MOISTURE CONTENT IN WOOD STRUCTURAL MEMBERS IN RESIDENCES WITH DECAY DAMAGE: RESULTS OF FIELD STUDIES

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ABSTRACT

Moisture and decay problems are occurring in South Carolina. Moisture contents in wood floor joists in houses with moisture problems are exceeding the 20% maximum level for air dried lumber. Elevated moisture levels are occurring because of condensation and wood in contact with damp foundation walls. Severe damage is occurring even though wood moisture contents may have not reached the fiber saturation point that most authorities agree is necessary for decay to begin. The author challenges the validity of some information concerning the need for vapor barriers in southeastern climates contained in a recent DOE publication Moisture and Home Energy Conservation.

This paper contains a discussion of wood decay fungi and *Poria incrassata*, a water-conducting fungi that is being found increasingly in residences. Field observations indicate that moisture management techniques such as vapor retarders, crawl space covers, foundation waterproofing, footing drains, and adequate ventilation are being improperly used or ignored. Conditions for wood decay are being generated during construction. Earth-filled porches, a grade ground line too close to foundation sill, and needed foundation vents being restricted by appendages such as porches, carports, chimneys, and heating and cooling equipment are all examples of poor construction techniques that generate moisture and decay problems.

INTRODUCTION

Frequent incidences of moisture and decay damage are occurring in tightly constructed houses with air conditioning in South Carolina. The ASHRAE Handbook - 1985 Fundamentals (ASHRAE 1985) defines a humid climate as one in which one or both of the following conditions occur:

1. A 67 F or higher (20^{o}C) wet-bulb temperature for 3500 or more hours during the warmest six consecutive months.

2. A 73 F or higher (23^{o}C) wet-bulb temperature for 1750 or more hours during the warmest six consecutive months.

Coastal and some inland areas of South Carolina are included in these areas. Field investigations by the author and inspectors of the Plant Pest Regulatory Division of Clemson University have found high moisture content in the structural members of houses, not only in these areas but also in areas of the state not included in this humid zone.

Summer residential cooling in humid areas that also have a significant winter heating load have produced conflicting recommendations for locating the vapor retarder in residential walls. The publication Moisture and Home Energy Conservation (DOE 1983) makes recommendations

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relative to vapor retarders that contradict state recommendations in Arkansas, North Carolina, South Carolina, Virginia, Georgia, and Alabama. It is the intent of this paper to discuss undocumented field observations, not controlled research, that the author has encountered over the past 13 years.

An increasing number of moisture problems in residences are being reported to housing specialists at Clemson University by local extension agents who are asked for assistance by homeowners. Inquiries range from mildew control to structural decay in walls and floors. Homeowners seek advice for correcting the problem and preventing recurrences. Few people are trained in residential moisture management and fewer still are capable of recognizing decay problems and recommending remedial action. In March 1985 the author presented a training session for extension agents on psychrometrics, moisture vapor management, and prevention of interior and exterior moisture problems. Resources for the training included the following publications:

1. Moisture and Home Energy Conservation prepared by National Center for Appropriate Technology, DOE/CE/15095-4

2. Prevention and Control of Decay in Homes prepared by Arthur F. Verrall and Terry C. Amburgy, USDA and USHUD.

These two publications are excellent in the overall definition of the relevant problems but lack consistency on vapor retarders and do not reflect the actual conditions found in the field. Both publications were obtained from the Superintendent of Documents, U.S. Government Printing Office.

Housing educators need reliable resources that can be used with homeowners and builders for managing internal and external moisture. Modern day construction techniques are generating conditions that speed up the decay process and threaten homeowners with increased decay problems.

Wood-Inhabiting Fungi

Wood is a versatile building material and has a long life if kept dry. Fungi will, however, attack wood that is improperly selected, installed, or protected. Levi (1983) reported that homeowners spent about two billion dollars repairing damage caused by fungi and insects.

