A New Whole Wall R-value Calculator

An Integral Part of the Interactive Internet-Based Building Envelope Materials Database for Whole-Building Energy Simulation Programs

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INTRODUCTION

During fall 2004, the old version of the ORNL Whole Wall R-value Calculator will be replaced by an updated new whole wall R-value calculation tool. The new calculator will be a part of the newly developed *Interactive Envelope Materials Database for Whole-Building Energy Simulation Programs*. It will offer many new advancements over the old tool, including the capability of whole wall calculations for complex residential buildings (fourteen new architectural details, three types of foundations, five shapes of floor plans, multistory building options, etc.). The new material database will provide a direct link between existing hotbox testing results, advanced three-dimensional heat transfer simulations, and whole building energy analysis. Only hotbox tested wall systems will be represented in this new database.

During 2003 and 2004, we have developed about one hundred new configurations of basic wood and steel framed wall technologies. However, a redevelopment of many wall technologies which were represented in the old version of the ORNL Whole Wall R-value Calculator would require additional technical information about geometries of architectural details, material configurations, structural component details, etc. That is why we would like to invite all building material or wall system producers to contact us regarding the inclusion of their technologies into the new ORNL Internet Material Database. The following paper summarizes the theoretical foundations for this new approach and presents some examples of whole building thermal analysis for residential buildings.

GENERAL PROJECT OUTLINE

Today, it is estimated that in residential and small commercial buildings, over 50% of the energy loss is associated with heat transfer and air leakage through building envelope components. However, there are many other building characteristics like floor plans, types of foundation, geometries of wall details, material configurations, dynamic response of building components, surface physical properties, etc., which may also control the overall energy performance of the building shell. Thus it is essential to accurately represent the full complexity of building envelopes in energy analysis.

During the last decades, numerous wall technologies have been introduced to the building marketplace. Some of them represent a complex three-dimensional internal structure. Also, building designs are getting so advanced that in the near future, a single change in a building envelope configuration may no longer be able to significantly improve energy consumption. Only an optimized combination of subsystems may cause notable changes in energy use.

At the same time, many building designers and energy modelers only understand basic heat transfer principles and merely operate in a 1-D environment. Requesting 3-D transient heat transfer analysis for each envelope component seems unrealistic. Therefore a simple computational tool supporting thermal analysis of the building envelope in shell-dominated buildings would be very helpful in the designing process.

The concept of *Interactive Envelope Materials Database for Whole-Building Energy Simulation Programs* was developed to reinforce an accurate, fast, and simple energy analysis of building energy consumption in shell-dominated buildings. This database uses several already existing subroutines, experimental results, and calculation techniques. The main purpose of this database is to serve architects, system designers, and energy modelers by enabling detailed envelope analysis during whole-building energy simulations. However, it can also be utilized for performance comparisons between different envelope technologies. The user simply selects the material configuration and sets dimensions. Later, the Internet program calculates whole-wall/roof/ or floor R-values, generates 3-D dynamic thermal characteristics, and calculates detailed air leakage for the selected building envelope system. This information is then converted into the format required by programs such as BLAST, DOE-2, or ENERGY PLUS.

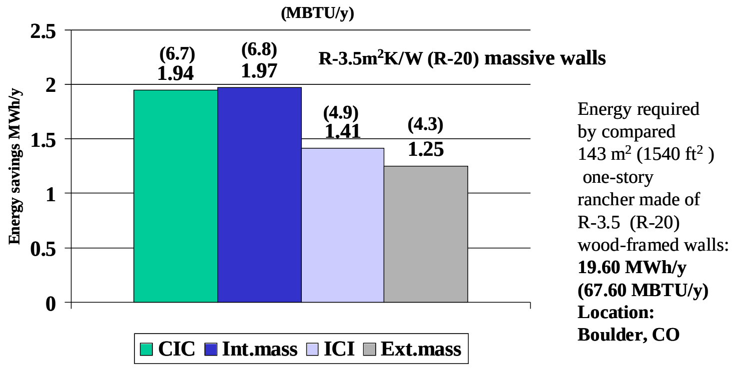
FUTURE ZERO-ENERGY BUILDINGS AND ADVANCED THERMAL ANALYSIS OF BUILDING ENVELOPE

Since the 1970s, several zero-energy buildings have been constructed in different countries and in a wide variety of climatic conditions. The main lesson learned from these exercises was that while it is possible to design and construct a million-dollar zero-energy house, the real engineering challenge is to build such a house for a low-income family.

