ENERGY, SHADING, AND DAYLIGHTING ANALYSIS FOR THE AUSTIN BERGSTROM INTERNATIONAL AIRPORT TERMINAL

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Figure 1. Airport South elevation

ABSTRACT

Our firm was under contract with the City of Austin, Texas to perform energy analysis and analysis of the daylighting potential within the New Austin Bergstrom International Airport Terminal. Design of the Passenger Terminal Facility for the New Austin Airport included large glass areas for viewing arriving and departing planes, the sky, and the surrounding terrain. The glass was envisioned to provide quality natural lighting for the terminal during daylight hours in order to improve the quality of the space and save energy throughout the usable life of the terminal. For the glass to achieve the design goals, adverse qualities were minimized and beneficial qualities must be enhanced.

Using computer simulation, we studied the shading devices on the south clearstories to maximize the daylight and minimize problems of direct gain in a large commercial space. The study also included analysis of skylights above the baggage claim, indirect lighting of major spaces within the airport, and the controls of the artificial lights for integrating the efficient use of the available daylight. The energy, shading, and daylighting analysis includes analysis of a mix of low and high volume spaces. The daylight sources include glass walls, clearstories, and skylights.

PROJECT DESIGN

The New Austin Bergstrom International Airport Terminal is a 400,000(37,160m2) square foot building built on the site of the vacated Bergstrom Air Force Base. The design consists of a well oriented building with the long axis running east and west and major glass areas facing north and south. This orientation is ideal for daylighting the building, as the sunlight is much easier to control on the north and south elevations. In addition, this orientation allows minimum solar gain during the summer and maximum solar gain during the winter. Although this building requires cooling throughout most of the year, maximum solar loads occur when the outside temperature is lower and could be used more effectively as an economizer cycle for cooling.

Although there are significant quantities of glass in the building, the orientation of that glass, has been properly selected, shaded, and detailed, to enhance the quality of the space. In doing so, the detrimental effects to human comfort and energy consumption are greatly minimized. LumenMicro was used to quantify the lighting and daylight within the space. Enercalc was used to quantify the energy implications, and Autodesk 3D Studio was used to generate a 3D animation of the sun in the space for one day of each month of the year. It was interesting to note that the representation of

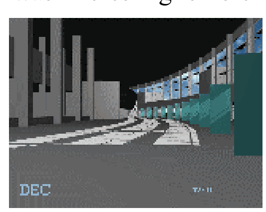

Figure 2. Dec. sun at noon

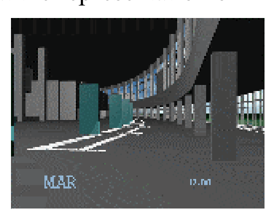

Figure 3. Mar. sun at noon

data from LumenMicro and Enercalc had meaning to the technical team members, but many other team members including the decision makers did not adequately understand the implications of the numerical data. The 3D animations were used to effectively portray the dynamics of the sun in the space to the non technical team members and the decision makers. Our discussion of the data along with the animation allowed all team members to understand the potential problems and how to avoid them. The daylight from the clearstories has been shown to have positive effects both on human comfort and the energy consumption of the building. It was our intent to minimize the detrimental elements of the direct sunlight to periods of the year when it can be a welcomed addition or easily tolerated.

In this and other buildings with similar orientations, the glass has been shown to have positive effects on both the human comfort , human psychology, and the energy consumption of the building. **The minimum energy consumption of the insulated box without glazing is limited by the technology of the equipment required to provide light, air, and human comfort. For a building to perform below that level, you must install glazing as well as use it effectively.** To use glazing effectively, a careful balance must be calculated between glazing (allowing daylighting and passive solar), lighting systems (which respond to the daylighting), and shell loads (which respond to the passive solar). This calculation can be used to optimize the energy use and human comfort within a building and permit the full impact of the views and openness of the glazing as part of the building shell. The space changes with the seasons, and that change allows warming direct light primarily in circulation areas in the winter and indirect light in the entire terminal during most of the spring and fall, and all of the summer. This terminal is a good example of the proper implementation of the climate responsive process. Most people who use the airport terminal realize it as a light, open, airy place which has a close link to the views and exterior spaces. It is a delightful space that leaves a good impression with both the traveler and the airport staff.

