Forum on Moisture Problems in HUD Code homes in hot, humid climates

Case Study

Just a little north of New Orleans

FLORIDA SOLAR ENERGY CENTER
A RESEARCH INSTITUTE OF THE UNIVERSITY OF CENTRAL FLORIDA

By Neil Moyer-Principal Research Engineer

Present during most of the investigation were the homeowners, one of their invited guests and a local manufacturer's field representative. The purpose of the visit was to try to determine the possible cause(s) of the reported gypsum wallboard failure on most of the exterior walls. This appears to be a repeated problem in this home.

• HOUSE DESCRIPTION....

The house is a singlewide 3-bedroom 2-bath dwelling enclosing 1368 square feet of living space. The exterior walls are a 2x4 stud frame with 3/8" plywood sheathing covered with vinyl siding to the exterior and 5/16" vinyl coated gypsum wall board to the interior. The cavity space is filled with unfaced R-11 fiberglass insulation. The crawlspace skirting is continuous and in good condition. There is not a ground cover laid down underneath the home. The major axis of the roof lays in an east-west direction that places the smallest exposed wall area to the greatest sunloading. Heating and cooling is accomplished with a centralized forced air system. A single air handler unit is located in the utility room. The fiberglass ductboard duct system is located under the floor with metal risers completing the connection to the registers. The air conditioning compressor is located on the south side of the building near the rear entrance. A manually controlled exhaust fan in the utility room ceiling provides ventilation.

• OBSERVATIONS....

The master bathroom wallboard between the mirror and the bathtub shows evidence of severe moisture absorption. A number of other exterior wall locations also showed signs of moisture absorption as was noted when a slight pressure was applied (the wallboard did not feel solid). The only interior wall that showed any signs was in the utility room near the electrical service panel. There were no obvious signs of mold or mildew growth.

An inspection of the ductwork was done by removing a number of the supply registers and checking the connection of the riser to the main trunk line. All connections leaked; in some cases, the hole was large enough that a fist could easily pass through. This leakage would tend to pressurize the belly pan area, unless the air/vapor barrier is compromised. In that case, the leakage would be to crawlspace – and tend to depressurize the house.

The dryer vent was disconnected from the exterior exhaust port. All of the moisture and heat from the clothes dryer is deposited into the crawlspace.

The air/vapor barrier was sealed at the electrical service entrance, which leads to the electric panel in the utility room. The tapes that were providing the seal had failed, opening a rather large hole to the under floor area.

The air conditioner system is a 4-ton unit with a 4-½ ton evaporator coil. The general condition of filters and coils appeared to be good. The condensate drain pipe from the air handler unit ends in the crawlspace below the air handler unit. It dumps the water onto the ground, creating a puddle of water.

A series of holes had been drilled through the exterior plywood sheathing on the master suite end wall

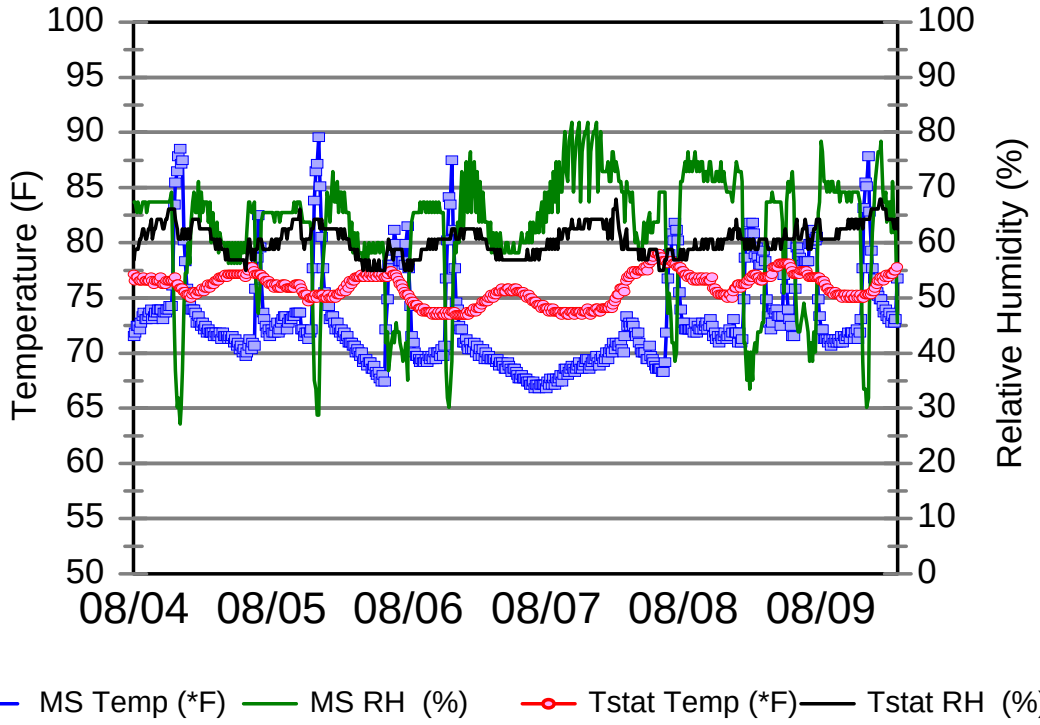
and a majority of the northern wall. The holes were added to the sheathing with the intent to eliminate the moisture problem.