A proper balance between the cost of “high-tech” materials and equipment and the reduction of whole-building energy consumption is critical for designing affordable low-energy buildings. The most effective way to optimize the building envelope is parametric analysis of all components. To illustrate the importance of this parametric analysis during the designing of low-energy buildings, Figure 1 shows potential energy savings calculated for four different configurations of massive walls of the same R-value. These configurations can be utilized to represent existing building envelope technologies, for example:

- ICI configuration may represent Insulated Concrete Forms,
- Ext. mass may represent a concrete block wall insulated from the interior side with foam sheathing, etc.

Energy savings are computed by comparisons of energy consumption in a single-story rancher with massive walls against a similar house built with traditional wood-framed walls.

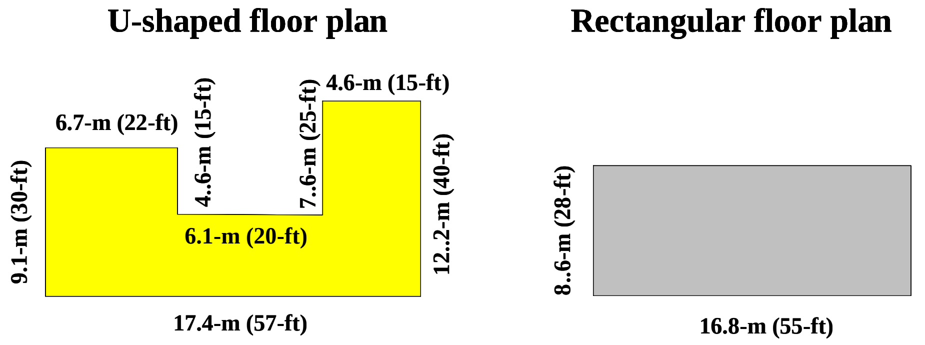


Energy required by compared 143 m² (1540 ft²) one-story rancher made of R-3.5 (R-20) wood-framed walls: **19.60 MWh/y (67.60 MBTU/y)**
Location: Boulder, CO

CIC:	**Int.mass:**	**ICI:**	**Ext.mass:**
Concrete 7.6-cm. (3-in.)	Foam 10.2-cm. (4-in.)	Foam 5.1-cm. (2-in.)	Concrete 15.2-cm. (6-in.)
Foam 10.2-cm. (4-in.)	Concrete 15.2-cm. (6-in.)	Concrete 15.2-cm. (6-in.)	Foam 10.2-cm. (4-in.)
Concrete 7.6-cm. (3-in.)		Foam 5.1-cm. (2-in.)	

Figure 1. Energy savings estimates computed for one-story rancher with R-3.5 (R-20) massive walls for Boulder, CO.

As shown in Figure 1, potential energy savings are the function of wall material configuration. Most efficient are the configurations with thermal mass located on the interior side of the wall. Simple changes in configuration of the same wall materials (insulation and concrete) may bring energy savings in the range +/- 30% from each other. The scale of differences in energy savings is close to 0.7 MWh/y (2.4 MBU/y). This is equivalent to the energy effect generated by adding 5 cm (2-in.) of rigid foam sheathing. This example demonstrates that sometimes it might be wise to optimize a configuration of building envelope materials before making recommendations for a costly addition of thermal insulation.


U-shaped floor plan

Rectangular floor plan

Figure 2. Schematics of two floor plans used in comparisons.

Another example shows how relatively small changes in building envelope configurations (floor plan, addition of window, addition of door, and application of different wall structural components) may notably modify building thermal characteristics. As shown in Figure 2 above, two floor plans were considered for one-story 144 m^2 (1540 sqft) house. List of basic building components which are different in both houses is presented in Table 1.

Table 1. List of basic building components which are different in both houses.

Foundation plan	**U-shaped**	**Rectangular**
Number of corners	**8**	**4**
Wall openings	**Windows: 7 – 1.2x1.5-m. (4x5-ft), 2 – 1.2x0.9-m (4x3-ft), 1 – 1.2x1.8-m. (4x6-ft)** **doors: 2 – 2.1x1.2-m. (7x4-ft)**	**windows: 7 – 1.2x1.5-m. (4x5-ft), 1 – 1.2x0.9-m. (4x3-ft)** **doors: 1 – 2.1x1.2-m. (7x4-ft)**
Elevation area	**167-m^2 (1800 ft^2)**	**124-m^2(1320 ft^2)**
Windows + Doors	**22-m^2 (237 ft^2)**	**16-m^2(172 ft^2)**
Opaque wall area	**145-m^2 (1560 ft^2)**	**108-m^2(1160 ft^2)**

It is assumed that in both houses, traditional 2x4 wood-framed walls insulated with R-1.9 (R-11) fiberglass batts and exterior wood siding are used. Relations between in-cavity, clear wall, and whole wall R-values are presented in Figure 3.