The calculation procedures have allowed the building design team to select strategies which achieve the optimum energy and financial impact within the architectural and engineering design parameters. These were addressed within three categories; the categories were interconnected to achieve optimization.

The first category addressed building shell considerations and the energy flows through the shell on an annual basis allowing for solar and all climatic variables. We provided information regarding the energy impact for items which included:

- Consideration of building shading devices
- Enhancing the use of skylights
- Shading coefficients of glazing
- Coatings for glazing
- Performance films for glazing
- Glazing selection

The second category addressed was the effective use of daylighting in the building. We provided calculation documenting:

- The quantity of daylight available at various times of the year
- The quantity of daylight available with different sky conditions
- Daylight available in various interior spaces
- Optimizing the aperture location for daylighting
- Effective use of mixed glazing types to enhance daylighting
- Light shelves
- Shading devices
- Computer generated representation of daylight in spaces

The third category was used to achieve the energy savings of the daylighting and quantify the available illumination levels of the mix in light sources. These calculations included point by point calculation of lighting from natural sources as well as direct and indirect artificial lighting sources. The strategies analyzed included:

- Analysis of all major spaces within the terminal for the integration of natural and artificial light
- Control strategies for integration of natural and artificial light sources
- Color consideration of light sources
- Indirect lighting system analysis and quantification of performance
- Direct lighting system analysis and quantification of performance

The systems and strategies analyzed were determined by the design team. The additional information from the simulation was used to provide supplementary design opportunities and allow performance criteria to broaden the possibilities afforded by prescriptive standards. We performed analysis on 5 representative zones within the airport terminal. This information was used as a prototypical procedure for the other areas to be designed and built. Actual conditions and light levels were very close to the calculated levels in all locations.

Concessions and South Facing Holding Area. Much of the analysis was performed on the concessions area and the adjacent hold rooms. The concessions area is a space 50’ high, 500’ wide, with a crescent shape up to 70’ wide. The

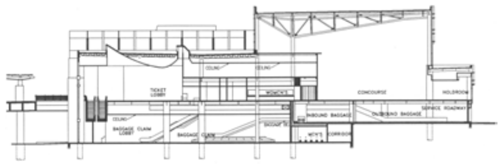

Figure 4. Airport section

south face is a glass clearstory 30’(9.15m) tall starting 20’(6.1m) above the floor. The glass area is designed and sized for view out and provides adequate quantities of daylight illumination even on cloudy days. The analysis tried to minimize the detrimental effects of large areas of south facing glass in a commercial building. External shading devices have been optimized for control of direct sunlight from March through October. The shading coefficient of the glazing has been optimized minimize adverse effects of the large quantity of glazing in the building.

The holding areas needed particular attention since there is 37 individual units and they are occupied much of the time the terminal is operating. The shading device on the south glazing is the most important strategy to be implemented in this area. It effects energy consumption, quality of daylighting, and human comfort. The two outer rows of fixtures were connected to the same controls as the concession area lighting to turn the lights off one hour after sunrise and on one hour before sunset. Photocells dimmers control the next two rows of lighting.

After studying various glazing coatings, films, fillings, layers, and types, it was determined that a double glazed glass system with a clear tint for good color balance would be optimum glazing choice for the south clearstory glazing. The glass had a moderate (50) shading coefficient and a “low e” film on the third layer from the outside. No frit surface or gas filled cavity was recommended.

East and West End of the Terminal Building. Direct morning and afternoon sunlight into the east and west end of the terminal building is both a problem and an opportunity. Direct sunlight in these hold rooms will have the highest probability for comfort problems in these areas. Early and late in the day there is direct penetration making tinted glass essential in these areas. A darker tint (below 15%) was used for these areas.

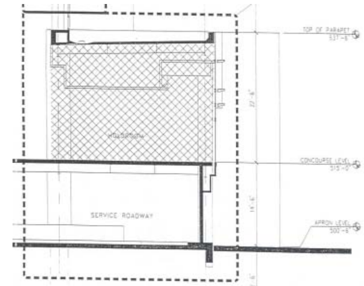

Figure 5. Holdroom section

Baggage Claim Area. Large fin-like skylights had been designed, but were shown to contribute very little to the light levels 50’(15.25m) below. The shape of the skylights was retained, but several adjustments reduced energy consumption and doubled the daylight contribution. These changes included: 1) reducing the height of the glass to 13’-6”(4.1m) to 5’-0” (1.5m) off the roof, and as near 5’(1.5m) as possible; 2) lowering the ceiling to the top of the glazing and painting it white; and 3) replacing one wall of glass with a white reflective surface. The lighting above the skylight area should be controlled to turn the lights off three hours after the sunrise and on three hours before sunset.

