Don’t do stupid things. Life is tough enough.

Energy enters the US economy at a slower rate than what we consume. More energy goes into heating and cooling buildings than any other single use (40%) followed by the transportation sector (30%). We cool our buildings with electricity and heat our buildings with natural gas. We are going to triple the cost of air conditioning. We are going to double the cost of heating. The transportation sector will compete with the building sector for the same energy. The transportation sector will win.

A rational person would suggest making buildings smaller with smaller windows and smaller appliances. I remind you that this is America. We like to build big. We are not going to have smaller buildings, but we are going to have ultraefficient buildings. We will double and triple the amount of thermal resistance in the typical building enclosure. We will insulate. And insulate big time.

Energy security = changing design practices

This is good and bad. Good for energy security, bad for building durability. Insulation reduces energy flow. There is no such thing as a free thermodynamic lunch. Reducing the energy exchange across building enclosures reduces drying potentials. As we change our building technology to account for the new energy cost realities, we are in for a world of hurt in terms of corrosion, decay, mold and other moisture-induced deterioration. It gets worse, or better (depending on who profits from the problems), when you consider that more than 80% of the buildings that will be around in 2035 already exist and will need to be insulated. Who knows how to do that? I can tell you who does not: the models on TV doing renovation shows.

Building science, building diagnostics, building technology and building rehabilitation are going to boom because things are going to bust. Can it get even better? Yes. Jobs can’t be outsourced offshore. This has to be fixed by Americans here in America. The future is in construction. Actually, the future is in fixing construction.

One of the dominant building materials we use is cellulose fiber. However, it does not make sense for us to get this cellulose fiber by cutting down 1000-year-old trees. We should grow and harvest fibers. We are beginning to do so. The days of 2 x 10s and dimensional lumber are over. The age of engineered wood – oriented strand board (OSB), hardboard, particleboard, fiberboard and laminated paper composites – has arrived. All these products are cellulose fiber based. All will be in competition for the same cellulose fibers that the transportation sector covets.
The fibers the building sector gets will be second rate and expensive. And, engineered wood products are not as durable as actual wood. We will be adding stuff to the fibers to make that product work. I predict this will be stuff that won't stay for the sake of durability. Damage functions and the Arrhenius' equation, here we come.

The Perfect Wall is an environmental separator – it has to keep the outside out and the inside in. To do this, the wall assembly has to control rain, air, vapor and heat. In the old days, we had one material to do this: rocks. We would pile a bunch of rocks up and have the rocks do it all. But over time rocks lost their appeal. They were heavy and fell down a lot. Heavy means expensive. And falling down is annoying. So construction evolved. Today walls need four principal control layers – especially if we don't build out of rocks. They are presented in order of importance:

- a rain control layer
- an air control layer
- a vapor control layer
- a thermal control layer

A point to this importance: If you can't keep the rain out, don't waste your time on the air. If you can't keep the air out, don't waste your time on the vapor.

The best place for the control layers is to locate them on the outside of the structure to protect the structure (Figure 2). When we built out of rocks, the rocks didn't need much protection.

When we build out of steel and wood, we need to protect the steel and wood. And since most of the bad stuff comes from outside, the best place to control the bad stuff is on the outside of the structure before it gets into the structure. Also, after generations of building out of rocks, folks somehow got the idea that they wanted to be comfortable – and they figured out that rocks were not the best insulation. Rocks are not that bad compared to windows. Memo to architects: You can't build an energy efficient green building out of glass, but you can get design awards. We all know which is more important.

Back to rocks: They are heavy. You need a lot of them to make the wall have any decent thermal resistance so we invented thermal insulation.

But where to put the insulation? If we put the insulation on the inside of the structure, the insulation does not protect the structure from heat and cold.

Remember, we really do want to protect that darn structure – especially for the sake of making the structural engineer's life happier. Expansion, contraction, corrosion, decay, ultraviolet radiation and almost all bad things are functions of temperature; so all the control layers go on the outside. Keep the structure from going through temperature extremes. Protect it from water in its various forms and ultraviolet radiation and life is good.

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1Dr. Svante Arrhenius. Dead, European, Nobel Prize Winner, no longer fashionable to study. Arrhenius showed that every 10^° Kelvin rise in temperature "doubles the badness" for materials. Same for relative humidity and ultra-violet radiation. The Arrhenius Equation addresses the effect of the temperature, relative humidity and UV damage functions on building materials. He also "invented" the "Greenhouse Effect."
The Perfect Wall

What about this air control thing? Well, air can carry a lot of water and water is bad for the structure. So we have to keep air out of the structure as well because of the air-water thing – or if we let it get into the structure, we have to make sure it does not get cold enough to drop its water. Now, just one other thing tends to be important if you intend on living or working or keeping things safe in the building. We might want to control the interior environment.

We especially ought to be concerned about what is in the interior air because when we are in the interior we tend to breathe it. Well, it turns out that we can’t control air until we enclose air. So we need an honest-to-goodness airtight enclosure to provide conditioning such as filtration and air change and temperature and humidity control. And once again, the best place to control this air thing is on the outside of the structure – but under the insulation layer so the air does not change temperature. **Presto: the perfect wall!** A water control layer, air control layer and vapor control layer directly on the structure and a thermal control layer over the top of the other control layers. (See Figure 2.)

This was figured out long before I was born – I think the Canadians figured it out first², but the Norwegians have some claims to this, plus the Russians. I am going to go with the Canadians on this one because I am biased and proud of it. For a more detailed discussion of the physics of all of this go to the old masters: Hutcheon and Handegord³ and the new kids on the block, Burnett and Straube⁴.

**They’re all connected: Roof, Slab, Walls**

In a beautiful bit of elegance and symmetry, if you lie the perfect wall down you get the perfect roof (Figure 3). And then when you flip it the other way you get the perfect slab (Figure 4). The physics of walls, roofs and slabs are pretty much the same – no surprise (Figure 5). This insight was shone into a whole generation of practitioners by Max Baker⁵ when I was first getting started.

Most problems in building enclosures occur where roofs meet walls. The classic roof-wall intersection is presented in Figure 6 (with both credit and apology to Max Baker). Notice that the control layer for rain on the roof is connected to the control layer for rain on the wall, the control layer for air on the roof is connected to the control layer for air on the wall ... and so it goes. Beautiful. And when it is not so, ugly.

Time to put some meat on the bones of Figure 2. How should this perfect “conceptual” wall actually be built? The best of the best of the best can be found in Figure 1. This is a very special wall. I refer to it as the 500-year wall for these reasons:

• it represents 500 years of evolution
• it will last 500 years

It is the type of wall that typically had been saved for special buildings. Buildings that are passed down from one generation to the next. Museums, art galleries, courthouses, libraries. I call this wall the “institutional wall.” It is sweet in that it can be constructed in any climate zone. The only thing that may be changed is the level of thermal insulation. My advice here is very simple: whatever you think the right amount of thermal insulation should be, double it. If you love your kids, don’t argue with me.

**References**

²Hutcheon, NB, CBD – “50 Principles Applied to a Masonry Wall,” Canadian Building Digest, National Research Council Canada, Ottawa, Ontario, Canada, February 1964
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