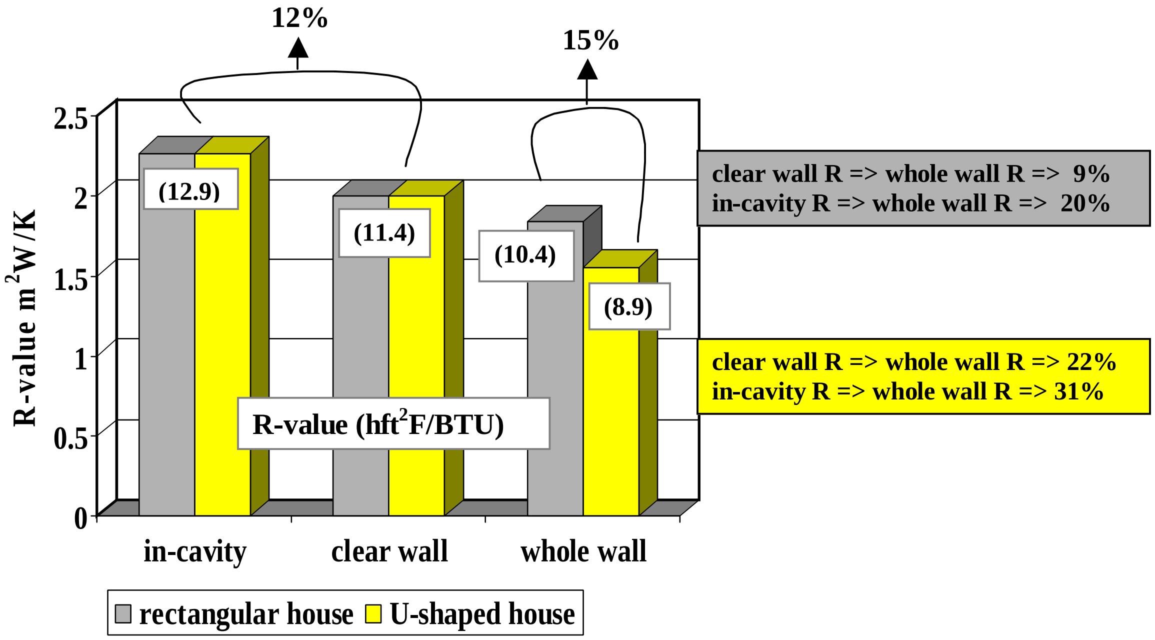


Figure 3. Relations between in-cavity, clear wall, and whole wall R-values for both compared houses (traditional 2x4 wood framing).

In both houses clear wall R-values are 12% lower from in-cavity R-values (in-series R-value for the center of cavity). However, differences in building envelope configuration generated differences in whole wall thermal performance for both houses.

Whole wall R-value (which included all wall architectural details and intersections – Kosny & Desjarlais 1994) for the house placed on the U-shaped floor plan is R-1.6 m^{2}W/K (8.9 hft^{2}F/Btu). Whole wall R-value for the house with rectangular floor plan is R-1.8 m^{2}W/K (10.4 hft^{2}F/Btu). The difference is about 15%. Also, opaque wall area of the U-shaped houses is about 25% larger from the other house opaque wall area. This yields about 35% difference in wall heat transfer rates for both houses. It is important to realize, that all these closely related differences would not be fully accounted for if conventional techniques for energy analysis were utilized.

DYNAMIC WHOLE BUILDING ENERGY SIMULATIONS – SOME ACCURACY PROBLEMS

Most whole-building energy simulation programs require 1-D descriptions of building envelope components. Unfortunately, proper analysis of complex thermal envelope systems sometimes requires an application of advanced 3-D transient heat transfer analytical tools. This situation may create accuracy problems in whole-building energy modeling. It may also generate uncertainties in sizing HVAC equipment because of inaccuracies in building load calculations. To reduce the cost of the process and minimize the potential for inaccuracies, a method of developing architectural component descriptions in simulation programs has to be as simple as selecting the specific material configuration, setting dimensions, and determining building orientation.

