STRUCTURAL VENTILATION OF THE BUILDING ENVELOPE

Improve Air Quality
Reduce Energy Consumption
Minimize Moisture Contamination and Deterioration
Of the Building Envelope

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Abstract

Buildings are a necessary part of our society to provide a safe, habitable, and protected environment. Typically, the more safe, habitable, and protected the environment; the higher the cost to operate the building. Outside air necessary to diminish indoor air contamination (COVID-19, mold, radon, etc.) results in increased energy costs. Structural Ventilation of the Building Envelope is a system that introduces continuously conditioned positively pressured outdoor air into the interior habitable spaces of a structure to be exhausted into the building envelope and subsequently to the exterior. Heat gain and loss through the building envelope are significantly reduced. Multiple studies of existing buildings have been performed that indicate that moisture accumulation and damage, air contamination, and inadequate ventilation simultaneously occur in whole or in part. WUFI analyzes the hygrothermal properties of the building envelope. Analyses indicate that the reduced moisture and regulated temperatures within the building envelope, transmitted by the supply of clean outside air into the living space of the structure, diminishes mold growth and structural deterioration of the building envelope and provides significant hygrothermal resistances of the building envelope resulting in reduced HVAC equipment sizing and operating costs. Structural Ventilation of the Building Envelope is applicable to residential, institutional, medical, retail, and commercial buildings; either new construction or retrofit. Installation is performed by the current building construction workforce with currently available materials; which result in lower installation costs. Structural Ventilation of the Building Envelope is the next generation of building ventilation. A simple solution for a complex society.

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https://vacek.llc, sam@vacek.llc, 10.15.22

The Issues

In the mid 1970's, the oil embargo resulted in rising energy costs. In an attempt to reduce these costs, the minimum building outside air intake was reduced to 2.5 L/s (5 cfm) per person. This minimum still exists today.

The recent onset of COVID-19 brought the realization that more fresh outside air was necessary to dilute and remove the indoor air contamination. The EPA and others have stated this recommendation.

Sick Building Syndrome, also identified as Building Related Illness, a condition where individuals exhibit sickness when occupying a particular building, has been linked to airborne mold contamination. Other airborne contaminants are also blamed. More fresh outside air, necessary to dilute and remove the indoor air contamination, as well as moisture and humidity control, are required. The EPA and others have stated this recommendation.

Radon Contamination, prevalent over more than half of the United States, is the leading cause of lung cancer following tobacco smoke. Radon is an odorless radioactive gas that is emitted from the earth and collects within structures. The best solutions are to ventilate beneath the building, if accessible, and to increase fresh outside air intake to dilute and remove the indoor air contamination. The EPA and others have stated this recommendation.

Clearly, proper ventilation is the solution.

The Conflict

Buildings are a necessary part of our society to provide a safe, habitable, and protected environment. Typically, the more safe, habitable, and protected the environment; the higher the cost to operate the building.

The conflict arises between this environmental goal and the costs necessary to maintain this goal. One viewpoint is "The best solution to breathe contaminant free indoor air is to inject clean outdoor air into the building to dilute the contamination. The worst solution is to recirculate and filter indoor air". The opposing viewpoint is "The worst solution to minimize HVAC operating costs is to inject clean outdoor air into the building to dilute the contamination. The best solution is to recirculate and filter indoor air".

Structural Ventilation of the Building Envelope simultaneously accomplishes both goals by minimizing indoor air contamination and reducing energy costs.

Conventional Systems

The majority of buildings are temperature controlled and humidity adjusted insulated enclosures. Shown in Figure 1 is a typical example. The HVAC system recirculates air within the building; air is drawn from within the space, conditioned, and circulated back into the space. The attic and cavity walls are unconditioned but ventilated with outdoor air.

Interior air is temperature adjusted through recirculation but humidity is inadequately maintained. Outside air is introduced through infiltration through doors, windows, the perimeter walls, and attic with variable results. The building envelope collects moisture and offers conventional thermal resistance.

Some buildings have heat exchangers, as shown in Figure 2, where some fresh outside air is introduced into the HVAC system and some indoor air is exhausted out of the building through the HVAC system. The heat exchanger works with the passage of outdoor air next to indoor air, allowing the outdoor air to be tempered closer to the indoor air temperature.

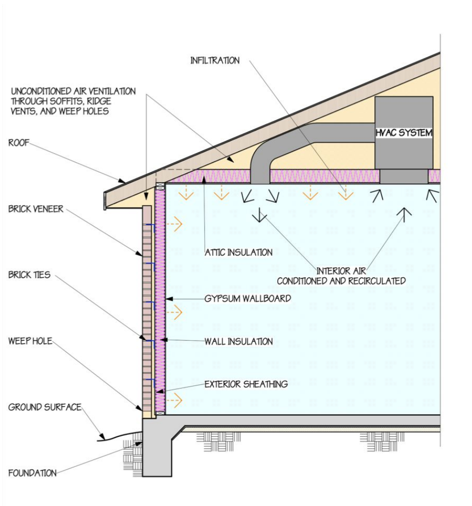

Figure 1 - Conventional HVAC System

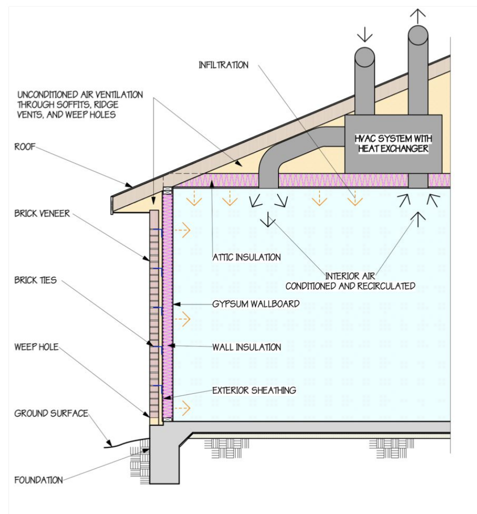

Figure 2 - Conventional HVAC System with Heat Exchanger

Other than small energy savings from the heat exchanger, the building characteristics are identical to Figure 1.

This leads us to Structural Ventilation of the Building Envelope (SV).

Structural Ventilation of the Building Envelope

The system was developed in the early 2000's and patented in 2007 and 2022. The system development began with the aid of the MOIST software and elaborate spreadsheets filled with hygrothermal equations. Technology has since improved.

Structural Ventilation of the Building Envelope (SV) is a system that introduces continuously conditioned, positively pressured, outdoor air into the interior habitable spaces of a structure where the outdoor air is cleaned, temperature adjusted, and humidity adjusted by a Dedicated Outdoor Air System (DOAS) before entering the habitable spaces of a structure. The positively pressured indoor air is exhausted into the building envelope and subsequently to the exterior.

<u>Part A - The Mechanical System</u>

The volume of outside air entering the structure is as specified by ASHRAE and is based upon the building occupancy and use. Refer to the guide and standards shown in Figure 3.

