Moisture damage in manufactured homes in Wisconsin

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Abstract

In mid-July 1986, reports of severe moisture damage in walls of manufactured housing in northern Wisconsin surfaced. A State task force investigated the damage and issued recommendations for repair and future prevention. The task force concluded that the damage was usually caused by condensation due to excessively high indoor humidities during winter. The excessive humidity was primarily the result of a combination of low ventilation rates during winter and a relatively high occupancy rate (often over three persons per 1,000 ft^2 floor area). The task force issued a report with recommendations for additional ventilation, moisture source control, and repair of the structural damage. A home inspection program was initiated for those homeowners who requested it.

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Introduction

In mid-July 1986, reports surfaced of severe moisture damage in walls of manufactured housing in northern Wisconsin. The homes concerned were built during the period 1970 to 1978 by Tri-State Homes, located in Mercer. Before declaring bankruptcy Tri-State built over 3,400 homes, of which more than 2,000 are located in Wisconsin. In response to the reported moisture damage, the Governor of Wisconsin appointed a seven-member task force to investigate the problem and develop recommendations for remedial measures. In September 1986, the task force released a report with their findings and recommendations (Merrill et al. 1986).[1] This paper summarizes that report and provides some additional background and analysis by the author. Opinions expressed are the author's unless indicated otherwise.

Members of the task force visited Tri-State homes in Mercer, Edgar, and Iron River on two separate trips in July and August 1986. We inspected 12 homes which had varying amounts of damage. On several of these homes the siding had been removed, which allowed us to thoroughly assess the damage, Although these 12 homes are not necessarily representative of all Tri-State homes with damage, the task force members believe the number of homes inspected was sufficient to show patterns and serve as a basis for recommendations. However, the task force recognized that there are inevitable exceptions to the symptoms described in its report, which may require

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different or additional remedial measures. Because of the limited time available, no quantitative measurements were done to further substantiate the findings.

Description of the Homes

The task force members visited 12 homes of similar size (around 1,200 ft^2), all ranch style, single story with cathedral ceilings, and typically built on a basement. Figure 1 shows one of the homes visited. Tri-State homes used a panel construction method for the walls and roof. The panels were constructed in the plant and assembled on site. Seams between panels were generally well sealed.

Because the most serious damage occurred in the walls, special attention to wall construction detail is in order. Wall construction is similar in all the homes visited: interior gypsum board, 3.5-inch rock wool batt insulation, plywood sheathing, a heavy reinforced, laminated, asphalt-coated building paper, and hardboard lapped siding (Figure 2). The insulation batt has facings on both sides which were stapled to the outside face of the stud. This method of installation usually resulted in compression and poor fit of the insulation around the studs. The facings were of three types: kraft paper, polyethylene (approximately 2 mil), or aluminum on one side and kraft paper on the other. The type of facing used is related to the year of construction (see Figure 2).

Occasionally Tri-State deviated from this design. For instance, one home visited was found to have a continuous polyethylene vapor retarder. In all homes inspected, electrical outlets, switches, and wiring penetrated this air/vapor retarder in many locations, rendering it even less effective.

The roof joists were nominally 2 inch by 6 inch. The roof cavity was partially filled with 3.5-inch insulation, leaving a ventilation air space above. There were cave vents but generally no ridge vents. There generally were no penetrations or electric wiring in the ceiling.

Many of the homes are heated with wood furnaces or a combination wood/propane gas furnace. The majority of the furnaces had a boiler and hot water distribution system. Few of the homes visited had any ventilation equipment installed in the bathroom or kitchen.

Half the homes visited had four or more occupants, with one family of seven. The average family size for this sample was 3.7 persons, or 3.1 persons per 1,000 square feet of floor area.

Description of Damage

Degree of damage to the homes varied. Some homes experienced decay of plywood sheathing and partial decay of studs. Bathroom walls, shaded bedroom corners, and the top of gable walls were especially vulnerable (Figures 3 and 4). There was no apparent correlation between damage and wall orientation, or the type of facing on the wall insulation. None of the homes visited were in any danger of collapse. The homes were all built with sufficiently redundant strength to prevent complete structural failure, even with advanced decay in the walls. The task force, therefore, saw no danger in postponing structural repairs until spring 1987, especially when measures were taken to prevent

further decay. Of course, where siding and sheathing had already been removed, replacement or sufficient protection before winter was recommended.

The task force found considerable damage to the top plate in only one house in one location. The owner reported problems with ice dams at that location. This same home also was the only house with extensive damage to some of the wall studs. The home was electrically heated and had a continuous polyethylene vapor retarder. Unfortunately, it had been penetrated in several locations. This home had four occupants. In the other homes visited, severe decay of the stud was limited to the first 1/4 inch of the outside face. We found no evidence of decay in the bottom plate in any of the homes visited.