Inaccuracies in Approximation of Thermal Bridges

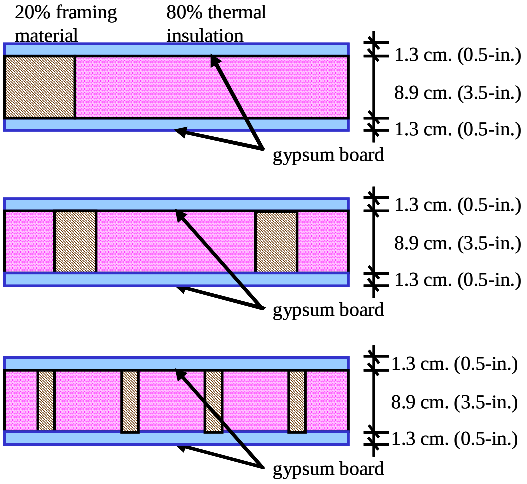
For decades, exterior building envelopes have been represented in whole building energy simulation programs by simple 1-D approximations. For example, in the case of wood-framed walls, clear wall areas use to be simulated using two material paths: in-cavity path and framing path. However, for numerous complex wall technologies which have been introduced to the building marketplace, the simple 1-D *"in-cavity and framing path approach"* (acceptable for wood-framed structures) cannot be applied.

In addition, currently built houses are becoming progressively larger and their architecture is becoming progressively more complex. As a result, the amount of structural components is increasing. The most current study performed for California Energy Commission (Carpenter 2003) demonstrated that *Framing Factor* (fraction of the opaque wall area represented by solid wood used for framing) for residential walls is close to 27%. The relevance of this finding is overwhelming:

- Actual **R-value for 2x4 wall** insulated with R-2.3 (R-13) fiberglass batts (nominal R-value of R-2.6 m^{2}W/K –(R-14.5)) is in the range between **R- 1.5 to 1.6** m^{2}W/K (R-8.5-9.0 hft^{2}F/BTU)**.**
- This is **35 – 40% reduction** of nominal wall R-value
- This is equivalent to **R-value of additional 3.8-cm. (1.5-in.) of EPS**

- This means that houses built in this way would require approximately **10-12% more energy** than it is predicted by currently used energy calculation tools.

A simple thermal modeling exercise, presented in Figure 4, illustrates the differences between heat flow calculated using a simplified parallel-path method (top case) and using a more-complicated (closer to reality) 2-D simulation models. Three theoretical wall sections with 20% of framing were simulated. Three different framing materials were assumed for thermal modeling: wood, 0.116 Wm/K (0.8 BTU-in/hft^{2}F); concrete, 1.40 Wm/K (9.7 BTU-in/hft^{2}F); and steel, 46.20 Wm/K(320 BTU-in/hft^{2}F). Expanded Polystyrene (EPS) foam - 0.035 Wm/K (0.24 BTU-in/hft^{2}F) served as a cavity insulation. Figure 4 shows that differences in R-value estimations depend on the thermal conductivity ratios between structural and insulation materials and the number of the framing material inserts. For the simplified in-series calculation (similar to traditional method of describing a wall in whole-building modeling input files) the errors in R-value calculations may exceed 44% for steel framing and 27% for concrete framing while less than 2% for wood framing. Unfortunately, real life situations are much more complex than the simple example above. In real buildings, the scale of errors can be different since proportions between wall area, amount of structural framing, and number of penetrations through the thermal insulation may be different from those strictly theoretical numbers analyzed in Figure 4.



Difference in R-value calculations are computed using comparison of the configuration case containing a single one framing material insert against cases with two or four framing material inserts.

Framing material	Ratio between thermal cond. Insul./Fram.	R-value differences Base case 1 insert	
		2 inserts	4 inserts
Wood	3	1.4 %	1.8 %
Concrete	40	17.8 %	27.5 %
Steel	1330	28.1 %	44.4 %

Figure 4. Results of comparisons between R-value estimations for three walls of the same framing factors.

Steel framing is considered much more difficult to analyze. Assume that a one-story 8.5 x 16.8-m. (55x28-ft) building has 2 × 4 steel stud walls insulated with fiberglass batts. Steel studs are installed at 40.6 cm (16-in.) o.c. On the exterior, the wall is finished with a 1.2-cm (0.5-in.) layer of plywood and wood siding. Some energy modelers probably will make the following assumptions:

Exterior walls materials:

1. Gypsum board	thickness 1.2 cm (0.5) thermal conductivity 0.16 W/mK (1.1 BTU-in/hft^{2}F).
2. Insulation	thickness 8.9 cm (3.5) thermal conductivity 0.041 W/mK (0.28 BTU-in/hft^{2}F).
3. Steel studs	web depth 8.9 cm (0.5) thermal conductivity 46 W/mK (320 BTU-in/hft^{2}F).
4. Plywood	thickness 1.2 cm (3.5) thermal conductivity 0.115 W/mK (0.8 BTU-in/hft^{2}F)
5. Wood siding	R- 0.17 m^{2}W/K (R-1 hft^{2}F/BTU)

Clear wall R-value calculated using the Modified Zone Method (ASHRAE 2001a) is R-1.16 m^{2}W/K (R-6.6). As depicted in Figure 5, the clear wall represents only 67% of the whole opaque area of the elevation for a considered building. Because wall details generate about 50% of the total heat transfer, the whole-wall R-value is much closer to reality than the clear wall R-value. In our example, the whole-wall R-value is R-0.94 m^{2}W/K (R-5.3) (about 18% less than the clear wall R-value).