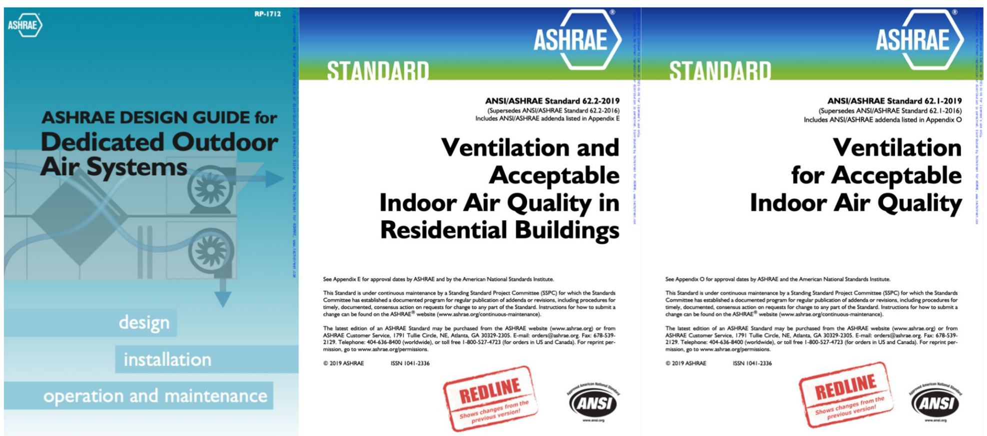

Figure 3 - ASHRAE Guide and Standards

Outside air is cleaned, filtered, and temperature and humidity adjusted through the DOAS for heating and cooling. This low volume/high velocity air is continuously injected into the building to regulate building temperature and humidity. Indoor air contamination is reduced since indoor air is not recirculated; rather exhausted out of the occupied spaces as recommended by ASHRAE. State of the art mechanical and ducting systems are currently available to economically achieve these goals. Further discussion of these mechanical and ducting systems are beyond the scope of this paper.

Part B - The Building Envelope Ventilation

SV indoor air is exhausted out of the occupied spaces and into the building envelope to regulate the temperature and humidity of the building envelope.

Shown in Figure 4 is a typical example of SV. The HVAC system draws outside air into the unit where it is cleaned and temperature and humidity adjusted. This air is circulated within the building, exhausted into the attic, exhausted into the exterior walls, and released into the exterior environment. The attic and cavity walls are conditioned and ventilated with indoor air.

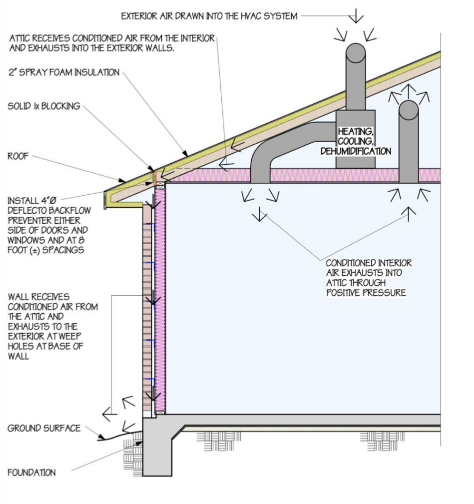

Figure 4 - Structural Ventilation (SV)

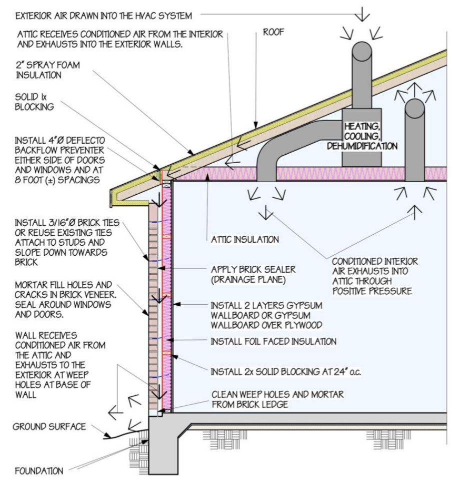

Figure 5 - SV and Flooded Structure

Outside air is conditioned prior to distribution through the structure. Infiltration is eliminated. The building envelope is conditioned to near interior conditions.

Differences for building retrofit or new construction include the absence of ventilation openings to the exterior (soffit vents, ridge vents, turtle vents) an updated HVAC system and ducting (high velocity/low volume), the use of insulation beneath the roofing, the installation of a backflow preventer at top of wall, and the use of additional sealants at material terminations of the building envelope.

Figure 5 shows a flooded structure equipped with SV. The sheathing behind the brick veneer, when wet, can become contaminated and soft. The sheathing is a part of the shear walls to keep the building upright. In order to remove and replace the moisture damaged sheathing and conform to existing construction, removal and replacement of the brick veneer is necessary. This SV repair method allows the brick veneer to remain intact, provides drying of the structure for this and future events, and minimizes repair costs.

Moisture Limitations

Many structural components are compromised by moisture. For example, mold can occur when the surface relative humidity of a building component exceeds 70%(±) and temperatures are above 4°C (40°F). Wood rot occurs at moisture contents of 30% or greater and with temperatures ranging between 10°C (50°F) and 40°C (100°F). Nail corrosion occurs at relative humidities greater than 60%; a maximum 20% wood moisture content is preferred to minimize nail corrosion within the wood. The Structural Board Association states that Exposure 1 OSB materials are intended to be used in covered and well ventilated areas; this exposure relates to an OSB moisture content of 8% to 9% or a solid wood moisture content of 12% to 15%. Relative humidities above 80% are not recommended. ASHRAE, ANSI, and EPA concur that the relative humidity of interior ambient air should be between 30% and 60% with temperatures between 20°C (68°F) and 27°C (81°F) at all times.

Excess moisture compromises structural components.

WUFI Analyses

WUFI, developed with the assistance of Oak Ridge National Laboratory (ORNL), analyzes the hygrothermal properties of building envelopes. WUFI allows realistic calculations of the transient coupled heat and moisture transport in multi-layer building envelopes based upon exterior weather data and normal interior climates. WUFI is an acronym for Wärme Und Feuchte Instationär, which translated means heat and moisture transiency.

An Office Building, defined in Figure 6, was analyzed using WUFI. The occupant requires 1.6 Air Changes per Hour (ACH). Location: Houston, Texas

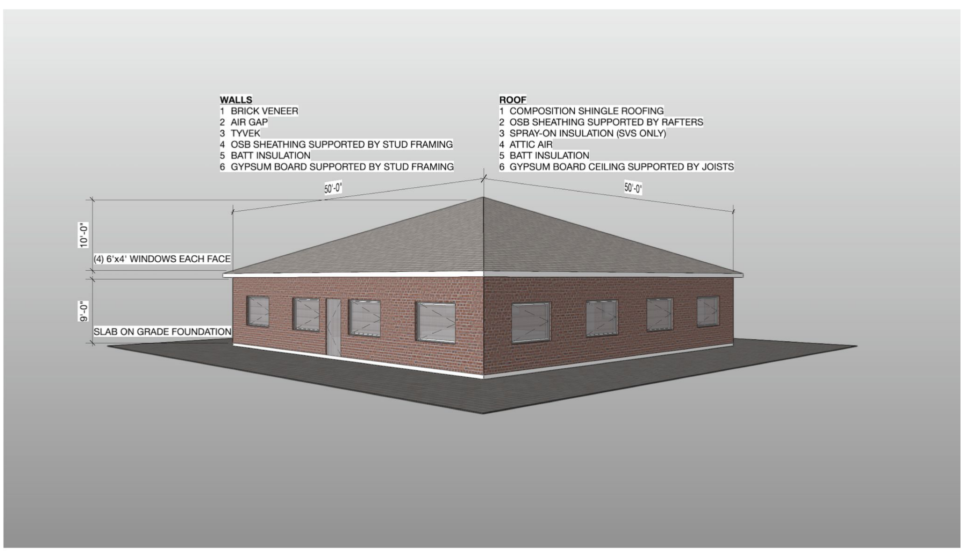

Figure 6 - WUFI Analysis of Office Building

Attic Assembly

The attic assembly shown in Figure 7.1 is the conventional system and Figure 7.2 is the SV system. The roofing is at the top, the ceiling is at the bottom. Blue is air and yellow is insulation. The green shading is the relative humidity of the air and the components, red is temperature, and dark blue is moisture content.