The interior of all of the damaged homes showed signs of severe mold on ceilings and corners. Occupants invariably reported extremely high indoor humidity and heavy condensation on the windows during the winter.

Many occupants reported problems with ice dams on the roof. However, roofs and overhangs seemed in good condition, and location of wall damage often did not coincide with the reported location of ice dams.

Causes for Damage

After viewing the homes and talking to the owners, the author believes the principal cause for the damage is condensation caused by excessively high indoor humidity during the winter, apparently due to insufficient ventilation. Wails were built very airtight. Heating equipment is generally located in the basement, allowing combustion air to enter the basement directly without providing significant ventilation to the living area. In homes with structural damage, indoor humidity during winter was reported by the homeowners at around 60 to 70 percent, and these homes experienced mildew in corners and heavy frost on the windows and storm windows.

It is difficult to determine why these homes experienced such high humidities while most other manufactured houses have no trouble. In some respects Tri-State homes were actually built to higher quality standards than was common at that time. As a result, homes were more airtight than was usual for homes built during that period, and neither the builder nor the homeowner realized that additional ventilation was necessary. Tri-State received many complaints from homeowners about moisture problems, often after the first winter. Instead of recommending additional ventilation, Tri-State representatives apparently told their clients to change their lifestyle to reduce moisture generation. The combination of low ventilation rates and relatively high numbers of occupants in many of the homes led to the high indoor humidity levels. In some homes a damp basement due to poor drainage is likely to have contributed to the problem.

The heavy building paper between the hardboard siding and plywood sheathing has been widely identified as the main reason for the decay in the

walls. Some believe that this paper acts as an outside vapor retarder providing a condensing surface in the wall. Although the actual water vapor permeance of this paper is not known at this time, it is unlikely to be substantially below 1 perm, barely qualifying it as a vapor retarder. Morever. the author's calculations show that condensation is more likely to occur on the inside of the plywood sheathing, whether an exterior building paper is present or not. The author assumed that the wall contained no effective air/vapor retarder, allowing moisture to enter the cavity virtually unimpeded. A phone conversation with a homeowner who had removed partially decayed sheathing confirmed the hypothesis that the plywood was wetted and decayed from the inside out. The calculations also show that the rate of condensation is affected very little by the presence of the paper. Consequently, the author believes that with the reported excessive indoor humidities condensation would have occurred on the plywood regardless of the presence of the building paper. There are Tri-State homes in the area with the same building paper in the walls which do not have any moisture damage. The owners of those homes invariably have not experienced high indoor humidities. This supports the author's and the task force's opinion that high humidity is the principal culprit, not the building paper. However, we do believe that the exterior building paper probably slowed drying out of wet walls during spring and summer by restricting air and water vapor flow.

Many people have pointed to the unusual installation of the insulation batts as a probable cause. The interior facing of the insulation was attached to the outside face of the wall studs. If properly installed the interior facing is attached to the inside facing of the studs. However, the kraft paper facing is not a very effective vapor retarder, and proper installation

likely would not have prevented the condensation. Polyethylene, when used, should have kept the moisture away from the plywood sheathing even though it was attached to the outside facing of the studs. Damage to the plywood in walls with polyethylene demonstrates that moisture was able to reach the plywood and that the polyethylene vapor retarder was not functioning properly. If a vapor retarder is damaged and torn, its placement is of no great importance.

In some walls of Tri-State homes, interior grade plywood was used for sheathing. The author believes that this has no bearing on the problem because the grade of plywood does not affect its susceptibility to decay. Exterior grade plywood is generally used to prevent delamination of the plies in case the plywood is wetted during construction.

The damage assessment strategy relied on the relationship between structural damage and inside signs of extreme humidity levels, such as mold on the walls and condensation in the windows. All damaged homes inspected had these signs, while homes without these signs had no structural damage. This has further been substantiated from phone calls with other homeowners who had removed the siding and inspected the sheathing. It is, therefore, reasonable to assume that homes without interior signs of high humidity do not have any structural damage.

All 12 homeowners also reported problems with ice dams on the roof. Although ice dams may have contributed to the problem, the lack of evidence of damage to the roofs or of extensive leakage and the prevalent damage in gable walls and corners suggests that excessive indoor humidity is the primary culprit, not ice dams.