Fungi that attack wood are small plants that use wood as a food source and lack chlorophyll; thus, they grow profusely in the dark. Fungi vary in the degree to which they adversely affect wood. Verrall and Amburgy classify fungi as molds, stain fungi, decay fungi, soft rot fungi, and water conducting fungi.

Molds. Molds or mildews can grow on wood at moisture contents of approximately 20% and above. They grow best at 75 to 85 F (24 - 30°C). Molds live primarily on starches and sugars in the wood and have a negligible effect on wood strength. However, they greatly increase the wood porosity, which causes the wood to wet much more easily than non-molded wood (Verrall and Amburgy). Molds are an excellent indicator of excessive wood moisture content and as such should serve as an alarm to begin corrective measures.

Stain Fungi. Common stain fungi are sapstain and bluestain. Wood that is heavily stained should not be selected, not because the stain reduces the strength, but because the stain may hide decay fungi, which are not killed by air drying and will become active if the wood is rewetted.

Decay Fungi. Decay fungi enzymatically degrade the wood cellulose and lignin after utilizing the available starches and sugars. They will reduce the wood strength until it fails as a building material. They can survive for years in wood that has become too dry for them to grow but will revive when rewetted (Verrall and Amburgy). Decay fungi need moisture and warm temperatures to grow. It is reported that decay fungi cannot colonize wood with a moisture content below the fiber saturation point, usually 28% to 30% for most species (Levi 1983). This author has found decay fungi in floor joists at moisture levels of 20% to 25%. The cause that may produce this will be discussed in the section "Biodeteration of Wood". However, it should be noted that the wood decay might have been initiated at an earlier time when the wood reached or was above the fiber saturation point.

Soft Rot Fungi. Soft rot is more of a problem in wood exposed to rain, such as siding or air conditioning cooling towers. Because it has little impact on the house structural members, no more will be added here. A thorough discussion is given in Verrall and Amburgy.

Water Conducting Fungi. This is a class of very destructive fungi, which develops a root structure from infected wood in wet soil. Once established, the fungi will pump water from the soil and enzymatically dissolve dry wood, completely destroying its structural integrity.

The most frequent specie of water conducting fungi is Poria incrassata. Optimum temperatures are 75 to 85 F (24 to 30^{o}C) according to USDA Technical Bulletin No. 1385. It is sensitive to high temperatures and to drying, but once its root is established, it grows profusely in residences, causing extensive to total damage in one to four years according to Spray and Hedden (1982). In 1968 Verrall reported that although Poria destroys, it is rare. However, the author is finding it in an ever increasing number of cases in tightly constructed homes with moisture problems.

MOISTURE MANAGEMENT PROBLEMS

Decay and moisture problems can be categorized by the source of moisture. Spray and Hedden (1982) used external and internal as categories.

External Moisture Sources

Some sources of external moisture that supply or pump water vapor into the structure are:

-- Gutter water or roof runoff,
-- Surface water,
-- Earth-filled porches,
-- Patios and flower beds that are back filled above the ground level in the crawl space,
-- Wet weather springs, and
-- Crawl space soil.

Internal Moisture Sources

Internal moisture is generated from expected human activities occurring in the residence. Levi (1983) named some of these sources as follows:

-- Cooking,
-- Bathing,
-- Cleaning and clothes washing,
-- Plants,
-- Drying of construction materials

MANAGING MOISTURE

Techniques for controlling external moisture are important considerations during construction. Spray and Hedden (1982) discuss various ways of managing external moisture. Included are gutters with downspout water piped away from the house on all sides. Site of the house must be graded so that surface water drains away on all sides. Foundation walls must be damp proofed to break the flow of water by capillary action into the masonry units. Earth filled porches and patios must be a minimum of 8 inches from the foundation sill. Wet weather springs or other chronic water sources are sometimes controlled with sump pumps. Condensation is best handled by providing adequate crawl space ventilation and ground cover to prevent condensation.

