Heat-flow and HAM models

They are not needed for estimating whole-building loads. In design of HVAC systems, any errors introduced by simpler methods tend to offset each other. As long as systems are not undersized, remaining errors are insignificant.

Optimal building envelope details are another matter. Why increase insulation when most of the heat is lost through thermal bridges? Because it's harder to quantify thermal bridges! But, energy use aside, temperatures of surfaces and components within an assembly affect both user comfort (if not health) and building durability.

Heat-flow Models

As long as the materials are non-hygroscopic and homogeneous, and no condensation occurs, it should be practical for a heat-flow model to accurately predict temperatures, even in 3D fields with transient boundary conditions. Voids with radiation or with convective fluids, and transparency to radiation can be also represented. However, a complete and accurate description of the materials, configuration, and boundary conditions may not be possible. Even if it is, using the wrong grid spacing or time-step in a finite element model will produce spurious results. Still, accurate absolute temperature and heat-flow predictions are within reach. Thermal models of glass and aluminum systems, for instance, should be quite accurate, as long as there is no condensation or air leakage.

With hygroscopic materials, heat-flow models can still give good comparative results. When interpreting results, keep in mind what might be happening because of latent heat, or heat carried by flow of water or air through materials. Comparisons are probably still valid, if the same hygroscopic materials experience similar temperature regimes in different configurations, or if different boundary conditions are used while configuration is held constant.

HAM Models

Heat-Air-Moisture models have to simplify. A representation of all of the effects that occur in reality would take too long to compute. More to the point, the required properties of materials cannot be measured by practical means and cannot be teased apart from the available measurements. Proposed European standards for HAM models suggest the following assumptions and simplifications:

- constant air density and atmospheric pressure
- no change of dimension due to temperature or moisture content
- thick elements are homogeneous, anisotropic, and porous, with connected pores
- thin materials (e.g. vapour barriers), air spaces, and imperfect contact between materials are represented by resistance factors for heat, vapour, and liquid flow (flow = potential/resistance) normal to a planar representation of the material.
- boundaries are represented by a layer of air that has a constant resistance to heat flow that accounts for wind speed and roughness. (Wind velocities and relative humidity in weather data may be used to determine rate of rain incident on the surface, but not changes in thermal resistance of the boundary layer). Heat loss and gain by radiation occurs at the exterior surface, passing through this fictitious resistive layer, as does incident rain.
- all flows are diffuse.
- air spaces are enclosed and unvented. convection and radiation are represented by proxy values of conductive resistance
- no ice occurs, hence no heat of fusion
- only a single potential for moisture flow (in theory two are required, either humidity by volume and temperature, or humidity by volume and moisture content)
- artificial separation of potential for moisture movement into two terms --- one for vapour, the other for liquid

- artificial separation and different transport equations in the hygroscopic range and in the capillary range (where in fact the two ranges usually intergrade without a sharp transition, and all processes operate in both ranges)
- moisture content at external surfaces is limited to capillary saturation
- no gravity
- no condensation on surfaces

In addition to the foregoing explicit assumptions, there are some unstated assumptions

- no surfactants (material properties are determined with pure water, and would be different if surface tension was different)
- no movement of solutes driven by concentration gradients, and no deposition of solutes in pores when water evaporates, or when temperature changes solubility

Limitations

In most walls, flows of heat and moisture carried by air leakage in channels and cavities is significant, and may well dwarf flows predicted by HAM Models.

Gravity moves significant amounts of exterior moisture into many walls.

Snow may reduce heat flow by providing insulation, or increase it if temperature at the interface is high enough to cause melting.

In closed cell materials where there is a thermal gradient, moisture can diffuse through cell walls, and be adsorbed or condense inside the cells. The standard HAM model cannot predict the moisture that collects in XPS or PU foam in thermal gradients. Pressure-plate measurements used to characterize materials for HAM input don't see closed pores.

Apart from heat of fusion (which is not included at all), is latent heat adequately accounted for? Adsorbed moisture has potential energy intermediate between that of water and vapour, depending on how much is adsorbed, so the heat associated with phase change is different in porous materials than it is in bulk.

Canned HAM

Many HAM modelling packages also contain modules that transform interior conditions, weather, orientation, location, and exposure information into the input the core model requires --- temperature, humidity, pressure, boundary layer resistances, rate of application of rainwater, and total radiation flux normal to each boundary. Some models require the user to do this pre-processing. Others do it automatically, from user responses to questions about location, orientation, and exposure. Best of all would be to give the user a choice. Then a user could choose between the rudimentary models provided with the HAM model, and more sophisticated models, such as CFD and rain dynamics models, to determine the incidence of rain and wind pressure from weather files and building shape, or shading models, to determine how to adjust incident radiation for times when the exterior surface is shaded from direct sun. Some packaged HAM offers the user very little control.

Conclusion

It's not difficult to think of applications for heat-flow models. But, where moisture movement and phase change are involved, they may be little help. With present HAM models, it's harder to be sure what design questions can be illuminated with confidence that the result is meaningful. HAM models with more flexibility, and fewer limitations, would be a help.

Suppose we had a HAM model that could accurately predict temperature, moisture content, and heat flow as functions of time. What then? To predict durability, we also need to know how much heat and moisture is too much --- another topic altogether.