Moisture Solution Becomes Efficiency Bonanza in Southeastern United States

Bruce Davis and Cyrus Dastur, Advanced Energy

ABSTRACT

This study compares the energy performance for space conditioning for a sample of houses built on closed crawl spaces to that of houses built on traditional vented crawl spaces. The closed crawl spaces have no foundation wall vents, a sealed polyethylene liner and one cubic foot per minute (0.5 liter per second) of air supplied by a heating, ventilation, and air conditioning (HVAC) system for each 30 square feet (2.8 square meters) of crawl space ground surface. The traditional vented crawl spaces have wall vents and polyethylene covering 100% of the ground surface. The study is being conducted in 12 identical, all electric, occupied, single-family detached houses located on one cul-de-sac in the southeastern United States. Using the matched pairs approach, the houses are divided into three study groups of four houses each. Energy use for each of the houses is being recorded from sub-meters attached to each heat pump. The findings indicate a 15% or greater average savings in heating and cooling energy use in the houses with properly closed crawl spaces compared to the houses with traditional vented crawl spaces.

Introduction

Wall vented crawl spaces are widely used in building construction throughout North America. They are cheap to build, functional in terms of providing a level foundation for flooring on sloping sites and popular as spaces in which to locate plumbing, ductwork and heating and air conditioning systems. Crawl spaces can be a source of a host of moisture problems. This crawl space project is a multi-year effort to characterize various strategies for investigating how crawl space ventilation impacts energy and moisture use in housing using this foundation type (Davis & Warren 2002). Of particular interest are crawl spaces built in the humid southeastern United States and other locations with similar climates.

This paper is intended as an update on a portion of ongoing research, however some references for context are useful. We are not the first to investigate the moisture performance of wall vented crawl spaces. Previous work includes a review of crawl space investigation and regulation through history (Rose 1994) and a review of many of the issues associated with wall vented crawl space construction (Rose & TenWolde 1994). The above material, along with that of several others, is included in *Recommended Practices for Controlling Moisture in Crawl Spaces,* ASHRAE Technical Data Bulletin, volume 10, number 3. Additionally, during the first year of this study, 2001, Rose contributed an update of the historical review of crawl space regulation as part of a technology assessment report (Davis et al. 2002). These articles reference a wide range of the authors and activities over the years that built the understanding of wall vented crawl space moisture problems and solutions, including a report on the energy penalties of ventilating crawl spaces in the mid-west (Hill 1998).

A goal of this research was to demonstrate practical, easily transferable and clearly understandable dry crawl space construction techniques that would, in addition to solving a multitude of moisture problems, be at least energy neutral and at best, would reduce energy consumption for space conditioning. When the project was initiated it was not hypothesized that the interventions would show energy savings. Some had their fingers crossed against the possibility that the moisture solutions might actually cause an increase in energy consumption. In particular it was expected that there would not be an energy savings during the summer because there was not any significant temperature difference between inside conditioned space and outside temperature. The measured result was a pleasant surprise when the interventions turned out to be quite beneficial for energy efficiency.

The Research

This paper reports on a study that is being conducted at 12 identical, all electric, occupied, single-family detached houses located on one cul-de-sac, six per each side of the street, in the southeastern United States. The 1040 square feet (97 square meters) houses were newly constructed on traditional wall vented crawl spaces. Shortly before move-in during the spring of 2001, the owners of all 12 houses agreed to participate in the study. Using the matched pairs approach, the houses are divided into three groups of four houses each. This paper reports on the energy use for space conditioning during Phase II of the project, which began June 1, 2003.

Experiment Design

All houses were built on controlled fill soil, which added to the uniformity of the site soil conditions. All houses had a series of building and duct air leakage performance measurements to confirm similarity of construction tightness. Given that the houses were found to be substantially air tight [Phase I = .32 CFM50 per square foot of surface area (SFSA) and Phase II .24 CFM50/SFSA], an outside air intake duct with integrated filter was installed for each heat pump system. This configuration provides 40 cubic feet per minute (19 liters per second) of outside air into the conditioned space of the house when the heat pump is conditioning the house.