Data from field observations indicate an alarming number of houses in which none of the above preventive measures are being incorporated into the building process. Houses are being built closer to the ground surface to present a pleasing low profile and to save on foundation building materials. From the author's field observations, more than 95% of the homes with decay problems did not have a damp-proofed foundation wall or footing drain. In addition, all houses investigated did not have adequate ventilation to carry away the moisture that was seeping into the crawl space. Foundation ventilators are often completely useless due to appendages such as porches, patios, garages, heating/air-conditioning equipment, chimneys, and shrubs. Crawl space ground covers, which are almost universally recommended by engineers, architects, and housing educators, are frequently discouraged by builders, heating equipment contractors, and some housing inspectors. The reasons most frequently given for not using ground covers are:

-- ground stays wet under the plastic,
-- therefore, the plastic "draws" moisture.

Internal moisture can be best managed by ventilation and/or dehumidification. Kitchen and bathroom exhaust fans should be used and ducted to the outside. An alarming number of kitchen fans have no exhaust and only filter the air. Most bathroom exhaust fans are ducted to the attic rather than through the roof. Some modern tight houses thus equipped are experiencing moisture and mildew problems.

A short checklist for managing internal moisture is:

1. Use exhaust fans ducted through the roof in kitchen and baths.
2. Vent clothes dryers to the outside and not into the crawl space.
3. Large families may need to remove wet towels from the bath and dry them outside.
4. Locate laundry centers outside the living areas if moisture is a problem.

Vapor Retarders

Conflicting recommendations can be found on vapor retarder placement. Zone of condensation is defined as those areas in which the average January temperature is 35 F (2°C) or below (DOE 1983; Verrall and Amburgy). The publication "Moisture and Home Energy Conservation" National Center of Appropriate Technology of DOE recommends no vapor retarder in walls and ceiling outside the zone of condensation, which is nearly impossible to achieve with current building materials, including foil-faced sheathing. More than 30 years of experience in South Carolina of placing a vapor retarder facing the living side has not produced conditions favoring wood decay. The newer recommendations for houses in humid regions--no vapor retarder or one on the exterior side of walls as recommended in ASHRAE (1985) and DOE (1983)--should be studied closely.

Ventilating Crawl Spaces

Standard rules of thumb are given for ventilation requirements in crawl spaces (ASHRAE 1985; DOE 1983; Verrall and Amburgy; Levi 1983a, b). Ventilation is needed to remove water vapor that migrates into the crawl space from the soil and through foundation walls that are not water-proofed. Ventilation is needed to prevent condensation or to remove it when it does occur. DOE (1983) suggests closing vents during periods of high outdoor temperature and humidity. For homeowners this practice is not feasible because it would require frequent adjustments and is not recommended by the South Carolina Extension Service.

These conflicting recommendations create a difficult situation for engineers, architects, and housing educators who are trying to convince homeowners and builders lacking training in psychrometrics, soil moisture transports, and water vapor management to design and build residences that are free from moisture and decay problems.

Crawl space ventilation to meet ASHRAE standards was inadequate in all houses investigated. Some reasons causing inadequate ventilation are:

1. Foundation vents were restricted by plumbing, air ducts, or shrubs,
2. Vents were covered by porches, patios, carports, or heating/cooling equipment,
3. Vent design - some vents have only one third of the total area as free unrestricted airflow, therefore, sufficient number of vents are not installed. (Designers, builders, inspectors, and loan officers could eliminate this reason for inadequate ventilation.)
4. Often the house layout creates dead air spaces that no ventilating air can reach.

MOISTURE LEVELS IN STRUCTURAL MEMBERS - FIELD OBSERVATIONS

Regulatory personnel at the author's university are required to investigate complaints from homeowners about termite and moisture control applicators. Data from investigating nearly 400 houses indicate mold and decay problems are occurring at wood moisture contents of 20% and above. Verrall and Amburgy as well as most plant pathologists report that fungi will only decay wood above the fiber saturation point, which for most wood species occurs at approximately 28% to 30% moisture content.

