Engineering Ethics Cases with Numerical Problems

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Civil Engineering Case 6

H.V.A.C. Design Ethics Case

Author:

Wayne Helmer

(Helmer@engr.siu.edu)

Robert Walker

Suggested Courses:

Heat Transfer

Level:

Junior & Senior

I. Narrative

You are a new engineer at a well-known solar/HVAC energy consulting company in the California area. Your responsibility is to help your clients design their houses. Many people come in with a general idea of what they want in a house. You are required to determine what materials should be put in the walls, what type and size of windows to use, etc. Since your background is in heating ventilating and air-conditioning, you are qualified to do this.

Another one of your responsibilities is to assure that the house satisfies the California Energy Standards. For every one of 16 zone locations in California there is a maximum energy budget standard. Mild climates such as coastal areas near Los Angeles have heating energy budgets of 1.1 kbtu/ft^2 of floor area, while cooler climates in the mountains have budgets of 18.4 kbtu/ft^2 of floor area. For example, Sacramento, California (zone 12) has an annual energy budget of 28.6 kbtu of site energy used per square feet of floor space (14.2-heating, 14.4-cooling). A house may not be legally built in the state of California without this certification. The methods usually used to certify houses are computer programs like MICROPAS by Enercomp of Davis, California. You are very familiar with this program and have used it extensively in your house design projects.

II. Engineering Background

The heating and cooling annual energy consumption depends mainly on two factors: weather conditions (mainly degree days, DD), and building related factors, such as insulation in the walls, outside air leakage rate (infiltration), type of windows, etc. The effective degree days for a given location in California can be obtained from ASHRAE handbooks. The thermal resistance of the walls, windows, slab, ceiling, etc. are calculated from input data on the house. Then the annual heating energy can be manually estimated from:

Annual Heating Energy = $[\Sigma\ U_iA_i + mc)_{inf}\ ]$xDD

Where U = individual overall heat transfer coefficient of the wall, ceiling, etc.

$U = 1/\ \Sigma R$

$\Sigma\ R$ = combined thermal resistance of the individual components in the wall,

ceiling, etc.

A_i = corresponding surface area associated with U_i

m = mass flow rate of infiltration (sometimes given in air changes/hour,

ACH)

c = specific heat of air

DD degree Days

Annual cooling energy can be calculated in a similar manner (though slightly more complicated). The important thing to remember here is that if either U or A is decreased for a given building component, the annual energy consumption is decreased for a given sized house in a specific location. Highly energy-efficient houses have U values in the order of 0.03 to 0.05 Btu/hr-ft^2-F (R_{factor} = 20 to 33) for the opaque walls. Normal double-glazed windows have a U ~ 0.55 Btu/hr-ft^2-F (R_{factor} ~ 2). New high-performance windows can have values much lower than this (R_{factor} = 3 to 6), at a much higher price!

III. Engineering Problem

One day a contractor friend of yours asks you to oversee the design of a set of residential homes in a new subdivision in Sacramento. His houses are all similar with respect to their construction, geometry and, thus, energy consumption. Data on one of their solar homes is given below:

Floor area = 1500 sq. ft. (30 ft x 50 ft)

Opaque wall area = 1000 sq. ft.

Window area = 280 sq. ft.

Infiltration = 0.25 air changes per hour

Windows: standard double pane

Ceiling insulation: 12 inch glass fiber

Wall construction is shown in Figure 1.

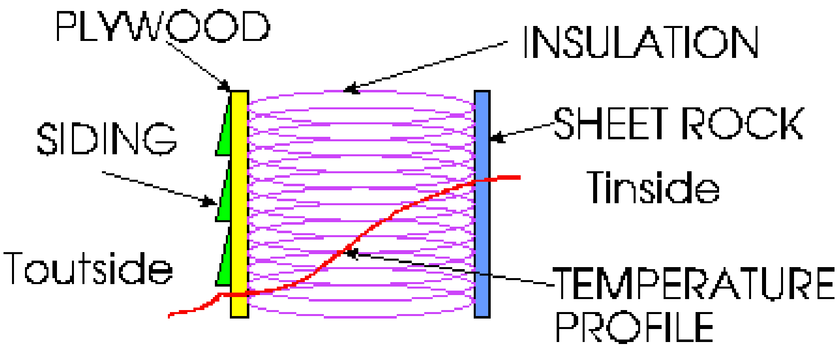

Figure 1. Typical House Wall Construction.

Table 1. Wall Material Properties

Material	Thickness (in)	R_{factor} (x/k)
Wood	3/8	.47
Plywood	1/2	.62
Glass Fiber	3 1/2	11
Glass Fiber	12	38
Sheet Rock	3/8	.32

You are asked to verify that the house satisfies the California Energy Standard heating budget by a computer code, using any one of a number of manual calculation methods.

IV. Ethical Problem

Calculating the annual energy consumption of the standard house you find that the design is not in compliance. The calculated heating energy consumption is 16.8 Btu/sq. ft., while the maximum allowable heating energy consumption by the code is 14.2 kBtu/ sq. ft.

You call your contractor friend and inform him of the situation. He questions your calculations and says that he is certain that his houses should be in compliance. You tell him that you have checked your calculations manually and by computer. You tell him that one way the standard can be meet is by installing special high-performance windows or by using lower window areas. You mention that these high-performance windows with triple glazing and argon gas can reduce his window UA to 50 Btu/F.