The three crawl space groups are Control, Experiment #1, and Experiment #2. The Control group has wall foundation vents and 100 % of the ground surface is covered with 6-mil polyethylene. The seams are overlapped six inches (15 centimeters), are not sealed and the polyethylene is held in place with turf staples. Although the building code allows a reduction in the amount of wall venting when a ground vapor retarder is present, all 12, 8 x 16 inch (20 x 41 centimeter), foundation vents were retained. Current code would not require the ground vapor retarder since these vents provide the net free area to meet the 1:150 ventilation requirement. The framed floor is insulated with well-installed, R-19 fiberglass batt insulation.

The Experiment #1 group had the wall foundation vents blocked and sealed from the inside with foam plugs and mastic. The ground and walls were covered with a continuous, sealed liner system of 6-mil polyethylene that was also sealed to the interior piers and to the foundation wall near the top. The top three inches (7.6 centimeters) of the foundation wall was not covered with the liner, but was painted with white mastic. This provided a gap for termite inspection. Foundation penetrations and cracks were sealed to reduce air infiltration. The framed floor is insulated with well-installed, R-19 fiberglass batt insulation.

The Experiment #2 group was modified to be the same as the Experiment #1 group, but the R-19 fiberglass batt insulation was removed from the floor and replaced with two inches (five centimeters) of R-13 foam insulation installed on the interior of the crawl space wall and band joist. The three-inch (7.6 centimeter) gap for termite inspection was retained. Please note that the wall insulation was not installed in the typically recommended form that specifies wall insulation to 24 inches (61 centimeters) below outside grade or horizontally on the soil in from the foundation wall for 24 inches (61 centimeters). The bottom edge of the crawl space wall insulation was only three to six inches below outside soil grade level.

Air sealing work was applied to all 12 houses during April and May of 2003. This involved sealing all the floor penetrations and substantially sealing the existing duct air leakage. All 12 houses received the same battery of pre and post air leakage measurements that they received at the beginning of the study. In addition, both Experiment #1 and Experiment #2 crawl spaces were fitted with an HVAC supply air duct that was adjusted over time to deliver one cubic foot per minute (0.5 liter per second) of HVAC conditioned air per 30 square feet (2.8 square meters) of crawl space ground surface. That amount of intermittent conditioned airflow was found to control the space below our daily average target of 60% relative humidity. This supply air is delivered whenever the thermostat calls for the heat pump to condition the living space of the house. To prohibit passive airflow between the crawl space and the heat pump duct system, the crawl space supply is fitted with a passive backflow damper that remains closed when the heat pump is off and only opens when the heat pump is running. Each heat pump was fitted with a standard utility electric meter so that kWh use could be recorded each month. All houses retained the outside air duct that provides 40 cubic feet per minute (19 liters per second) of filtered, outside air to the conditioned space of the house when the heat pump is on.

To record outside air temperature and moisture content three battery-operated data loggers were placed across the site in locations sheltered from rain and direct sun. The same type of data logger was used for recording conditions inside each house and inside each crawl space. Data was recorded every 15 minutes. One data logger was placed in the center of the house at the return grille, and two loggers (for redundancy) were located together in the center of the crawl space on the support beam for the floor joists. As mentioned above, each heat pump was sub metered to track space conditioning energy consumption. The total energy usage was recorded from the house meter. These readings were taken once per month.