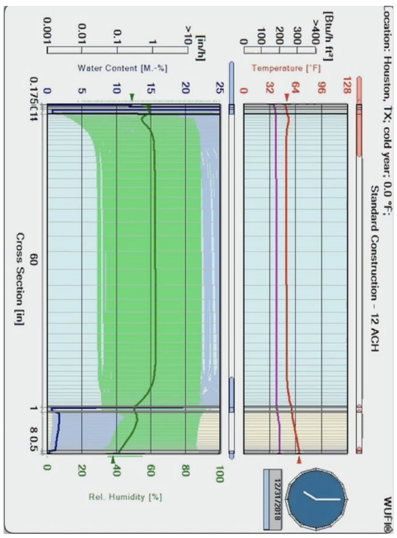

Figure 7.1 - Conventional System at Attic

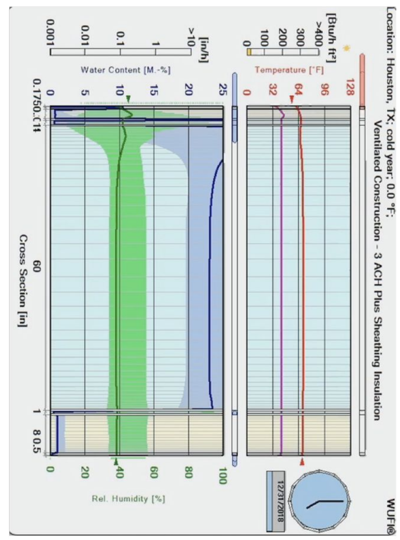

Figure 7.2 - SV System at Attic

Over a one year period, at the conventional system, the surface relative humidity exceeds 80%. Mold growth is expected. Nail corrosion is expected. OSB moisture contents are elevated.

At the SV system, these conditions do not exist except at the base of the roof insulation.

Figures 8.1 and 8.2 depict the temperatures and relative humidities at the top surface of the ceiling insulation of the conventional system and SV system, respectively. With the SV system, relative humidity is reduced 35% in the summer months and the temperatures increase 15°C (25°F) in the winter months and decrease 12°C (10°F) in the summer months. ***The RSI-6 (R-35) assembly becomes RSI_{HT}-38 (R_{HT}-215).*** R_{HT} is the Hygrothermal Resistance, defined later in this paper.

Figure 8.1 - Conventional System at Attic

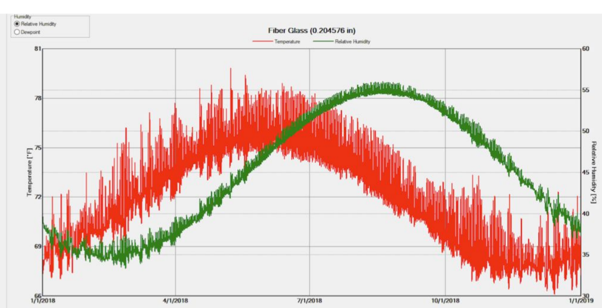

Figure 8.2 - SV System at Attic

Wall Assembly

The wall assembly shown in Figure 9.1 is the conventional system and Figure 9.2 is the SV system. Brick veneer is on the left, gypsum board is on the right. Blue is air, yellow is insulation. The grey area between the air and insulation is OSB sheathing. The green shading is the relative humidity of the air and the components, red is temperature, and dark blue is moisture content.

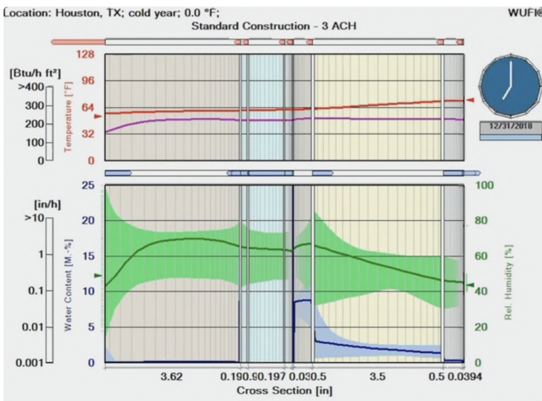

Figure 9.1 - Conventional System at Wall

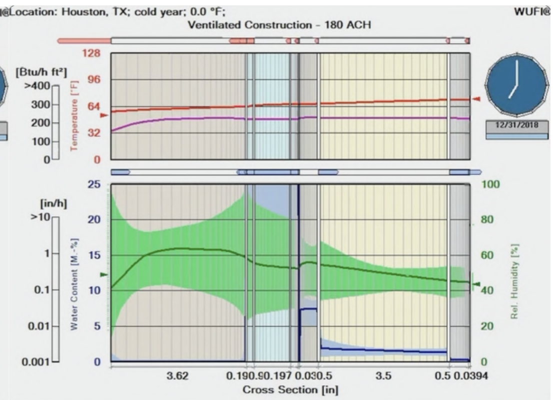

Figure 9.2 - SV System at Wall

Over a one year period, at the conventional system, exclusive of components outside the air cavity, the surface relative humidity exceeds 80%. Mold growth is expected. Nail corrosion is expected. OSB moisture contents are elevated.

At the SV system, these conditions do not exist.

Figures 10.1 and 10.2 depict the temperatures and relative humidities at the exterior surface of the OSB sheathing of the conventional system and SV system, respectively. With the SV system, relative humidity is reduced 15% in the summer months; the temperatures increase 8°C (15°F) in the winter months and decrease 12°C (10°F) in the summer months. ***The RSI-3.5 (R-20) assembly becomes RSI$_{HT}$-7 (R$_{HT}$-40).***

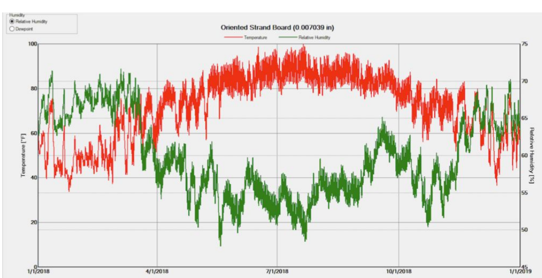

Figure 10.1 - Conventional System at Wall

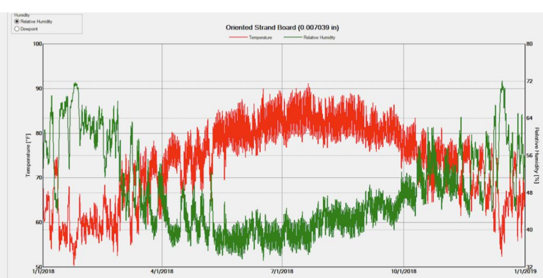

Figure 10.2 - SV System at Wall

Window Assembly

The window assembly shown in Figure 11.1 is the conventional system and Figure 11.2 is the SV system. The left figure is of a single pane of glass. The right figure is conditioned airflow sandwiched between two panes of glass. The green shading is the relative humidity of the air, red is temperature, and dark blue is moisture content. The interior glass surface humidity is lowered 50%.