Recommendations

In developing recommendations, the task force attempted to balance a number of factors:

1. The actions recommended were designed to be as low cost as possible, but be effective in solving the problem.
2. Minimum necessary measures were distinguished from optional measures. Minimum necessary measures are those that are essential to assure structural safety and acceptable health conditions. Optional measures provide additional protection or thermal insulation, but often add significantly to the cost.
3. Recommendations were based on available national or state standards whenever possible.
4. Recommendations were limited to moisture-related symptoms typical to the Tri-State homes investigated. Other more common moisture-related problems, such as roof-flashing leakage, were not addressed.

Minimum Necessary Actions

a. Ventilation

Providing these homes with an adequate ventilation system is necessary to lower indoor humidities and to arrest the decay in the walls. A relatively low rate of ventilation (in the order of 1/2 air change per hour) should be able to lower indoor humidities to safe levels. The task force estimated that relative humidities of 30 percent or lower (assuming a 70°F temperature) will prevent additional mold, decay, and significant condensation during winter. Ventilation also lowers concentrations of harmful substances in the

indoor air. Sufficient ventilation rates can generally be delivered by fans with a capacity of 100 cfm. With lower indoor humidity, decay and mold growth should stop. The additional cost of running the equipment is unlikely to exceed $1 per day in electricity and additional heating.

The task force did not recommend specific ventilation equipment or designs, but recommended a balanced ventilation system rather than an exhaust-only system because an exhaust-only would lower the indoor air pressure. Although lower air pressures may be beneficial in reducing air exfiltration through the walls, it also increases the danger of backdrafting of heating appliances, which could pose a major threat to safety and health. Negative air pressures in the home are also undesirable because of recent evidence that additional radon gas, if present in the soil, may be introduced into a home through negative air pressures.

Heat recovery ventilation equipment was not specifically recommended because of its higher costs. However, such equipment is perfectly acceptable if it delivers the desired ventilation rates. It has the advantage that the fresh air entering the house through the heat exchanger is heated, minimizing the danger of cold drafts.

The task force report includes several examples of balanced ventilation systems. The examples focused on inexpensive exhaust systems with ducted fresh-air intake.

b. Reduction of moisture production

The task force suggested several ways to reduce the amount of moisture entering the home:

Improve surface drainage in case the basement is damp and water enters the basement

Avoid storing large amounts of green firewood in the basement

- Vent clothes dryers outdoors
- Avoid drying clothes indoors
- Limit the number of house plants
- Cover kettles when cooking
- Limit the length of showers

Avoid operating a humidifier in the winter unless the indoor relative humidity is below 30 percent.

This list does not suggest that these measures are all equally important and effective. However, each measure certainly would contribute toward solving an indoor humidity problem.

c. Interior storm panel for bathroom window

Consistent damage around the bathroom window in many homes and the location of the window also suggested that water from the shower sprayed directly on the window and leaked into the wall. This could be prevented by installing an inexpensive barrier covering the window. This would also reduce condensation on that window. It does, however, limit the ability of the homeowner to open the window during the summer.

d. Repair of damage

The task force recommended replacement of materials wherever there is serious damage. Severely decayed wall framing can be shored or braced with new framing. Decayed plywood can be replaced with new plywood or other sheathing materials of the same thickness.

e. Sealing inside wall surface

In addition to reducing indoor humidity levels, the task force recommended sealing the inside of exterior walls to prevent or retard moist air penetration into the walls. This includes joints around window and door casings, baseboards, electrical outlets and switches, and painting walls and ceiling with a vapor retarder paint.

f. Inspection program

At the urging of the task force, the State of Wisconsin initiated a home inspection program. Inspectors at the Wisconsin Department of Industry, Labor and Human Relations (DILHR) are currently available to inspect Tri-State homes when requested by the homeowner. The inspectors have been specially trained and are qualified to make recommendations for the necessary repairs and preventive measures.

Optional Measures

a. Additional insulation

Calculations of condensation potential and rates show that the walls can be made more “forgiving” by adding insulation to the outside. This may be done by replacing the plywood with an insulating foam sheathing or by nailing such sheathing over the existing plywood. Doing so raises the allowable indoor humidity by approximately 10 percent relative humidity. Of course, adding insulation also reduces heat loss through the wall. However, the task force recommended this as an optional measure because of the considerable cost.

b. Removal of exterior building paper

Although the task force believed that the exterior building paper was not the primary cause for decay, there is certainly no harm in removing it. Removal would facilitate drying out of wet walls. The task force, therefore recommended that the paper be removed wherever it is exposed during the damage inspection. Removal of all building paper is optional.

c. Ridge vents

Ridge vents may be effective in reducing ice dams. Adding them in homes that experienced problems with ice dams in the past could, therefore, be beneficial. They may also be effective in dissipating any excess moisture that finds its way into the roof cavity, although the benefits are far from certain. However, ridge vents have little or no effect on interior humidity conditions and are, therefore, no cure for the condensation and mold problems experienced in many homes.