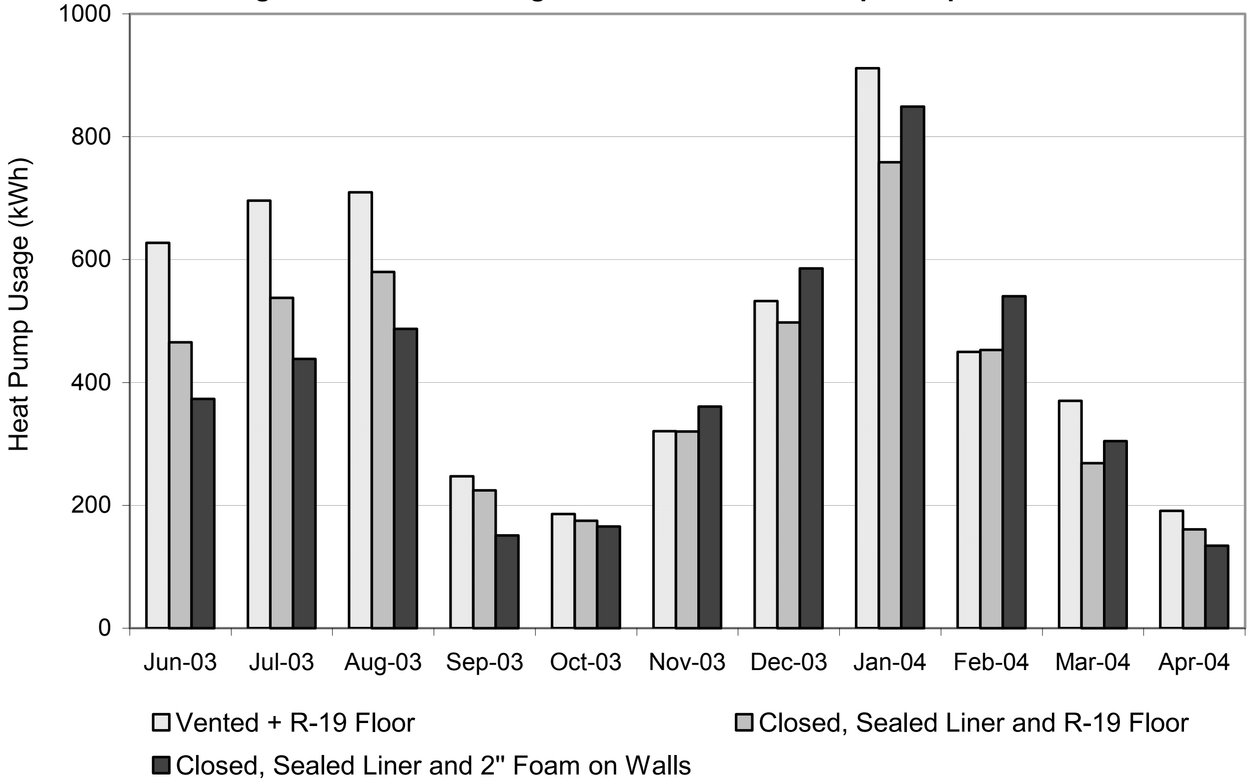
Findings

Figure 1 represents the average energy consumption in kWh used by the houses in each of the three study groups for each month since the beginning of Phase II. There were different energy consumption patterns for the three study groups. There were also differences when the data was segmented into cooling season, heating season, or total consumption.

For the cooling season, June through September, the average Experiment #1 house [closed with floor insulation] used 473 kWh [$47] less energy than the average Control house, a 21% savings. The average Experiment #2 house [closed with wall insulation] used 831 kWh [$83] less energy than the average Control house, a 36% savings. During the heating season there were two different patterns of energy consumption for the Experiment #2 houses compared to the Control houses with no clear explanation.

However, data for the heating season, November through March, shows that the average Experiment #1 house used 287 kWh [$29] less energy than the average Control house, an 11% savings. The average Experiment #2 house used 56 kWh [$6] more energy than the average Control house, a 2% increase. During the shoulder months the energy consumption difference was minimal.

Figure 1. Phase II Average Sub-Metered Heat Pump kWh per House



For the 11-month study period from June 2003 through April 2004 the average Experiment #1 house used 801 kWh [$80] less energy than the average Control house, a 15% savings. The average Experiment #2 house used 852 [$85] less energy than the average Control house, a 16% savings.

During the humid summer season of 2003 the closed crawl spaces were above 70% relative humidity only 5% of the time. The wall vented homes stayed above 70% relative humidity 98% of the time and above 80% relative humidity for 86% of the time. Additionally, the wall vented crawl spaces reached condensation conditions repeatedly throughout the summer season of the study. This condition never occurred in the closed crawl spaces.

For a temporary, three-week period at the start of the study, the data also demonstrated that small dehumidifiers would easily provide control for crawl space relative humidity. Other supplemental drying mechanisms have not yet been evaluated.

Discussion

The energy performance for both the Experiment groups has been substantially better than was generally expected before the project began. Reviewing the data, we hypothesized three possible reasons for the energy performance improvement in the closed crawl space houses. The first was that there had been a reduction of the latent load on the house, the second was that the whole house as a system improved and the third was that the house was more closely coupled to the ground temperature.

The magnitude of the impact of this research is potentially large since we showed that a straightforward construction measure has the potential to reduce space conditioning energy by 15%. In addition, there were the added benefits of preventing several common moisture problems, which in turn would reduce the rate of deterioration of structures and the costs of those associated repairs.