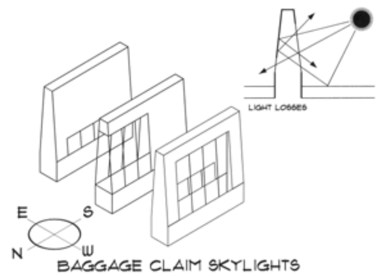

Figure 6. Baggage Claim Skylights

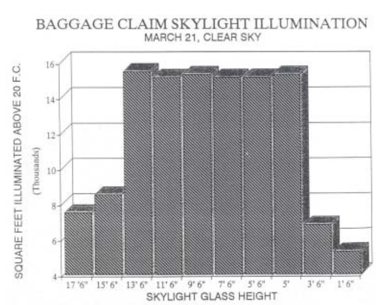

Figure 7. Daylight from varying sixes of skylight openings

West Ticket Counter. Skylights in the ticket counters areas were evaluated. The quantity and quality of the lighting form the skylights will be beneficial during the daylight hours. Direct sunlight will be present during limited periods throughout the year. Since the area is a circulation space, the direct penetration of short duration will enhance the use of the area. There is no depreciation of utility for this skylight with tinted glazing. The energy reduction benefit of tinted glazing should be realized.

CONCLUSION

Careful attention was placed on the human comfort factors for both the traveler, who spends relatively little time in a certain place, and the airport employees, who occupy certain areas for extended periods of time. The passengers can be classified as occupants moving through the space. Because of their movement and short duration of occupancy in the space, passengers are relatively tolerant of direct sunlight, irregularities in lighting and light levels, and comfort irregularities. Many of the vendors will occupy the space most of the day and some will occupy a single space all operating hours of the terminal facility. Since they occupy the space for prolonged periods, airport and vendor personnel are very concerned with those same issues.

It is important to control the quality of light and daylight while providing an environment compatible with human needs and human comfort. It is necessary to carefully address human comfort issues to allow a daylighting scheme to be successful and operate on a long term basis. If employees are subjected to excessive glare, poor lighting control, or excessive temperature fluctuations, their complaints will require the airport staff to close the clearstories, glass walls, and skylights in order to correct the problem. If the clearstories and glass walls are closed, the daylighting and view of the sky from the terminal will be lost. In this case all systems are operating as designed after five years of operation, and all comfort and lighting levels are very close to the predicted levels.

Homes produced with airtight duct systems (around 15% savings in Htg and Cooling Energy)

Palm Harbor Homes	22,000
Southern Energy Homes	8,000
Cavalier Homes	1,000
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Subtotal	31,000

Technical measures incorporated in BAIHP homes include some or many of the following features - better insulated envelopes (including Structural Insulated Panels and Insulated Concrete Forms), unvented attics, “cool” roofs, advanced air distribution systems, interior duct systems, fan integrated positive pressure dehumidified air ventilation in hot humid climates, quiet exhaust fan ventilation in cool climates, solar water heaters, heat pump water heaters, high efficiency right sized heating/cooling equipment, and gas fired combo space/water heating systems.

HOMES BY THE FLORIDA HOME ENERGY AND RESOURCES ORGANIZATION (FL.H.E.R.O.)

Over 400 single and multifamily homes have been constructed in the Gainesville, FL area with technical assistance from FL H.E.R.O. These homes were constructed by over a dozen different builders. In this paper data from 310 of these homes is presented. These homes have featured better envelopes and windows, interior and/or duct systems with adequate returns, fan integrated positive pressure dehumidified air ventilation, high efficiency right sized heating/cooling equipment, and gas fired combo space/water heating systems. The innovative outside air (OA) system is described below.

The OA duct is located in the back porch (Figure 1) or in the soffit (Figure 2). The OA is filtered through a 12"x12" filter (which is readily available) located in a grill (Figure 3) which is attached to the OA duct box. The flex OA duct size varies depending on the system size - 4" for up to 2.5 tons, 5" for 3 to 4 ton and 6" for a 5 ton system. The OA duct terminates in the return air plenum after a manually adjustable butterfly damper (Figure 4).