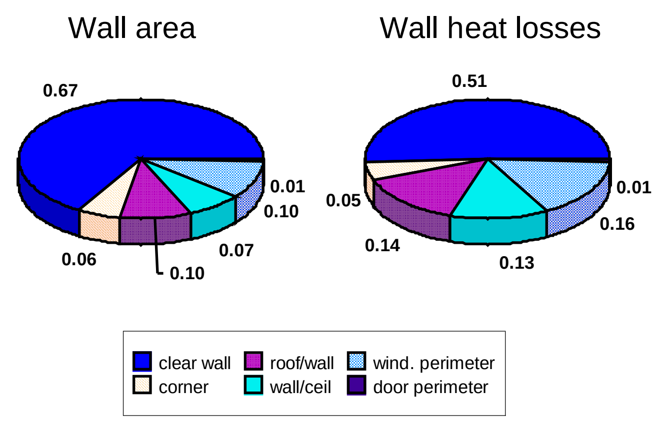


Figure 5. Distributions of the elevation area and wall heat losses for a conventional 8.9-cm (3.5-in.) steel stud wall.

Another simple example of the impact of proper whole wall/ roof /attic R-value calculations on the whole-house energy analysis is described in Table 2 for two identical single-story (144-m^2 or 1540-ft^2) ranchers having different walls. To make energy performance comparisons simpler, the same infiltration rates were assumed for both houses. Energy simulations were performed for the Atlanta climate.

In both houses, the roofs had triangular shapes. Traditionally framed building (8.5 × 16.8 m or 28x55-ft) had a pitched roof with rafters installed at 40.6 cm o.c.(16-in.), and a high point in the ridge of 1.6 m (64-in.). Nominal roof insulation was R-8.8 m^{2}AW/K or -(R-50) (thermal conductivity - 0.0417 W/mAK (0.29), thickness - 36.8 cm. or 14.5-in.). The ceiling was hung to the wood joists (25.4 × 3.8 cm – (10x2) installed at 40.6 cm o.c.(16-in.) and finished with 1.2-cm (0.5-in.) layer of gypsum board with thermal conductivity of 0.16 W/mAK (1.1 BTU-in/hft^{2}F). On 22% of the attic area, the declining roof surface reduced the thickness of the attic insulation. Consequently, the average insulation thickness was not 36.8 cm (14.5-in.), but 30 cm (11.8-in.). Moreover, wood joists penetrate the insulation at 40.6 cm o.c (16-in.). Based on all these facts, effective attic R-value was reduced by about 30%. In the case of the SIPs' roof, similar R-value reduction was only about 7%.

Table 2. A simple example of the whole house energy analysis for a single-story rancher for 2x4 wood framed walls and Structural Insulated Panel (SIP) exterior shell.

	Conventional 2x4 wood framing structure for walls, R-8.8 (R-50) attic insulation	SIPS structure 8.9 cm (3.5-in.) foam core for walls, 30.5 (12-in.) cm foam core for roof
Nominal Clear Wall R-value	**2.20 (12.5)**	**2.34 (13.3)**
Nominal attic R-value	**8.80 (50.0)**	**8.10 (46.0)**
Difference in HVAC energy consumption for nominal R-values	**about 1%**	
Effective Whole Wall R-value	**1.76 (10.0)**	**2.22 (12.6)**
Effective attic R-value	**6.11 (34.7)**	**7.57 (43.0)**
Difference in HVAC energy consumption for effective R-values	**about 6%**	

It is important to notice that differences in energy consumption presented in Table 2 would probably not be accounted for if traditional energy simulation techniques were used. This exercise also shows how difficult it is for novel building envelope technologies to document (in an analytical way) their superior energy performance.

Potential Errors in Dynamic Thermal Analysis Generated by Inaccuracies in 1-D Simplifications of Complex Building Envelopes

Since most of the whole-building energy simulation programs are using one-dimensional thermal calculation procedures; one-dimensional simplified descriptions of envelope components are used by the majority of energy modelers. For simple lightweigh wood-framed envelopes (conventional 2x4 wood framing), these simplifications cause insignificant errors in energy calculations. For more complex building envelopes incorporating highly conducting members and massive components, these errors can be more significant. Unfortunately, proper analysis of complex thermal envelope systems is time-consuming and requires application of advanced 3-D transient heat transfer analytical tools. Today, mostly because of economical reasons, this kind of analysis is performed using only inaccurate 1-D approximations.