The findings of this study would transfer well to houses of similar geometry and geography to the study homes. However there are many other types of houses in other locations. Given the matched pair experiment design we expect considerable transfer of results for both moisture control and energy savings, but we will not know how well the moisture and energy performance can be replicated in mainstream production houses until a number are constructed and evaluated. Another portion of this study focuses on validating a computer model to predict those results ahead of time. A hygrothermal model is being tested against the actual performance of the study houses. Once the model is calibrated it will be used to project performance for a number of construction types in different climates.

While current building codes allow (in a torturous fashion) for some versions of closed crawl space construction, there is a need to make building codes more accepting of closed crawl spaces. During our work to set up the houses in this study the scattered and conflicting nature of different building code elements governing closed crawl spaces became evident. For closed crawl spaces to be practical for both builders and code enforcement officials we are recommending a separate section in the code that is specifically dedicated to these construction methods. We have created that draft code language for a separate section. As long as closed crawl space construction is presented as a fragmented set of exceptions in the code for traditional wall vented crawl spaces, it will be subject to varying interpretations by code bodies unfamiliar with and uncertain about these closed crawl space construction techniques.

Proper closed crawl space strategies must address the following design issues: (1) pest management, (2) moisture management, (3) fire safety standards, (4) thermal standards, (5) combustion safety and (6) radon management. Successful implementation strategies will require attention to the following construction management issues: (1) understanding crawl spaces as physics- and logic-free zones [people have beliefs about crawl spaces rather than knowledge] and therefore you have to begin discussions with that in mind, (2) selection of a closed crawl space system, (3) pricing closed crawl space work, (4) managing labor [confined space safety, hard work, new job skills, pay], (5) managing job site logistics and (6) applying and adjusting codes and working with code officials.

Closed crawl space construction in the humid southeastern United States appears to be a very robust measure but it is not a magic, silver bullet. Builders could inadequately apply closed crawl space details and sequences and make mistakes as easily as they routinely make other construction technique mistakes. Installers have to responsibly plan and deliver closed crawl space work to achieve the total package of benefits.

Conclusions

Closed crawl space construction techniques in the humid southeastern United States appear to be very robust measures for providing dry crawl spaces for new construction and for retrofitting existing houses. Such crawl spaces have a sealed liner system to reduce moisture intrusion from the soil, the masonry walls, and from outside air flow into the space. They also require that both ground and surface water be prevented from entering the crawl space. In addition, they require some type of supplemental drying mechanism to control the limited amount of moisture vapor that will still migrate to the space and would accumulate over time. Phase II of this project has demonstrated from crawl space moisture vapor data that a measured amount of HVAC supply air [one cubic foot per minute (0.5 liter per second) for each 30 square feet (2.8 square meters) of crawl space ground surface] will provide the necessary supplemental moisture vapor control. Closed crawl space construction produces an environment that slows down and reduces the extremes of the moisture and temperature swings experienced in wall vented crawl spaces.

Insulation in closed crawl spaces has been demonstrated to be effective when applied to either the framed floor cavity or against the inside of the foundation wall. They have different seasonal performance characteristics.

For the Phase II period beginning in June 2003, the average Experiment #1 house [closed with floor insulation], when compared to the average wall vented crawl space house, provided a cooling season, June through September, reduction of 473 kWh [$47], a 21% savings. It provided a heating season, November through March, reduction of 287 kWh [$29], an 11% savings. For the 11 months recorded the average Experiment 1 house provided a reduction of 801 kWh [$80], a 15% savings.

In the same period, the average Experiment #2 house [closed with wall insulation] when compared to the average wall vented crawl space house, provided a cooling season, June through September, reduction of 831 kWh [$83], a 36% savings. It provided a heating season, November through March, increase of 56 kWh [$6] a 2% increase. For the 11 months recorded the average Experiment 2 house provided a reduction of 852 kWh [$85], a 16% savings.

This magnitude of space conditioning energy savings was unexpected and when combined with the moisture benefits of closed crawl spaces bolsters the argument for adoption of closed crawl spaces in the construction industry. Several production builders and some product manufacturers are already benefiting by promoting dry crawl space construction techniques and this segment of the construction industry is poised for substantial growth. The widespread application of these construction methods would benefit homeowners, construction businesses, energy efficiency policy, and the environment.

Acknowledgement

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