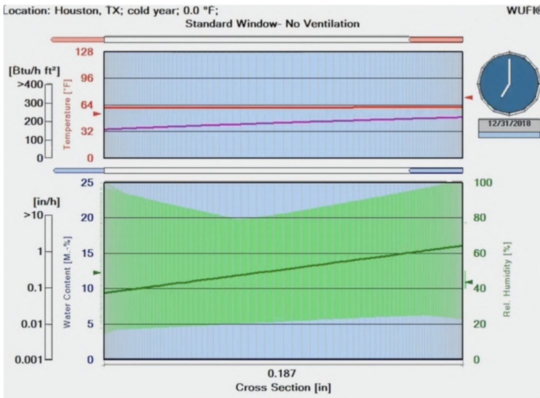

Figure 11.1 - Conventional System at Window

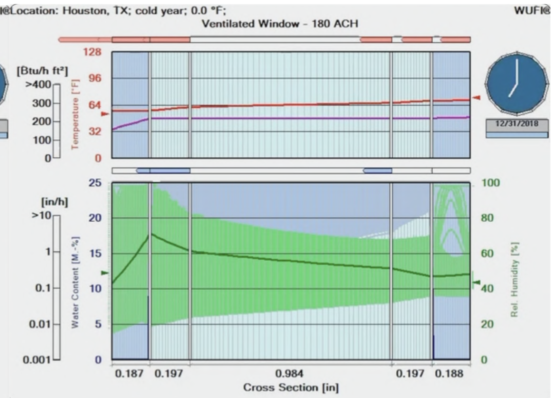

Figure 11.2 - SV System at Window

In this instance, it would be preferable to use insulated glass at the exterior pane to minimize condensation.

Figures 12.1 and 12.2 depict the temperatures and relative humidities at the interior surface of the window of the conventional system and SV system, respectively. With the SV system, relative humidity is reduced 50% in the winter months; the temperatures increase 15°C (25°F) in the winter months and decreases 8°C (15°F) in the summer months. ***The RSI-0.2 (R-1 assembly becomes RSI_{HT}-0.9 (R_{HT}-5).***

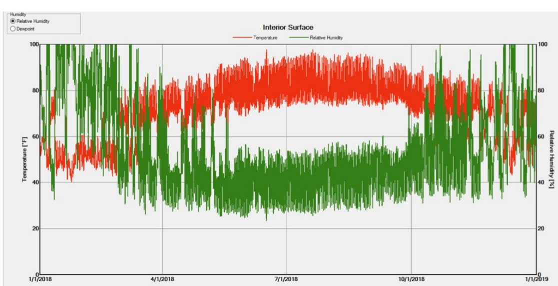

Figure 12.1 - Conventional System at Wall

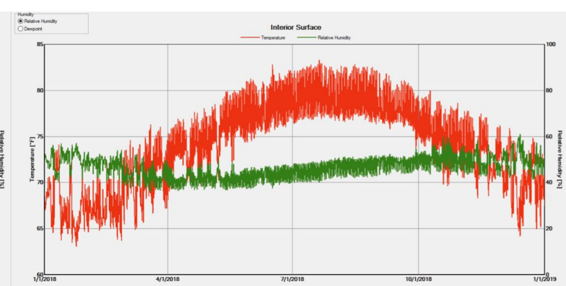

Figure 12.2 - SV System at Wall

If insulated glass was used at both panes, the thermal resistances would be additive. ***So, if each insulated pane is RSI-0.35 (R-2), ∑ R = RSI_{HT}-1.6 (R_{HT}-9) of the window assembly.***

SV controls the building envelope temperatures and humidities.

Additional WUFI Analyses

The School Building, defined in Figure 13, was also analyzed using WUFI.

The building requires 3.1 ACH.

Location: Houston, Texas

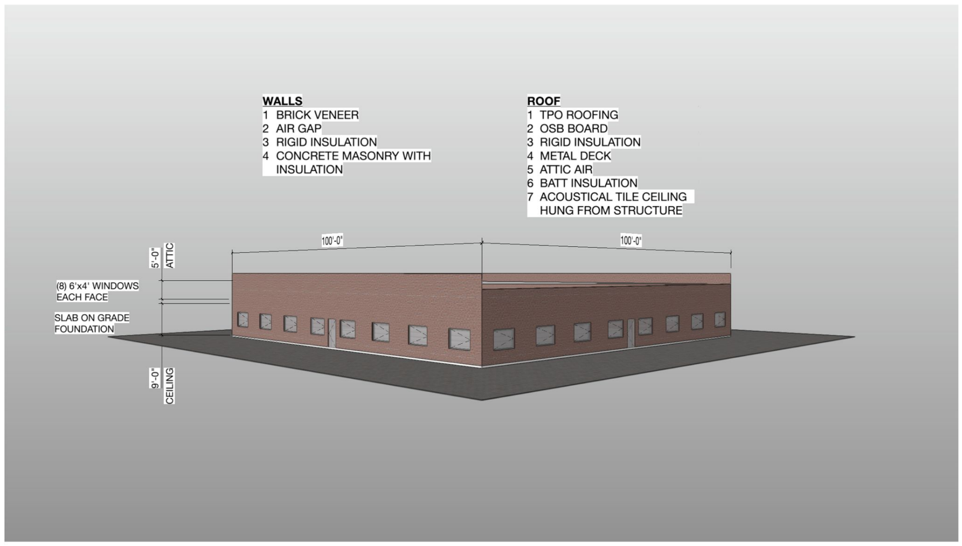

Figure 13 - WUFI Analysis of School Building

Thermal Resistance (RSI and R) and Hygrothermal Resistance (RSI_{HT} and R_{HT})

The designation RSI (R) is the static thermal resistance of a component, or assembly, due to the physical characteristics of the materials.

Hygrothermal Resistance, RSI_{HT} (R_{HT}) combines the static thermal resistance of the material with the dynamic coupled heat and moisture transport through the materials generated by the conditioned airflow through the building envelope.

Hygrothermal Resistance increases with exhaust air cavity height/width and exhaust airflow rate.

<u>Attics</u>

Figure 14.1 shows the R_{HT} of the attic of the Office Building (Figure 6) and Figure 14.2 shows the R_{HT} of the attic of the School (Figure 13). In each, static thermal resistance is approximately RSI-9 (R-50). With SV, the hygrothermal resistance increases significantly with greater attic height and greater air flow rates. Doubling the attic height increases R_{HT} by a factor of 1.7. Doubling the air flow rate increases R_{HT} by a factor of 1.7. ***At the Office Building, the Attic ACH = 3 resulting in an RSI_{HT}-35 (R_{HT}-200); an increase by a factor of 4. At the School Building, the Attic ACH = 4.7 resulting in an RSI_{HT}-50 (R_{HT}-275); an increase by a factor of 5.5.***

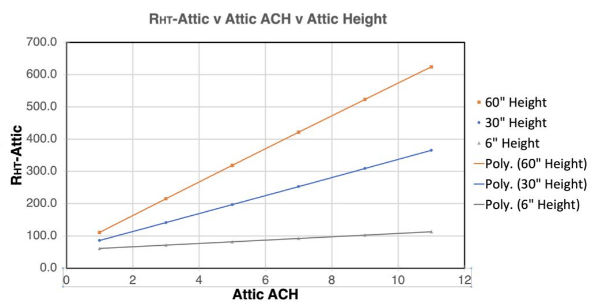

Figure 14.1 - R_{HT} of the Office Attic

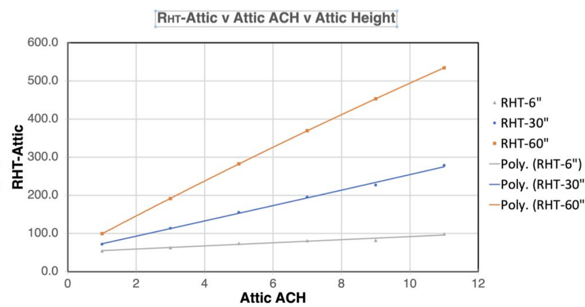

Figure 14.2 - R_{HT} of the School Attic

<u>Walls</u>

Figure 15.1 shows the R_{HT} of the walls of the Office Building (Figure 6) and Figure 15.2 shows the R_{HT} of the walls of the School Building (Figure 13). In each, static thermal resistance is approximately RSI-3.5 (R-20). With SV, the hygrothermal resistance increases significantly with greater air flow rates. At the Office Building, southern exposure of the brick veneer wall results in little change. Doubling the air flow rate increases R_{HT} by a factor of 1.6. ***The Cavity ACH = 180 resulting in an RSI_{HT}-7 (R_{HT}-40); an increase by a factor of 2.*** At the School Building, southern exposure of the brick veneer wall results in an increase of R_{HT}. Doubling the air flow rate increases R_{HT} by a factor of 1.5. ***The Cavity ACH = 585 resulting in an RSI_{HT}-19 (R_{HT}-110); an increase by a factor of 5.5.***