To illustrate the scale of this problem, an insulated concrete form (ICF) wall was analyzed using several heat transfer analytical procedures. The ICF wall is made of two EPS shells, perforated metal connectors, and a solid concrete core - as shown in Figure 6. Inside this wall, there is a 3-D network of vertical and horizontal channels that are filled with concrete and steel reinforcement during construction of the wall.

For accurate representation of the complex 3-D internal structure of the ICF wall, the Equivalent Wall concept was utilized. Equivalent theory is based on an advanced heat transfer analytical procedure that was developed by Kossecka and Kosny in 1996. Equivalent wall has a simple 1-D multilayer structure. Its dynamic thermal behavior is identical to that of the actual wall (Kossecka and Kosny 1997). ASHRAE project RP-1145 demonstrated that physical properties of equivalent wall could be used in whole-building energy simulation programs (ASHRAE 2001b).

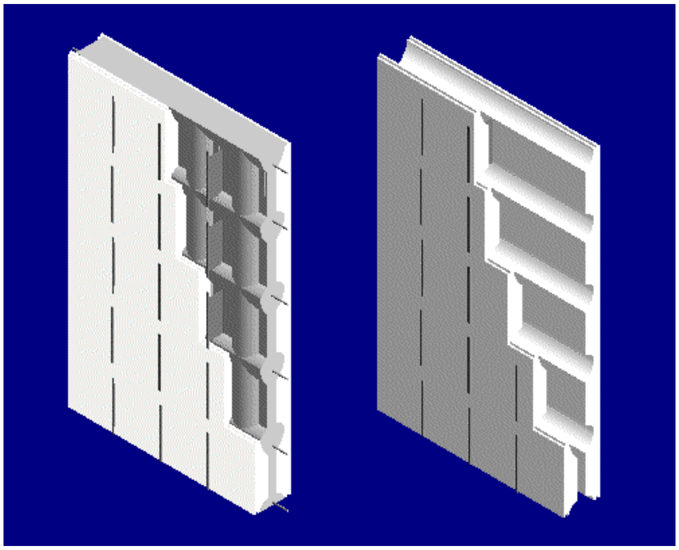


Figure 6. Insulated concrete form wall made of EPS shells.

At first, a finite difference computer model was developed for the ICF wall. Figure 7 depicts a complex temperature field on the interior surface of the ICF wall. A series of response factors, heat capacity, and R-value were computed using this model. They enabled generation of a series of 1-D equivalent wall.

Later a simple 1-D model was developed for the ICF wall. Because computer programs such as DOE-2, BLAST, or Energy Plus can perform only 1-D thermal analysis, it is most likely that whole-building modelers would make similar 1-D simplification.

The R-value calculated for the ICF wall using a simple 1-D model was 38% higher than the R-value calculated using detailed 3-D simulation.

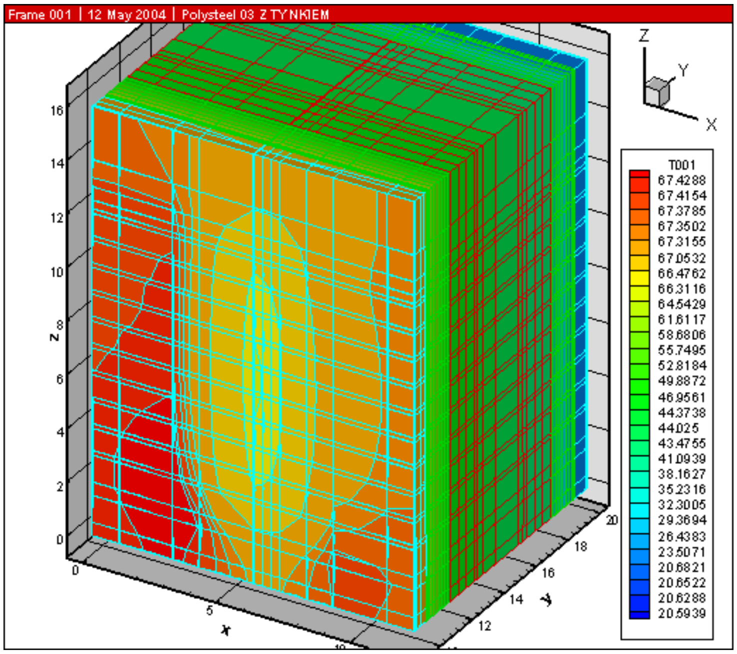


Figure 7. 3-D temperature field for fragment of the Insulated Concrete Form (ICF) wall made of EPS foam shells.