Measures Not Recommended by the Task Force

a. Alterations and rebuilding of roof

No significant damage was found in any of the roofs. Invariably high estimates for repair by contractors included extensive repair/changes to the roof. These estimates were generally in excess of $20,000. The task force members believe that extensive alterations of the roof are unnecessary unless there is evidence of extensive damage.

b. Interior vapor retarders

Installing effective air/vapor retarders in existing walls is difficult and expensive. If the recommendations for ventilation, source reduction, and

sealing of inside wall surfaces are followed, this effort and expense is unnecessary.

c. Ventilation of wall cavities

Research at the Forest Products Laboratory in Madison, Wisconsin, has demonstrated that ventilation of wall cavities does not prevent condensation (Sherwood 1983). Ventilation openings tend to increase penetration of humid indoor air into the wall, which may cause more rather than less condensation.

Conclusions

Deterioration of Tri-State home walls was primarily due to excessive indoor humidity during winter. Additional ventilation combined with sealing inside wall surfaces and moisture source reduction should prevent additional damage and improve indoor air quality in the majority of homes.

Structural damage to the homes visited was primarily limited to the sheathing. Wall framing usually sustained only minor damage with the exception of framing members around bathroom windows.

The heavy building paper between the sheathing and siding was unlikely to have caused the condensation during winter, but may retard the drying of the wall in the spring. Lowering indoor humidity was expected to reduce the occurrence of condensation and the need for drying.

Roofs were generally not damaged. Extensive alterations to the roof were considered ineffective and were, therefore, not recommended unless major damage occurred.

References

Merrill, J., Marx, G., TenWolde, A., and Wrzeski, S., Moisture in Tri-State Homes: A Manual for Homeowners, State of Wisconsin, Office of the Governor, Madison, Wisconsin, 1986.

Sherwood, G. E., Condensation Potential in High Thermal Performance Walls--Cold Winter Climate, Res. Pap. FPL 433, USDA Forest Service, Forest Prod. Lab., Madison, Wisconsin, 1983.

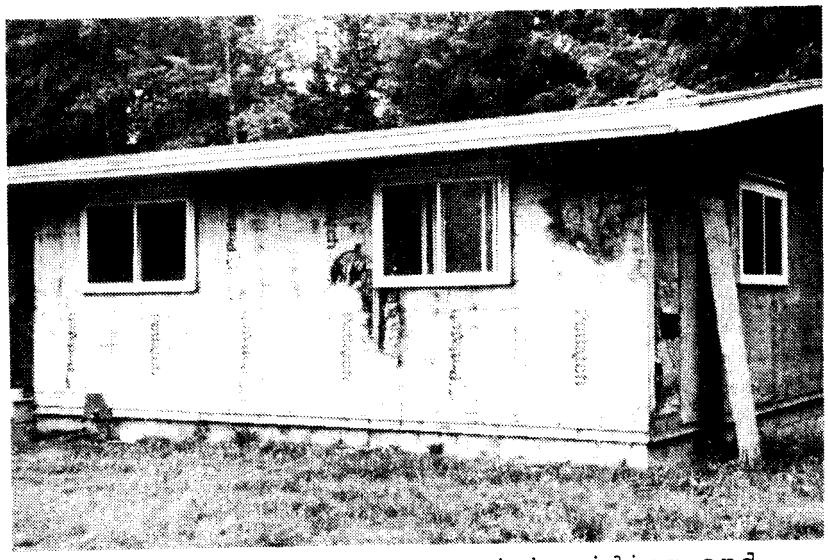


Figure 1. Tri-State home with siding and building paper removed.

Figure 3. Decay of plywood sheathing around bathroom and bedroom windows.