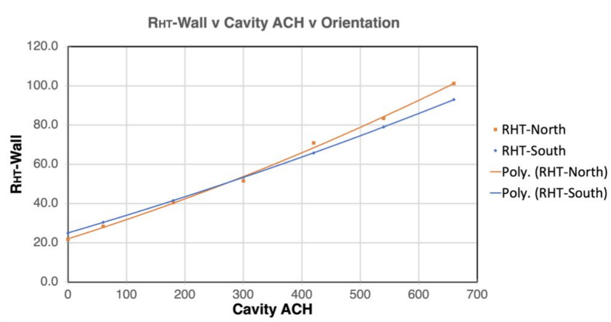

Figure 15.1 - R_{HT} of the Office Walls

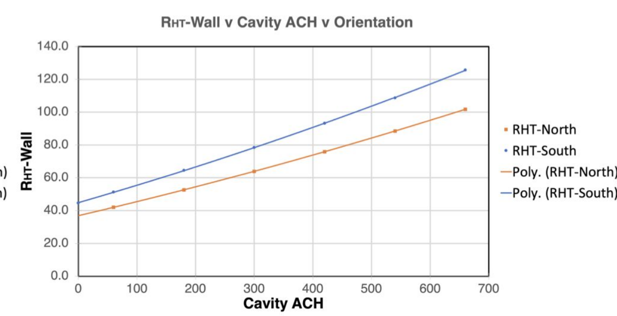

Figure 15.2 - R_{HT} of the School Walls

Windows

Figure 16 shows the R_{HT} of the windows of both buildings. In each, static thermal resistance of a single pane clear window is approximately RSI-0.2 (R-1). Southern exposure and dark tint of the window results in a increase of R_{HT} by a factor of 1.5.

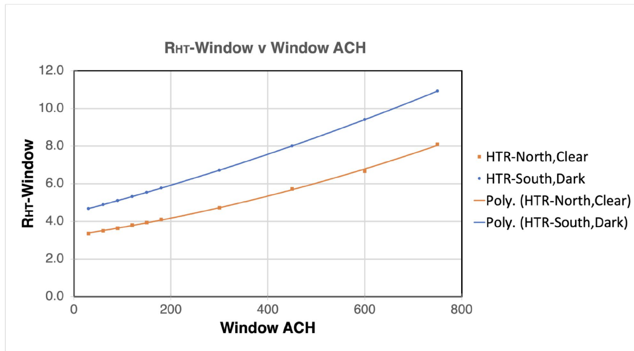

Figure 16 - R_{HT} of Windows

With SV, the hygrothermal resistance increases significantly with greater air flow rates. Doubling the air flow rate increases R_{HT} by a factor of 1.3. ***At the Office Building, the Window ACH = 180 resulting in RSI$_{HT}$-0.9 (R$_{HT}$-5). At the School Building, the Window ACH = 585 resulting in RSI$_{HT}$-1.4 (R$_{HT}$-8).***

As stated earlier, R and R_{HT} are additive. ***If we install thermal windows each side of the air stream that are each RSI-0.35 (R-2), the Office Building windows would attain RSI$_{HT}$-1.6 (R$_{HT}$-9). The School Building windows would attain RSI$_{HT}$ = 2.1 (R$_{HT}$-12).*** Each increase is significant.

SV significantly increases the hygrothermal resistance of the building envelope.

HVAC Sizing

The Office Building was analyzed with Manual J based upon the lowest R_{HT} of the winter months at various locations within the United States.

Figure 17 provides the heating and cooling requirements of the building in various cities. At each city, the conventional heating and cooling requirements are shown as the tall orange and blue bars. The SV heating and cooling requirements are shown as the short orange and blue bars. The grey bars are the percent SV unit sizing is of conventional unit sizing. ***The percentages range from 69% to 75%.***

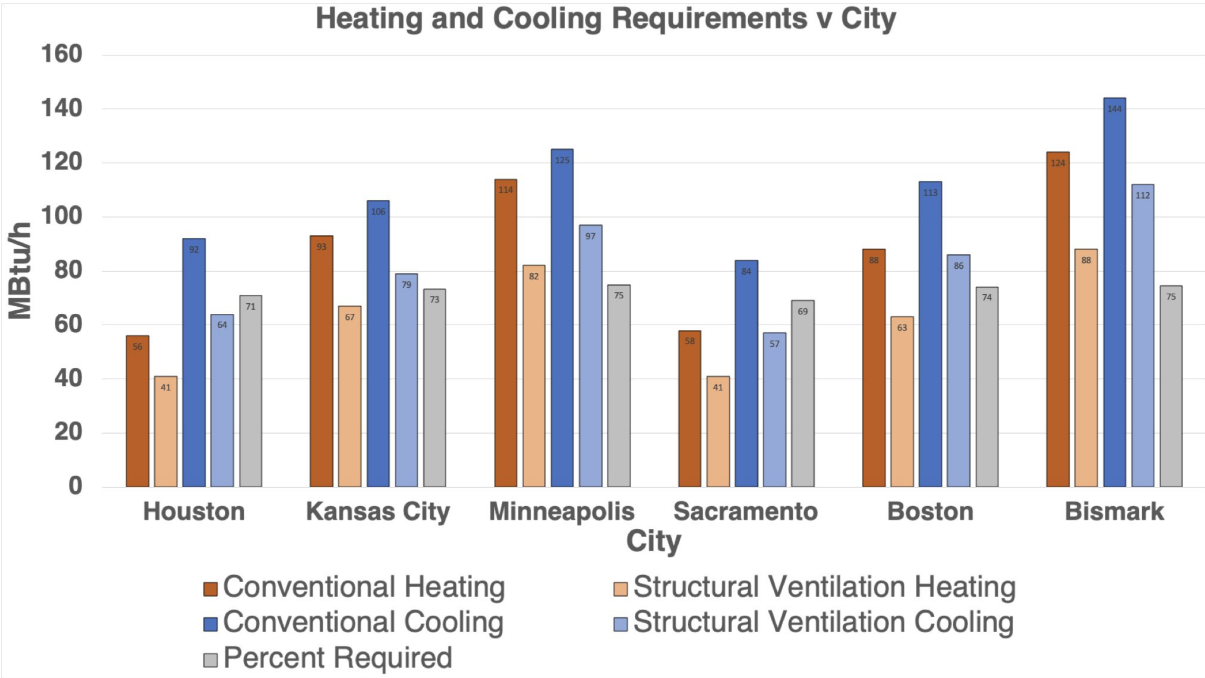

Figure 17 - Office Building Heating and Cooling Requirements v City

SV results in smaller equipment sizes regardless of location.

Energy Usage for Heating

The Office Building was analyzed with the WUFI Post Processor based upon the R_{HT} of winter monthly averages that are based upon hourly calculations. Typically, the R_{HT} is greater before and after the coldest month.