Simple DOE-2.1E modeling was performed for six US climatic conditions on a previously used ranch house to illustrate how inaccuracy in 1-D descriptions can affect simulation of cooling and heating energies. Equivalent wall generated for EPS form was used as a base for this comparison.

It was found that DOE-2.1E runs utilizing 1-D approximations in input files can generate inaccuracies in energy estimation exceeding 10% (Kosny and Kossecka 2000). Similar miscalculations can be made for other building envelope components like roofs, floors, or foundations.

NEW GENERATION OF ENEERGY CALCULATION TOOLS REQUIRE APPLICATION OF MORE ACCURATE IMPUT DATA ON BUILDING ENVELOPES

Due to the very fast progress in development of building envelope technologies, it is expected that in the near future, designers of energy-efficient buildings will have to treat a building as a collection of subsystems generating trivial energy effects if they are analyzed separately. However, if these small components are configured to optimized form and sequence, they may generate relatively significant energy savings. In that light, parametric analysis can be one of the key advantages of using future whole-building energy simulation tools.

Following a rapid technological development of building envelope materials and systems, energy simulation tools have come through a tremendous transformation as well. Most improvement projects were focused on refining energy calculation methods, improving computational engines, and the development of user-friendly interfaces. At the same time almost no attention was paid to the quality of material input data for building envelopes. Practically, a structure of the building envelope part of input file for Energy Plus is no different from input files used by Tamami Kusuda in 1960-ties for his underground shelter simulations (Kusuda 2001). It is very common that energy calculation tools supporting retrofit projects are using in-cavity R-values. In situations where houses have very "busy" elevations and it is difficult to identify clear wall area (see Figure 8), there is not a single energy simulation tool which would require usage of whole wall R-values incorporating all architectural details and intersections.

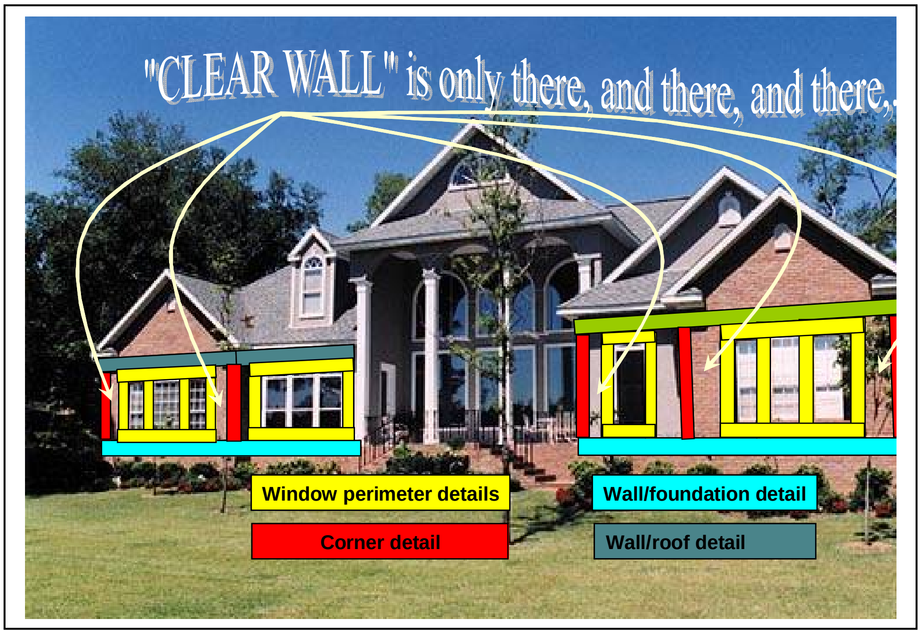


Figure 8. Clear wall area in houses is difficult to find today.

Therefore, a concept of *Interactive Envelope Materials Database for Whole-Building Energy Simulation Programs* was developed at ORNL to reinforce an accurate, fast, and simple parametric analysis of building energy consumption.

In 1994, ORNL introduced a whole-wall R-value procedure (Kosny and Desjarlais 1994). It was based on hot-box test results and 3-D heat conduction simulations. Whole-wall R-value combines thermal performance of the clear wall area with typical envelope interface details, including wall/wall (corners), wall /roof, wall/floor, wall/door, and wall/window connections. Results from these detailed simulations are combined into a single whole-wall R-value and compared with simplified "center-of-cavity" and "clear-wall" R-values. Since 1995, The Whole Wall Thermal Performance Calculator (Christian and Kosny 1996) has been available on the Internet. In 1996, ORNL developed the equivalent wall concept (Kossecka and Kosny 1996), which transforms complex 3-D thermal characteristics of building envelope components into simple one-dimensional equivalents. A potential application of the equivalent wall theory in whole-building energy simulations was analyzed by ASHRAE Project TRP-1145 (ASHRAE 2001b). Since 1996, ORNL has performed over twenty dynamic hot-box tests. Based on results collected during these tests, dynamic thermal characteristics of over a dozen massive wall assemblies were derived (Kosny et.al. 1998).