Figure 1 OA Intake Duct in Back Porch

Figure 2 OA Intake Duct in Soffit

Figure 3 Filter Backed Grill Covering the OA Intake

Figure 4 Butterfly Damper for OA control

The damper can be set during commissioning and closed by the homeowner in case the OA quality is poor (e.g. forest fire). This system introduces filtered and conditioned ventilation air only when the cooling or heating system is operational. The ventilation air also positively pressurizes the house. Data on the amount of ventilation air or positive pressurization is not available from a large sample of homes. A few measurements indicate that about 25 to 45 cfm of ventilation air is provided which pressurizes the house in the range of +0.2 to +0.4 pascals.

Measured Home Energy Ratings (HERS) and airtightness on these FL. H.E.R.O. homes is presented next in figures 5 through 8. Data is presented for both single family detached (SF) and multifamily homes (MF). See Table 2 below.

Table 2. Summary statistics on FL.H.E.R.O. Homes
n = sample size

	SF	MF
Median cond area	1,909	970
% constructed with 2x4 frame or frame and block	94%	100%
Avg. Conditioned Area, ft^2	1,993 (n=164)	1,184 (n=146)
Avg. HERS score	87.0 (n=164)	88.0 (n=146)
Avg. ACH50	4.5 (n=164)	5.2 (n=146)
Avg. Qtot (CFM25 as %of floor area)	6.9% (n=25)	5.0% (n=72)
Avg. Qout (CFM25 as %of floor area)	3.0% (n=15)	1.4% (n=4)