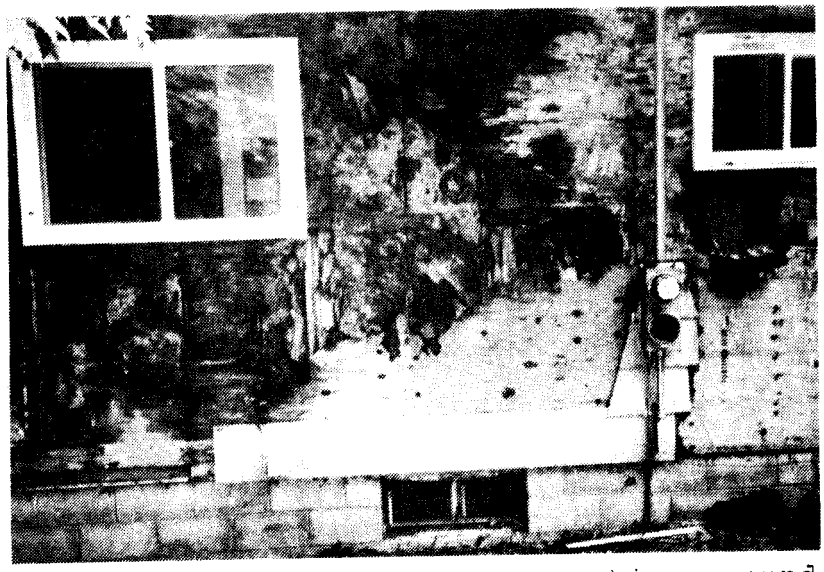
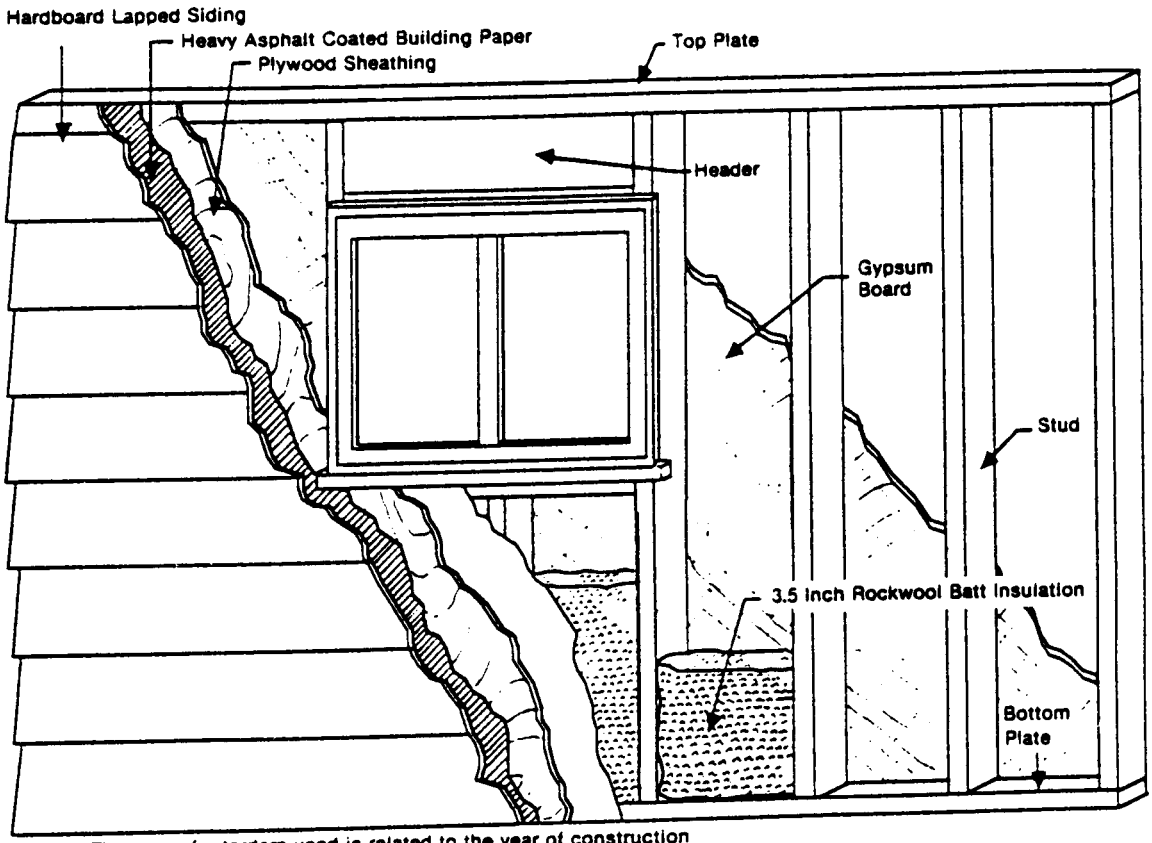


Figure 4. Decay of plywood sheathing around bathroom and kitchen windows.



*NOTE: The type of retarders used is related to the year of construction

year	inside facing	outside facing
1970-1974	kraft paper	kraft paper
1974-1975	polyethylene	kraft paper
1975-1976	kraft paper	kraft paper
from 1977	aluminum	kraft paper

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Figure 2. Sketch of the wall construction of Tri-State homes.