Three testing procedures were introduced by ORNL to collect experimental data on component air leakage (Kosny 2003). These procedures enable separate air leakage analysis for building envelope details, such as window and door perimeter, wall/ foundation intersection, wall/ceiling intersection, and wall/roof connection. At the beginning, a series of tests were performed on conventional wood-frame technology. Intersections incorporating a concrete basement wall, floor, above-grade wall, and wall/window interface were investigated. Several types of air-sealing methods were analyzed during these experiments.

Interactive Envelope Materials Database for Whole-Building Energy Simulation Programs utilizes all the theoretical concepts and experimental procedures described above. It will consist of four computational modules:

1. Building geometry calculator
2. Whole-wall, roof, ceiling thermal calculator
3. Air leakage calculator
4. Input file generator

The building geometry calculator remembers all geometry data for the building (e.g., building dimensions, number of corners, windows and doors, shape of roof, size and distribution of structural members, etc.). It enables calculations of elevation area distribution for major building envelope components.

The whole-wall, roof, ceiling, thermal calculator consists of five independent sections:

1. Hot-box test results database
2. Clear-wall, roof, and floor R-value database and detail R-value database
3. Whole-wall, roof, floor R-value calculator
4. Experimental dynamic thermal characteristics database
5. Dynamic characteristics calculator

All historic hot-box results for hundreds of wall, roof, and floor material configurations will be available in the ORNL hot box test result database. **At present it is the world's largest material database for wall technologies and the only material database which contains walls' transient characteristics.** The R-value calculator will be based on the Whole Wall Thermal Performance Calculator (Christian and Kosny 1996). Its calculation capability will extend to roof and floor structures. Using thousands of already existing results of detailed 3-D heat transfer simulations for clear walls, wall details, and roof and floor details, it will process them into whole-wall, whole-roof, or whole-floor R-values.

Dynamic hot-box results and dynamic thermal characteristics for complex building envelope systems will be accessible as well. The dynamic thermal characteristic calculator will be based on the Equivalent Wall Program (Kossecka and Kosny 1997). It will generate a series of response factors, structure factors, and equivalent wall for a given materials configuration. It will also reconfigure dynamic thermal characteristics to incorporate the effects of building envelope details using computational procedures developed by the ASHRAE research project TRP 1145 (ASHRAE 2001b).

The air leakage calculator will utilize experimental results on component air leakage and will process detailed information linking available component air leakage experimental data with the type of building envelope, complexity of architectural components, type and number of windows and doors, etc. This calculator will simplify the process of the whole-building air leakage analysis and minimize the possibility of errors and miscalculations.

At the end of the process, the input file generator will combine all data developed by all calculation modules and develop an envelope-related part of the input file for a specific whole-building energy simulation program.

GENERAL CONCLUSION

Eventual implementation of the full range of physical characteristics of building envelope components into whole-building energy simulation programs requires development of an advanced interactive materials database. Such a database would enable a modeler unfamiliar with advanced heat transfer analysis to develop simple and accurate descriptions of envelope systems in a form readable by most simulation programs. To reduce the cost of the designing process and minimize the potential for inaccuracies, developing architectural component descriptions in whole-building energy simulation programs has to be as simple as selecting the specific material configuration, setting dimensions, and orientation.

Analysis of building envelope assemblies containing thermal bridges often requires application of 3-D simulation tools. It is very common that application of simplified (not accurate) 1-D description created for a single building envelope detail may generate relatively insignificant errors in whole-house energy consumption predictions. For more complex building envelopes these errors can simply exceed 10% of the whole house HVAC energy consumption.

Sophisticated whole-building energy simulation programs have been developed, but they cannot be fully utilized without accurate input files. The lack of an appropriate materials' database for building envelope technologies (especially for new non-wood technologies) is today one of the major barriers in a successful deployment of new envelope materials and systems. That is why a development of an interactive materials database is a critical step in introducing a new generation of whole-building energy simulation programs.

To serve this need, ORNL has introduced the *Interactive Internet-Based Envelope Material Database for Whole-Building Energy Simulation Programs,* which links experimental data on thermal characteristics of building envelopes with advanced analytical methods available for thermal and energy analysis.

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