, depending on the vapor pressure.

Asphalt roll roofing was used in this study because it was readily available locally. Other types of cover that will resist the action of decay organisms and still retain vapor barrier characteristics may be used (2).

Not all houses need a soil cover, nor is a soil cover a defense against moisture from other sources, such as leaks or where wood is in contact with damp soil. Soil cover is advisable where winter condensation in header and end joists together with obviously moist wood or presence of decay is observed. A simple test denoting need for a cover is the occurrence of a soil that during the winter months is wet enough to ball up in the hand.

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Literature Cited

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(3) U. S. FOREST PRODUCTS LABORATORY
    1949. CONDENSATION CONTROL IN DWELLING CONSTRUCTION. Housing and
    Home Finance Agency, 73 pp., illus. Washington 25, D. C.

(4) ———
Table 1.—Relation of wood temperatures and dewpoint at
moisture contents above and below 30 percent

<table>
<thead>
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<th>Station</th>
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1Readings made between January 1944 and June 1945 at Madison, Wisconsin.
Figure 1.--Contacts used to obtain moisture content of the wood.

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Figure 2.--Typical relationship of wood temperature and dewpoint during increase and decrease of wood moisture content.

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Data taken from station I in north header joist.
Figure 3.—Effect of soil cover on moisture content of wood subfloor structures in house No. 1 in northern Illinois.

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Figure 4.--Effect of soil cover on wood subfloor structures in house No. 2 in northern Illinois.

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