Figure 18 provides the annual heating energy usage of the building at several cities. The conventional heating and SV heating requirements are presented as separate groups. The SV group shows percentages in the bars that indicates the percent SV energy usage is of conventional usage. ***The percentages range from 49% to 71%.***

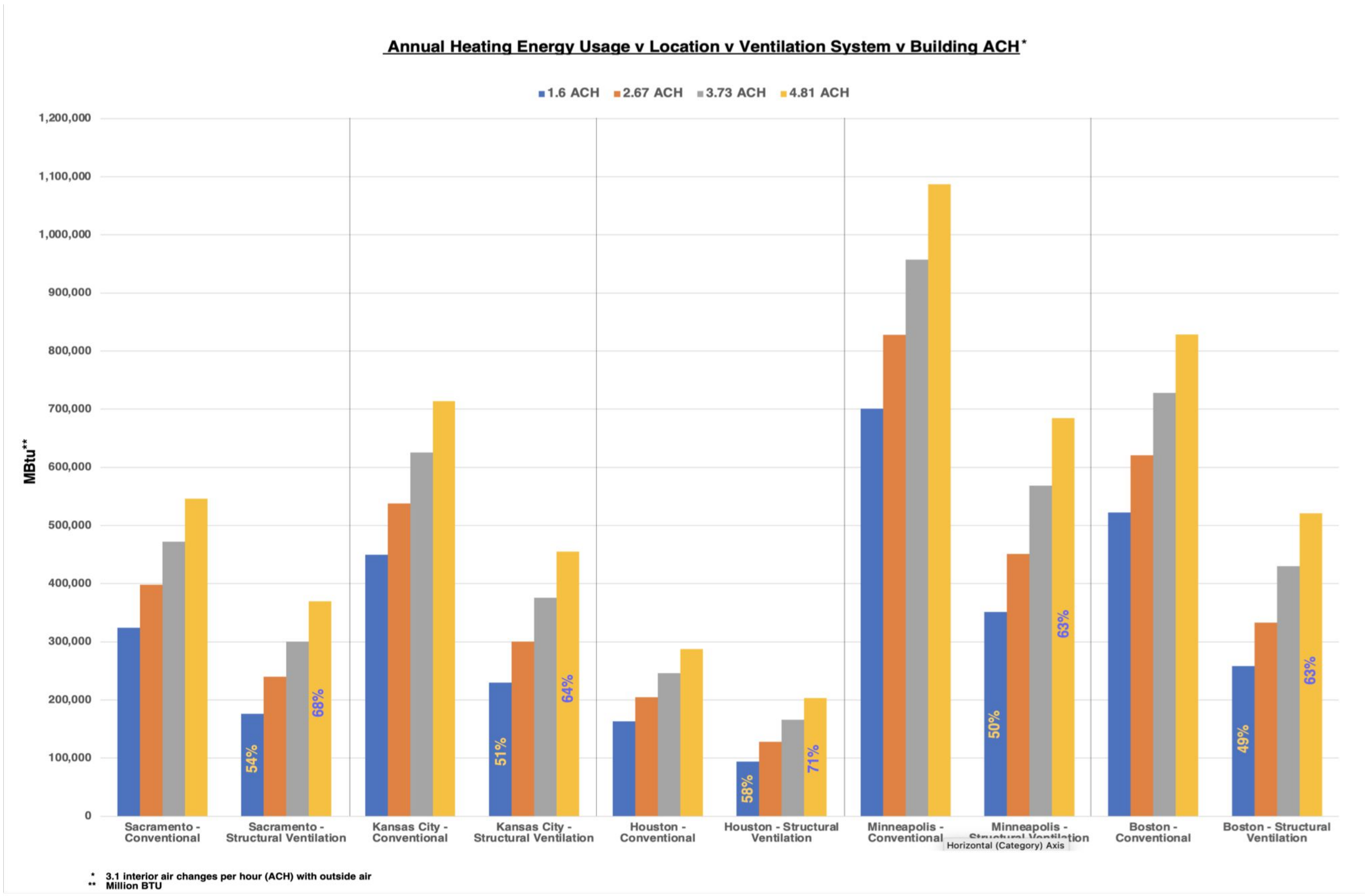

Figure 18 - Office Building Heating Energy Usage v City v Ventilation System v Building ACH

SV results in significant energy savings regardless of location.

The School Building was also analyzed with the WUFI Post Processor.

Figure 19 provides the annual heating energy usage of the school building at several cities. The conventional heating and SV heating requirements are presented as separate columns. The SV columns show percentages in the bars that indicates the percent SV energy usage is of conventional usage. ***The percentages range from 66% to 75%.***

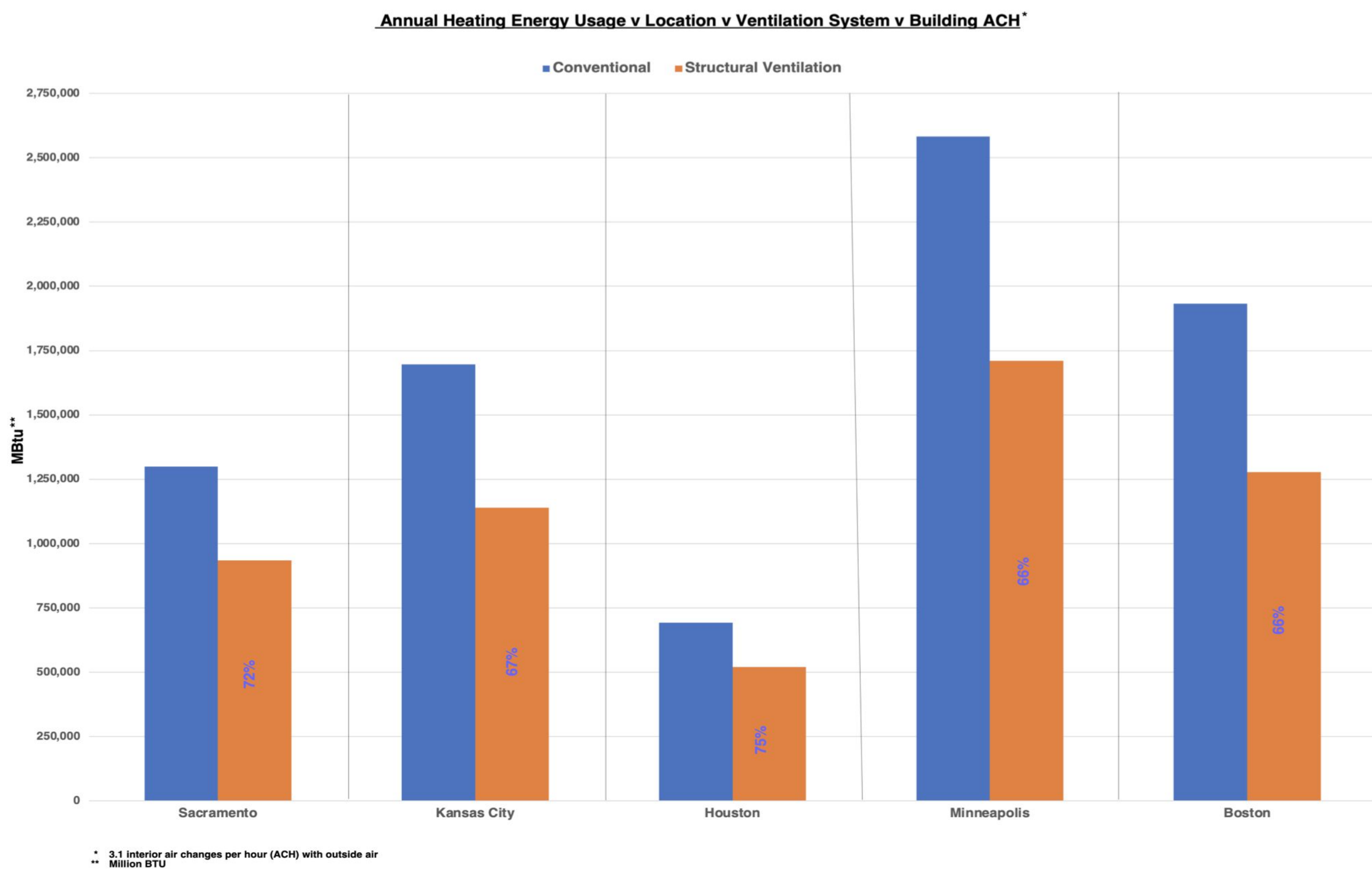

Figure 19 - School Heating Energy Usage v City v Ventilation System

SV results in significant energy savings regardless of location.