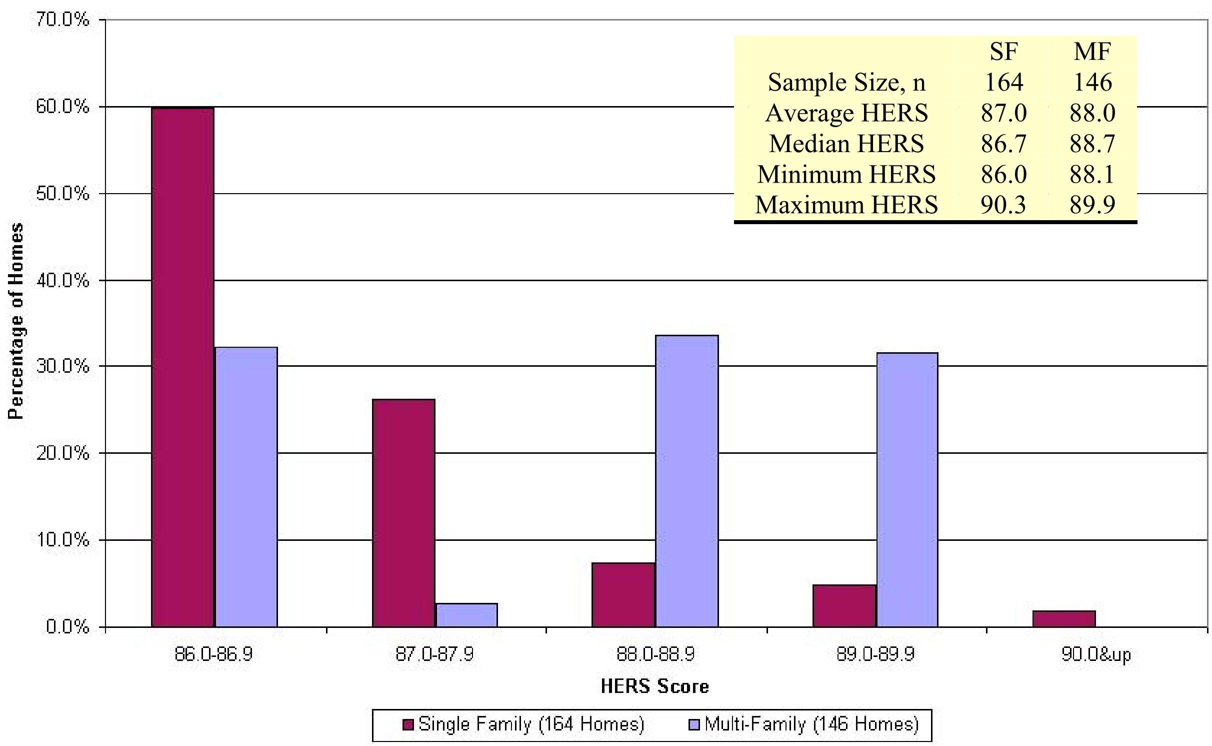

Figure 5 HERS Scores for FL H.E.R.O. Homes

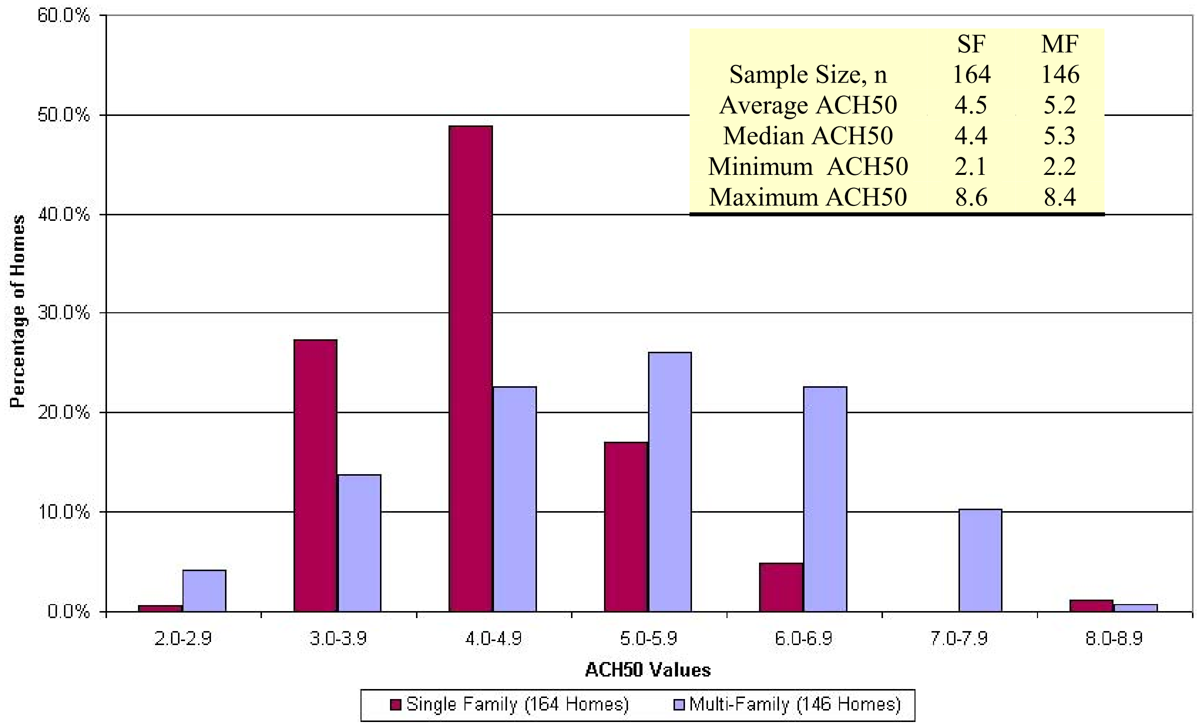

Figure 6 ACH50 Values for FL H.E.R.O. Homes

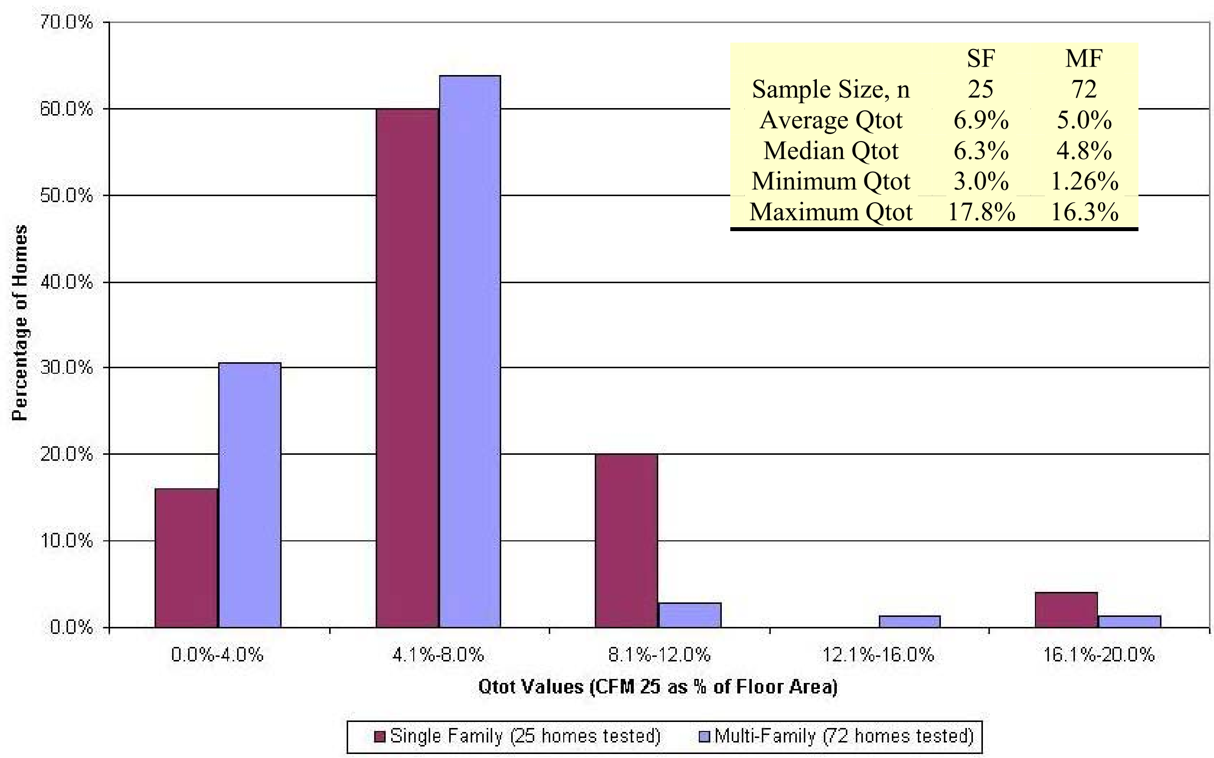

Figure 7 Qtot Values for FL H.E.R.O. Homes

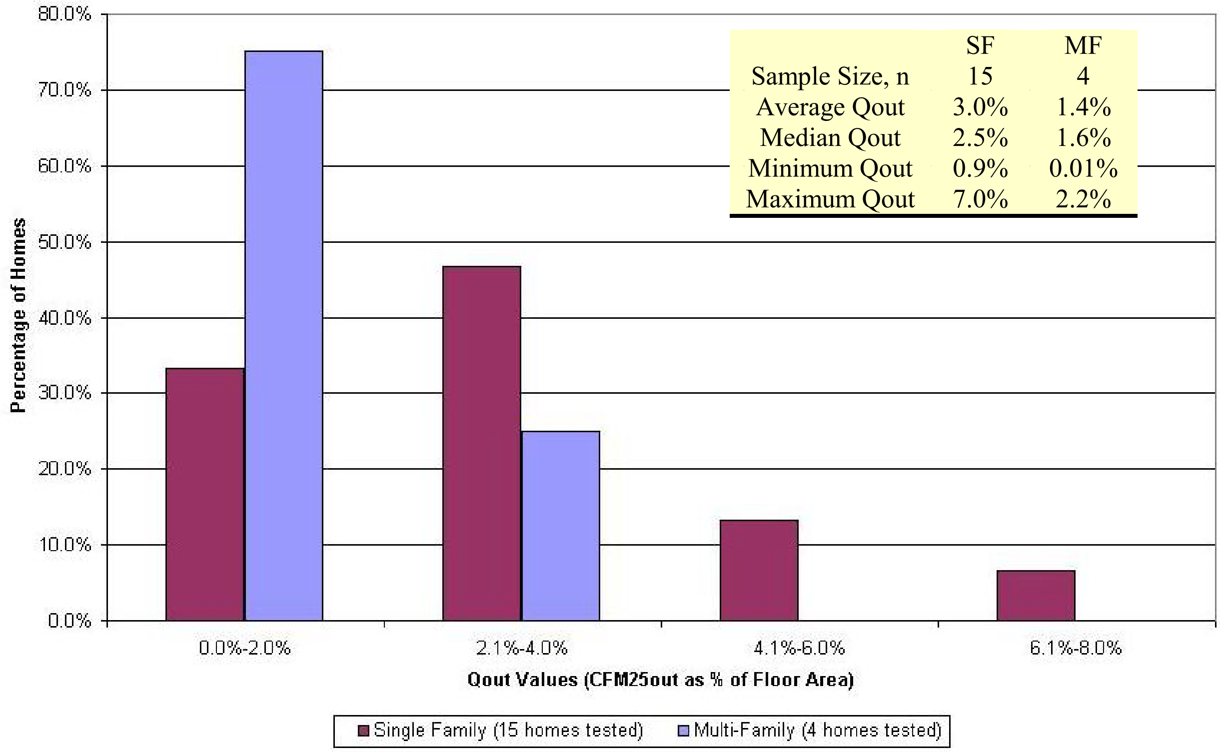

Figure 8 Qout Values for FL H.E.R.O. Homes

Data is available for other typical non BAIHP, new Florida homes (FPL , 1995 and Cummings et al, 2001). The FPL study had a sample size of over 300 single family homes and the median Qout was 7.5% , three times that of the FL. H.E.R.O. homes. In the Cummings study of 11 homes the measured average values were : ACH50= 5.7, Qtot=9.4% and Qout=4.7%. Although the sample sizes are small the FL. H.E.R.O. homes appear to have significantly more airtight duct systems than typical homes.

The remainder of the paper presents status of other tasks of the BAIHP project.

OTHER BAIHP TASKS

Moisture Problems in HUD code homes

The BAIHP team expends considerable effort working to solve moisture problems in existing manufactured homes in the hot, humid Southeast.

Some manufactured homes in Florida and the Gulfcoast have experienced soft walls, buckled floors, mold, water in light fixtures and related problems. According to the Manufactured Housing Research Alliance (MHRA), who we collaborate with, moisture problems are the highest priority research project for the industry.