The homeowners were asked about house operation. The master bedroom door is generally closed during the day (to keep the kids out). The other doors are generally open. The thermostat is usually kept at about 75F with the fan in the auto position. The ventilation fan in the utility room is used intermittently- usually when cooking and laundry are done. They also noted that the electric bill has increased notably this last summer.

• TESTING....

The house is a system of components, parts and pieces that are put together to form a system designed to provide shelter and comfort for the occupants. When this system does not function properly, testing is required to determine the source or causes of the problem.

A couple of sets of Onset Computer Stowaway temperature and relative humidity dataloggers were set to the residence to be placed by the homeowner. They were asked to locate one on top of the thermostat and the other in the general location of the worst moisture problem. The master bath was selected by the homeowner and placed the sensors on top of the wall light fixture. (The operation of the bathroom lights affected the temperature and relative humidity readings. This explains the temperature peaks and relative humidity valleys that are noticed in the data.)



The master bedroom suite appears to be overcooling. This is most probably the result of at least three factors…

1. The master bedroom suite is located on the east end of the home and is located under a rather large shade tree.
2. The supply register in the master bedroom is very close to the air handler unit. This supply receives more than its design flow – balancing of these systems is not done.

Additionally, the conventional wisdom is to supply nearly one-third of the total air handler flow to the master suite to prevent comfort problem complaints by the homeowner.

3. The master bedroom door is closed a fair portion of the time. This isolates the master suite from the rest of the house. There is an exhaust fan in the master bath that will allow conditioned air to pass to the outside by the pressurization of bedroom.

The thermostat temperature and relative humidity readings appear to be fairly normal, about 75-77 degF and a relative humidity ranging between 55 and 65 percent.

A blower door test was done to determine the airtightness of the building envelope. A series of building pressures and associated airflows was recorded. This provides the necessary inputs to determine the CFM50 of the house.

Blower Door Test Results
CFM50 = 1789
ACH50 = 9.7
[C=151.4, n=0.63, r=0.999]

As a frame of reference, most new homes of today have an airtightness of approximately 0.75 to 1 CFM50 per square foot of floor area. In this case, the house is a little leakier than the normal.

A duct system airtightness test was also completed. A duct tester was attached to the air handler unit. The supply registers were temporarily sealed off and the system was then depressurized to 25 pascals . The total and outside leakage flow components were measured. An airtight duct system would have zero leakage or both the $CFM25_{total}$ and $CFM25_{out}$ would be 0.

Duct Test Results
$CFM25_{total}$=329
$CFM25_{out}$=290

Pressure differential measurements were completed to determine a magnitude and direction of flow across the envelope when the air handler fan operates. Interior door closure effect was also measured when the air handler fan operated.

Condition	**Pressure differential (house with reference to outside)**
All fans off	-0.2 pa
Air handler on	-2.6 pa
Air handler on and master suite door closed	-5.7 pa
Air handler on and all interior doors closed	-5.8 pa

The pressure difference was also measured across each closed door when the air handler fan was operating.

Measurement of pressure across closed doors	**Pressure differential (room wrt living room)**
Master Suite	6.7 pa
End bedroom	1.0 pa
Center bedroom	3.4 pa
Hall bathroom	1.6 pa

- **CONCLUSIONS....**

The building experiences extended periods of depressurization. This is created by a number of factors.