Moisture Issues

Moisture infiltration is a common problem with building envelopes. Moisture, typically from the exterior environment, passes through defective joints in the exterior finishes and roofing. The joints typically occur at material terminations such as window and door perimeters, roofing and wall penetrations, roof to wall interfaces, and the like.

As noted earlier, moisture can also develop due to naturally occurring moisture due to hygrothermal activity within the building envelope. This is most prevalent when low permeability materials are installed.

The following building envelope moisture content readings were compared to WUFI analyses. Red is well above expected values, yellow is slightly above expected values, green similar to expected values, and blue is below expected values.

Expected moisture content readings of interior components were determined by air temperature and humidity readings.

Figures 20.1 through 20.3 represent moisture content readings at the walls of a one-story, one-year old, daycare. Gypsum sheathing was measured at the exterior faces of the wall studs and gypsum board was measured at the interior of the structure. The interior gypsum board finish moisture contents are elevated at the perimeter of the building. Window leaks are evident. The gypsum sheathing behind the brick veneer is very wet.

Figure 20.1 - Daycare Gypsum Board Moisture Content Readings

Figure 20.2 - Daycare Windowsill Moisture Content Readings

Figure 20.3 - Daycare Gypsum Sheathing Moisture Content Readings

In this instance, the weep holes at the base of the wall were plugged with mortar, rainwater was seeping behind the veneer, and the windows leaked.

Figures 21.1 through 21.3 represent moisture content readings at the third floor walls of a three-story, three-year old, house. Gypsum board, baseboards, and windowsills were measured at the interior of the structure.

The gypsum board finish moisture contents are moderate at the perimeter walls and the interior walls. The baseboards are typically moist beneath windows and at doors. Windowsill reading are elevated.

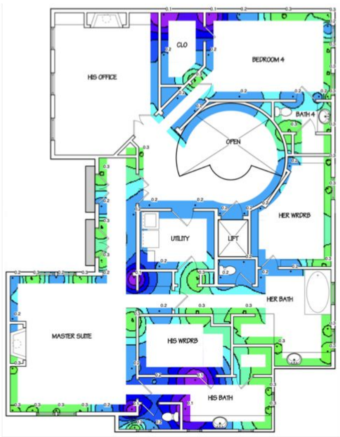

Figure 21.1 - House Gypsum Board Moisture Content Readings

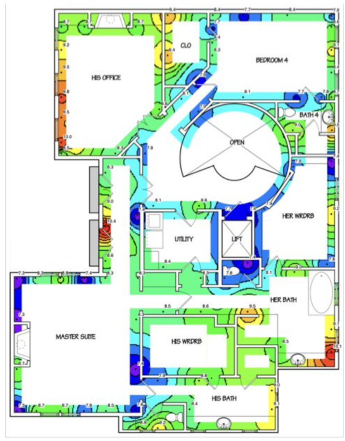

Figure 21.2 - House Baseboard Moisture Content Readings

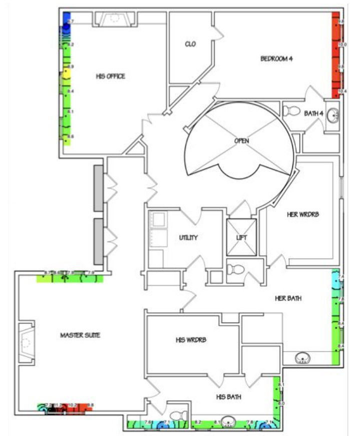

Figure 21.3 - House Windowsill Moisture Content Readings

Window and door leakage are the prime contributors. Moisture is collecting within the building envelope.

Figures 22.1 through 22.4 represent moisture content readings at the third floor walls and ceiling of a three-story, four-year old, house. Gypsum board, baseboards, windowsills, and the ceiling were measured at the interior of the structure.

The interior gypsum board moisture contents are elevated at the central area of the house and some exterior walls. The baseboards are more moist at the interior of the building as opposed to the perimeter. Windowsill readings are elevated. The ceiling is typically moist with greater moisture at the right side of the drawing.

Figure 22.1 - House Gypsum Board Moisture Content Readings

Figure 22.2 - House Baseboard Moisture Content Readings

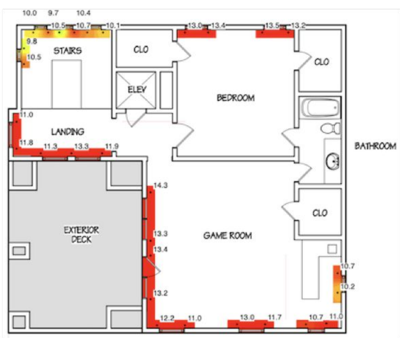

Figure 22.3 - House Door and Windowsill Moisture Content Readings

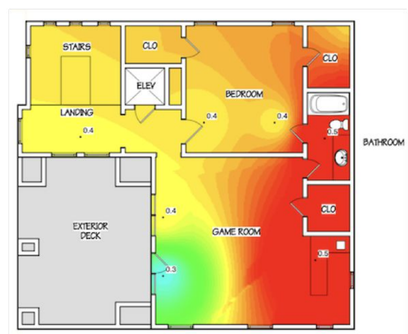

Figure 22.4 - House Ceiling Moisture Content Readings

Moisture is collecting within the attic due to the lack of adequate ventilation. Moisture from this source is infiltrating the interior and perimeter walls of the upper floor. Window and door leakage are also issues.

Building Envelope Defects

Plugged Weep Holes

Plugged weep holes is the most common defect. See Figures 23.1 through 23.4. This occurs in at least 80% of structures investigated. From the exterior, the weep holes are visibly open; however, the air cavity is actually filled with mortar behind two or more brick courses. The resulting damages are exposing the exterior wall sheathing to excess moisture rendering it incapable of resisting Code specified lateral shear wall loads, rotting wood framing, and mold contamination.

Figure 23.1 - Mold decontamination

Figure 23.2 - Sheathing removed

Figure 23.3 - Sheathing moisture damage

Figure 23.4 - Plugged weep hole

These conditions would not exist with SV since the air passages would be required to be open to allow the system to function and moisture would be dried by continuous exhausted interior air.

<u>Window Leakage</u>

Window leakage is the second most common defect. See Figures 24.1 through 24.4. This occurs in at least 60% of structures investigated. The resulting damages are exposing the exterior wall sheathing to excess moisture rendering it incapable of resisting Code specified lateral shear-wall loads, rotting wood framing, and mold contamination.

This defect is typically due to improperly installed or absent flashing at the perimeter of the windows, lack of exterior sealants at the window perimeters, and/or misaligned or mis-fabricated windows frames.

Figure 24.1 - Sheathing moisture damage

Figure 24.2 - Sheathing moisture damage

Figure 24.3 - Mold at windowsill

With the SV system, these conditions would not exist since the windows would be located in front of the airstream and integral with the exterior finish. Moisture entering through the finish would be directed along the exterior edge of the airstream, dried by continuous exhausted interior air, and allowed to drain at the base of the wall.