He does not want to reduce the window area, since this is a selling point of his house design. He also complains that he cannot afford the high-performance windows. He casually comments that he really will not have to change the window type at all, since he will put in the cheaper windows in the houses after the design is certified. He tells you to do the design certification based on the high-performance windows and send him the results.

V. Engineering Solutions

The UA values for the building envelope are given as follows:

<u>Walls:</u>

The combined R_{factor} is given by:

$R_{wall} = R_o + R_{side} + R_{ply} + R_{in} + R_{sr} + R_i$

$= 0.16 + 0.24 + 0.62 + 11 + 0.32 + 0.68 = 13.0$

$U_{wall} = 1/R_{wall} = 1/13 = 0.077$ (Btu/hr-ft^2-F)

Then

$UA_{wall} = 0.077$(Btu/hr-ft^2-F) (1000)ft^2 = 77 Btu/hr-F

<u>Ceiling:</u>

$UA_{ceiling} = A_{ceiling} / R_{ceiling} = 1500/38 = 39.5$ Btu/hr-F

<u>Slab:</u>

$U'P_{slab} = 0.6$ (Btu/hr-ft-F) 160 ft = 96 Btu/hr-F

Where P is the perimeter of the slab

<u>Windows:</u>

$UA_{window} = 0.55$(Btu/hr-ft^2-F) 280 ft^2 = 154 Btu/hr-F

<u>Infiltration:</u>

mc = ACH(volume)Density(c)

= 0.25(1500ft^2)8ft(0.075lb/ft^3)0.24Btu/lb-F = 54 Btu/hr-F

(standard residential construction has a wall height of 8 feet)

Then

$\Sigma UA + mc = 77 + 39.5 + 96 + 154 + 54 = 421$ Btu/hr-F

The heating degree days at Sacramento, California are 2502 F-Days

Then

$Q_{annual} = [\Sigma UA + mc]DD = 421(Btu/hr\text{-}F)(2502F\text{-}Day)(24hr/Day)$

= 25.2 million Btu per heating season.

Then

$Q_{annual}/ft^2 = 25.2x\ 10^6/1500 = 16.8\ kBtu/ft^2$

which is above that allowable energy consumption of 14.2 $kBtu/ft^2$

Changing the windows from double glazed to high performance windows with more panes and argon gas can yield an R_{factor} of about 6. Then:

$UA_{window} = 0.166(Btu/hr\text{-}ft^2\text{-}F)\ 280\ ft^2 = 47\ Btu/hr\text{-}F$

This will yield

$Q_{annual}/ft^2 = 314(2502)24/1500 = 12.6\ kBtu/ft^2$

which is below the maximum allowable annual heating energy consumption for this area of 14.2 $kbtu/ft^2$.

VI. Ethical Questions and Solutions

1. What factual issues relevant to the case may not yet be answered? You may make assumptions as to how these questions should be answered.

Is the building owner going to advertise his homes as having the high performance windows?

Would it be legal to put in the cheaper windows after a design calling for the more expensive windows has been certified?

Is the added expense of high-performance windows actually excessive?

Would adding more insulation in the walls provide an adequate solution?

2. What are the relevant sections of professional codes, such as the code of the National Society of Professional Engineers (N.S.P.E.)?

N.S.P.E. Code:

1.b. "Engineers shall approve only those engineering documents which are safe for public health, property and welfare in conformity with accepted standards." ["Accepted standards" here could refer to the California Energy Standards. Note that the engineer has approved (or will approve) the documents (building blueprints) that conform to the California Energy Standards. The engineer can only verify the design, not the actual construction. Building inspectors would be required to do that.]

1.c. "Engineers shall not reveal facts, data or information obtained in a professional capacity without the prior consent of the client or employer except as authorized or required by law or this Code." [At first this may appear to require that the engineers say nothing. But look at the next section.]

1.d. "Engineers shall not permit the use of their name or firm name nor associate in business ventures with any person or firm which they have reason to believe is engaging in fraudulent or dishonest business or professional practices."

3. Should you inform your boss of these problems?

You probably should inform your boss so that he/she knows what is happening, and can be an ally for you.

4. What conflicting moral obligations are evident in the case?

You have an obligation to abide by the professional codes, which require you to protect public health property and welfare. This includes the welfare of your client. You also have an obligation to abide by the law. The course of action the contractor is considering is probably illegal. You also have an obligation to your company to provide high-quality engineering work and to do so in a way that does not unnecessarily antagonize clients. Finally, you have an obligation to help your contractor friend save money, but also avoid problems with the law.

5. Design alternate solutions to present to your engineering manager. How well do alternatives meet the conflicting moral obligations?

One option is to include the high-performance windows in your design and attempt to persuade your friend not to install the cheaper windows. You could argue that this is almost certainly illegal and would probably be reported by home buyers. If successful, this option would fulfill all of your obligations. If your friend rejects your advice, you could include the high-performance windows in your design, but alert authorities to the possible violation of the law. This might terminate your friendship with the contractor. Another option would be to attempt to terminate your contract with the contractor. This would not fulfill your obligations to your employer or to your friend as much as you would like, but it would at least protect your professional reputation, as well as that of your employer.

Another option would be to ignore the contractor's comments about possible illegal action and include the high-performance windows in his design. Then he can forget the whole matter, reasoning that what he does with the plans is his business. This would fail to protect the public, or yours or your firm's professional reputation.

One of the more attractive solutions is to suggest design changes that would enable him to meet the UA requirements more inexpensively. For example, you could call for more insulation in the walls to achieve a lower overall building UA.