- The supply side duct leakage is very significant. The operation of the air handler fan causes the house to operate in a negative pressure. This is because the supply leaks dump the air into the belly pan area that is open to the crawlspace (because of the damaged air/vapor barrier near the electric service entrance).
- The extended period of time that the master bedroom door is closed only serves to increase the negative pressure of the main living area of the house. This bedroom receives a great deal of the total supply air delivered to the house (mainly because of the location of the registers with respect to the air handler fan). When the bedroom door is closed, there is not enough opening for the air to return back to the air handler fan. This excess air is then vented through any and all holes that might exist in that room. One of the largest holes is intentional – the bathroom exhaust fan.
- The utility room interior wall that experienced damage was caused by the passage of warm moist outside (crawlspace) air entering through the damaged air/vapor barrier membrane, and exiting the electric panel (and any other holes that may have been in that wall assembly). The driving force of the air movement is the depressurization of the main living space by both duct system leakage and master bedroom door closure.

Overcooling of the master bedroom results in an interior condition temperature lower than the outside dewpoint. The average dewpoint temperatures for this area during the summer months is usually in the low 70 degree range (ASHRAE 90-2 1993 Table 6-3)

- The master bedroom is cooler than the rest of the house. This space is largely protected from the sun because of a rather large shade tree. The room is usually with a closed bedroom door which means that it is pressurized when the air handler fan is operating- this prevents the intrusion of hot humid exterior air into that space.

The vapor retarder location and application is not well suited for the climate in which the home was placed.

- The use of vinyl-covered wallboard on an exterior wall in the hot, humid south should be avoided- or used with great caution. The vinyl will act as a vapor barrier on the cold side of the wall. (The vapor barrier should be placed on the warm side.)
- The drilling of holes through the exterior plywood sheathing more than likely exacerbated the problem. The plywood was acting as a vapor retarder; with the addition of holes at the top and bottom of the stud wall, exterior water vapor would have an easier path to the vinyl covered wallboard.
- The use of tapes as a primary means of sealing will generally lead to failure. This is the case of the electrically service penetration under the utility room.

• RECOMMENDATIONS....

A number of factors must be considered in the proper retrofit of this home to ensure that failure does not happen again. The following should be done:

Air conditioning and heating system:

- All supply duct system leaks should be air sealed with a mastic (such as RCD#6 or equivalent). The seal must be applied to the air barrier of the ductboard (the reinforced foil backing). The areas to be sealed include all of the supply duct risers connections to the main trunk line and the connection of the air handler unit to the main trunk line (this was not checked at the time of my inspection – but should be carefully considered in the retrofit).
- The air balance of the duct system should be checked. This should be done with all of the interior doors closed. The balance will probably include adjustment of supply air to the master bedroom and the addition of a return air grill through the wall directly to the return air plenum of the air handler unit. Also, the end bedroom should have an additional supply vent directly connected to the main trunk line. The pressure differentials across the various closed bedroom doors should be

checked and be less than 3 pascals. The pressure differential from the living area to the outside should be 0 when the interior doors are open and no more than 3 pascals when all interior doors are closed (ideally this should also be 0 for best performance.)

- The condensate drain line from the air handler unit needs to be redirected to deposit the condensate to the outside, away from the crawlspace.

Clothes dryer:

- The clothes dryer vent needs to be reconnected such that it is properly supported and vents to the outside.

Electrical service entrance:

- The air/vapor barrier at the electrical service entrance needs to be repaired with a more permanent solution. This would include a mechanical means of fastening the materials together as well as an air/vapor seal.

Wall assembly:

- All damage wall panels should be removed and replaced. The replacement panels should be finished with a vapor permeable material to allow moisture movement to the inside. The ideal location for a vapor retarder is on the warm side of the wall. In the hot, humid climate, the warm side is the exterior (ASHRAE Fundamentals 1989, Chapter 21). The exterior plywood sheathing will act as a vapor retarder in this case. Every material located to the inside of the plywood should be at least ten times more permeable to allow for drying to the inside.
- The holes that were drilled into the plywood sheathing should be sealed or closed. The sealing could be done with the same mastic (RCD #6 or equivalent) used to seal the ductwork.

- **PICTURES....**

Exterior view

Interior view of kitchen

View of AHU and ms floor register

AC coil with filters

Ventilation fan (utility room and msbath)

Small duct leak at duct riser (kitchen)

Temperature / RH datalogger @ thermostat

Temperature / RH datalogger in master bath

Master bath wall damage

Air conditioner condensor unit