<u>Restricted Attic Ventilation</u>

Restricted attic ventilation is the most probable cause of mold growth within attics. See Figures 25.1 and 25.2. Required by the building codes, attics are to be ventilated with raw outdoor air, typically provided with soffit and ridge vents. If not ventilated, moisture collects within the attic.

In many structures, the soffit vents are restricted due to insulation covering the vents with rafter vents compressed or absent. This easily results in mold growth. Inadequate ceiling insulation at the attic floor exacerbates the condition.

Figure 25.1 - Soffit vents

Figure 25.2 - Compressed rafter vents

With SV, these issues would not occur. Outside air is terminated and the attic is conditioned with exhausted indoor air. Proper ventilation is achieved.

<u>Roof Leakage</u>

Roof leakage can go undetected. See Figure 26.1. In this instance, a scupper leaked behind the exterior stucco finish. The wall was constructed with the stucco applied directly to the exterior sheathing; an air cavity did not separate the exterior finish from the structural framing.

Figure 26.1 - Scupper leakage damage

With the SV system, these conditions would likely not exist since moisture entering through the finish would be directed along the exterior edge of the airstream and dried by continuous indoor air ventilation.

<u>Deteriorated Slab on Grade Vapor Barrier</u>

This is a common problem with vapor barriers more than 30 years of age. The polyethylene sheets lose their elasticity and become brittle. See Figure 26.2. Disturbed vapor barriers due to foundation or plumbing repairs are common.

Figure 26.2 - Moisture from damaged vapor barrier

With the SV system, moisture and contamination released into the air from the defect would be minimized.

Door Leakage

Door leakage is similar to window leakage. See Figure 27.1. This defect is typically due to improperly installed or absent flashing at the perimeter of the door frame, lack of exterior sealants at the door frame perimeters, and defective thresholds.

Figure 27.1 - Door leakage

With the SV system, these conditions would be minimized by the drying affect of the wall cavity and interior environment.

Cap Flashing Leakage

Cap flashing is the cap on the top of parapets. Defects are typically related to open joints and unsealed penetrations. Water enters the parapet and results in deterioration and mold growth. See Figures 27.2 and 27.3.

Figure 27.2 - Cap flashing separations

Figure 27.3 - Cap flashing openings

With the SV system, these conditions would be minimized by the drying affect of the airstream within the wall.

Solutions

Regarding indoor air contamination, outdoor air ventilation in buildings is the solution to minimize COVID-19 contamination inside buildings. Moisture control and outdoor air ventilation in buildings are the solution to minimize mold contamination inside buildings. Underfloor ventilation and outdoor air ventilation in buildings are the solution to minimize radon contamination inside buildings.

Outdoor air ventilation and moisture control are necessary.

Most conventional systems recirculate and filter interior air to adjust temperature and rely on opening of doors and infiltration through the structure for outside air. Interior relative humidity reduction is dependent upon warmer outside temperatures. Structural Ventilation results in:

1. Conformance with ASHRAE Standards.

2. Outdoor ventilation in buildings and within all building envelopes with temperature and humidity regulated by interior needs. Fresh air injected into the building is exhausted into the building envelope.

3. Reduced moisture within the building envelope such that surface relative humidities are typically below limitations inward of the air stream. The potentials for mold growth and material deterioration are diminished.

4. Improved hygrothermal resistance of the building envelope results in 70% of the required energy to operate the HVAC systems at peak demand resulting in reduced mechanical system costs. This energy reduction is applicable regardless of geographic location.

5. Improved hygrothermal resistance of the building envelope results in 50-70% of the required energy to operate the HVAC systems during the heating months resulting in reduced energy costs. This energy reduction is applicable regardless of geographic location.

6. Ease of construction using the current labor force

7. Less costly repairs to flood damaged structures

8. Readily installed in buildings upgrading to the system

9. Structural sustainability is improved and structural repair costs are reduced since SV minimizes moisture accumulation due to its drying characteristics.

Summary

Buildings are a necessary part of our society to provide a safe, habitable, and protected environment. Typically, the more safe, habitable, and protected the environment; the higher the cost to operate the building.

Structural Ventilation of the Building Envelope will:

- Minimize Moisture Contamination, and Deterioration of the Building Envelope

- Improve Indoor Air Quality

- Reduce Energy Costs

Structural Ventilation of the Building Envelope is the next generation building ventilation system.

References

ASHRAE. 1997. ASHRAE Handbook—Fundamentals. Atlanta: ASHRAE.

ASHRAE. 2017. ASHRAE Handbook—Fundamentals. Atlanta: ASHRAE.

ASHRAE. 2019. Standard 62-1 Ventilation for Acceptable Indoor Air Quality, ASHRAE Atlanta

ASHRAE. 2019. Standard 62-2 Ventilation and Acceptable Indoor Air Quality in Residential Buildings, ASHRAE Atlanta

ASHRAE. 2016. Standard 160 Criteria for Moisture-Control Design Analysis in Buildings, ASHRAE Atlanta

ASHRAE. 2017. RP-1712 Design Guide for Dedicated Outdoor Air Systems, ASHRAE Atlanta

Fraunhofer Institute for Building Physics. 2021. WUFI Pro v 6.52, Holzkirchen Branch, Fraunhoferstr. 10, 83626 Valley

International Code Council. 2018, International Building Code

International Code Council. 2018, International Residential Code for One and Two-Family Dwellings

International Energy Agency. 1996, Final Report, Volume 3, Task 3: Material Properties

Structural Board Association. 1996. Technical Bulletin: OSB Performance Under High Humidity Conditions, Structural Board Association, 45 Sheppard Ave,. E. Suite 412, Willowdale, Ontario, M2N 5W9 Canada

United States Department of Agriculture. 1999. General Technical Report FPL-GTR-113 Wood Handbook: Wood as an Engineering Material, USDA

United States Environmental Protection Agency. 1991. EPA 402-F-91-102 Building Air Quality Guide: A Guide for Building Owners and Facility Managers, EPA

United States Patent and Trademark Office. 2007. United States Patent 7,247,090, System and Method for Inhibiting Moisture and Mold in an Outer Wall of a Structure, Sam S. Vacek

United States Patent and Trademark Office. 2022. United States Patent 11,248,814, Systems and methods for controlling air properties in structures and inhibiting moisture accumulation and mold propagation in structures, Sam S. Vacek

COVID-19 Specific Links

https://www.epa.gov/coronavirus

https://www.ed.gov/improving-ventilation-schools-colleges-and-universities-prevent-covid-19

https://www.thedenverchannel.com/news/national/coronavirus/epa-issues-new-guidelines-on-air-ventilation-to-prevent-spread-of-covid-19

https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/Improving-Ventilation-Home.html

https://www.osha.gov/sites/default/files/publications/OSHA4103.pdf

Mold Specific Links

https://www.epa.gov/sites/default/files/2014-08/documents/base_3c2o2.pdf

https://www.epa.gov/indoor-air-quality-iaq/indoor-air-pollution-introduction-health-professionals

https://cfpub.epa.gov/si/si_public_record_Report.cfm?Lab=NHEERL&dirEntryID=76755

Radon Specific Links

https://www.epa.gov/radiation/epa-assessment-risks-radon-homes

https://www.epa.gov/radon

https://clarksvillenow.com/local/state-offers-free-radon-test-kits-part-of-radon-action-month/

https://www.epa.gov/radiation/what-radon-gas-it-dangerous

https://projects.oregonlive.com/radon/

https://www.columbian.com/news/2017/mar/20/evergreen-begins-mitigating-schools-radon/

https://www.epa.gov/radon/health-risk-radon