The BAIHP team has conducted diagnostic tests (blower door, duct blaster, pressure mapping, moisture meter readings) on about 40 such problem homes from five manufacturers in the past two years and shared the results with MHRA. These homes were newly built (generally less than 3 years old) and in some cases just a few months old when the problems appeared. The most frequent causes were:

- Leaky supply ducts and/or inadequate return air pathways resulting in long term negative pressures.
- Inadequate moisture removal from oversized a/c systems and/or clogged condensate drain, and/or continuous running of the air handler fan.
- Presence of vinyl covered wallboard or flooring on which moist air condenses creating mold, buckling, soft walls etc.
- Low cooling thermostat set point (68-75F), below the ambient dew point.
- Tears in the belly board and/or poor site drainage and/or poor crawlspace ventilation creating high rates of moisture diffusion to the floor.

Note that these homes typically experience very high cooling bills as the homeowners try to compensate for the moisture problems by lowering the thermostat setpoints. These findings have been reported in a peer reviewed paper presented at the ASHRAE IAQ 2001. conference (Moyer et al)

The Good News:

As a result of our recommendations and hands-on training, BAIHP partner Palm Harbor Homes (PHH) has transformed duct design and construction practices in all of its 15 factories nationwide producing about 11,000 homes/yr. All Palm Harbor Home duct systems are now constructed with mastic to nearly eliminate air leakage and produced with return air pathways for a total cost of <$10/home!! The PHH factory in AL which had a high number of homes with moisture problems has not had a single problem home the past year!

Field Monitoring

Several houses and portable classrooms are being monitored and the data displayed on the web. (Visit http://www.infomonitors.com/). Of special interest is the side-by-side monitoring of two manufactured homes on the campus of the North Carolina A & T U. where the advanced home is saving about 70% in heating energy and nearly 40% in cooling energy, proving that the Building America goal can be met in manufactured housing. Other monitored sites include the Washington State U. Energy House in Olympia, WA; the Hoak residence in Orlando, FL; two portable classrooms in Marysville, WA; a classroom each in Boise, ID and Portland, OR. See other papers being presented at this symposium for details on two recently completed projects giving results from duct repairs in manufactured homes (Withers et al) and side by side monitoring of insulated concrete form and base case homes (Chasar et al).