Air dried structural lumber will come to equilibrium of 12% to 15% for most areas of the U.S. according to Wood Handbook (1974). The equilibrium moisture content for wood at 60F (16^{o}C) and 60% relative humidity is 11.1%. However, floor joists in the houses checked in South Carolina were never this low, indicating that higher values of relative humidity and conditions generating condensation are being maintained in these crawl space areas. Wood moisture content will not go above 20% unless the relative humidity is above 90% or repeated surface condensation is occurring (Wood Handbook 1974). The author found that houses with moisture and decay problems frequently had floor joist moisture contents over 20% but seldom above 25% to 28%. Research has established the critical moisture content of 28% (or the fiber saturation point) for decay to begin. Levi (1983) suggested that when wood moisture content exceeds 20% that remedial action be taken to prevent further wetting and possible decay. The author supports this recommendation because of observations of severe structural damage in crawl spaces at moisture contents below 28%. The wood may well have been at 28% prior to the time of the observations, but moisture contents in floor joists from the rotted portion to sound clear wood in the same joist were not observed above 20% to 25%. The author suggests that a topic for research may be to investigate wood moisture-decay relationships in actual crawl spaces where the porosity of wood has been changed by the presence of mildew and molds and where there is a progression of organisms from mildew to bacteria to the wood decay organisms.

Biodeterioration of Wood

Spray and Hedden (1982) discussed the conditions that generate wood decay. Organism attack of wood has been observed by the author to progress from mildew, mold, and bacterial activity to the more destructive wood decay fungi. Although molds and mildew do not reduce the structural integrity of the wood, they do increase its porosity (Verrall and Amburgy). Molds permit condensation on the wood surface to penetrate the wood deeper and more rapidly. This process of organism progression from the nondestructive molds to the decay fungi may be a reason that the authors found active decay fungi in wood floor joists at moisture contents of 20% to 25%.

RECOMMENDATIONS

Well-constructed homes that remain free from moisture and decay problems can be a reality for homeowners if the following suggestions are taken:

1. Avoid soil contact with any untreated wood. Wood structural members should be at least 8 inches above soil.
2. Surface water should be drained away on all sides.
3. Eliminate rain seepage around gutters, dormer windows, porches, trim boards, and joists.
4. Eliminate all earth-filled porches and planters.
5. Prevent water from collecting on wood or around the foundation.
6. Ventilate all crawl spaces adequately. Refer to ASHRAE (1985), DOE (1983), Verrall and Amburgy, and Levi (1983a) for recommendations.
7. Remove all interior generated moisture through kitchen, bath, and other ventilation fans.

8. Install vapor retarders on insulated walls, floors, and ceilings.

9. Avoid and correct all plumbing leaks.

10. Waterproof all foundation walls.

11. Install ground cover in crawl spaces.

12. Collect and pipe all roof water away from the foundations.

13. Use only air-dried lumber that is free from decay.

14. Use treated lumber in areas that may be subject to moisture.

CONCLUSION

Moisture and wood decay can be controlled in modern tight construction. Established building techniques for controlling surface, ground, and condensed water must, however, be closely followed.

The following conclusions are offered based on field data and observations not obtained under controlled research conditions or with continuous moisture content monitoring.

1. Wood decay in crawl spaces of houses with moisture problems may be occurring at wood moisture contents below the established minimum level, which is the fiber saturation point (28%-30% for most species).

2. Inadequate crawl space ventilation is being installed because of ventilator restrictions. Ventilator designs have reduced free areas and many vents are covered by porches, carports, and other appendages.

3. Conditions that favor water conducting fungi are being created in new construction and during remodelled additions.

4. Moisture management is misunderstood by most homeowners and many builders.

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