“Cool” Roofs and Unvented Attics

Seven side-by-side Habitat homes in Ft. Myers, FL. were tested under unoccupied conditions to examine the effects of alternative roofing strategies. After normalizing the data to account for occupancy and minor differences in thermostat set points and equipment efficiencies, the sealed attic saved 9% and the white roofs saved about 20% cooling energy compared to the base case house with a dark shingle roof for the summer season in South Florida. Visit http://www.fsec.ucf.edu/%7Ebdac/pubs/coolroof/exsum.htm for more information.

Habitat for Humanity

Habitat for Humanity affiliates work in the local community to raise capital and recruit volunteers. The volunteers build affordable housing for and with buyers who can't qualify for conventional loans but do meet certain income guidelines. For some affiliates, reducing utility costs has become part of the affordability definition.

To help affiliates make decisions about what will be cost effective for their climate, BAIHP researchers have developed examples of Energy Star homes for more than a dozen different locations. These are available on the web at http://www.fsec.ucf.edu/bldg/baihp/casestud/hfh_estar/index.htm . The characteristics of the homes were developed in conjunction with Habitat for Humanity International (HFHI), as well as Executive Directors and Construction Managers from many affiliates. Work is continuing with HFHI to respond to affiliates requesting a home energy rating through an Energy and Environmental Practices Survey. 36 affiliates have been contacted and home energy ratings are being arranged using combinations of local raters, Building America staff, and HFHI staff.

HFHI has posted the examples of Energy Star Habitat homes on the internal web site PartnerNet which is available to affiliates nationwide.

“Green” Housing

A point based standard for constructing green homes in Florida has been developed and may be viewed at http://www.floridagreenbuildings.org/. The first community of 270 homes incorporating these principles is now under construction in Gainesville, FL. The first home constructed and certified according to these standards has won an NAHB energy award.

BAIHP researchers are participating as building science - sustainable products advisor to the HUD Hope VI project in Miami, redeveloping an inner city area with over 500 units of new affordable and energy efficient housing.

Healthy Housing

BAIHP researchers are participating in the development of national technical and program standards for healthy housing being developed by the American Lung Association.

A 50-year-old house in Orlando is being remodeled to include energy efficient and healthy features as a demonstration project.

EnergyGauge USA®

This FSEC developed software uses the hourly DOE 2.1E engine with FSEC enhancements and a user-friendly front end to accurately calculate home energy ratings and energy performance. This software is now available. Please visit http://energygauge.com/ for more information.

Industrial Engineering Applications

The UCF Industrial Engineering (UCFIE) team supported the development and ongoing research of the Quality Modular Building Task Force organized by the Hickory consortium, which includes thirteen of the nation's largest modular homebuilders. UCFIE led in research efforts involving factory design, quality systems and set & finish processes. UCFIE used research findings to assist in the analysis and design of two new modular housing factories – Excel homes, Liverpool, PA and Cardinal Homes - Wyliesburg, VA.

CONCLUSIONS

The entire BAIHP team of over 20 researchers and students are involved in a wide variety of activities to enhance the energy efficiency, indoor air quality and durability of new housing and portable classrooms.

In addition to energy efficiency, durability, health, comfort and safety BAIHP builders typically consider resource and water efficiency. For example, in Gainesville, FL BAIHP builders have incorporated the following features in developments:

- Better planned communities
- More attention given to preserving the natural environment
- Use of reclaimed sewage water for landscaping
- Use of native plants that require less water
- Storm water percolating basins to recharge the ground water
- Designated recreational areas
- Better designed and built infrastructure
- Energy efficient direct vented gas fireplaces (not smoke producing wood)

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REFERENCES

Cummings, J.B., Withers, C., McIlvaine, J., Sonne, J., Fairey, P., and Lombardi, M., "Field Testing to Characterize the Airtightness and Operating Pressures of Residential Air Handlers," FSEC-CR-1285-01, Florida Solar Energy Center, Cocoa, FL., November 30, 2001.

FPL, 1995. "New Home Construction Research Project Findings, Results & Recommendations," Final Report to the Florida Public Service Commission, June 1995.

Moyer, N., Beal, D., Chasar, D., McIlvaine, J., Withers, C. and Chandra, S. "Moisture problems in manufactured housing: Probable causes and cures", Proc. ASHRAE Indoor Air Quality 2001, Nov, 2001