EXECUTIVE SUMMARY

Recent research [Enermodal 1996, Kosny and Desjarlais 1994, Christian and Kosny 1995, Tuluca et al. 1997] has shown that thermal bridging through framing and at corners and junctions can significantly reduce the thermal resistance of wall and roof assemblies. Many transient calculation programs ignore this effect. Even for those that do account for the reduced thermal resistance, the transient or dynamic behavior of the thermal bridging is almost never taken into account in transient building energy simulation programs. This report presents the development of an equivalent wall model, which can be used to model lateral heat flows and thermal bridging in composite wall and roof assemblies in transient building simulation programs.

An equivalent wall model involves creating a fictitious one-dimensional, multi-layer wall lacking thermal bridges and with properties selected (total resistance and thermal capacitance) so that its dynamic response to the transient conditions is the same as the complex assembly of equivalent thickness. The relationship between thermal structure factors (which define the distribution of thermal resistance and thermal mass through the thickness of the wall) and response factors plays a pivotal role in the development of the equivalent wall model.

Twenty complex wall assemblies were analyzed in this study: 15 wood and steel-stud systems and 5 insulated concrete assemblies (insulated concrete forms (ICF wall), sandwich walls with metal and plastic ties and two-core block masonry walls, with or without insulation inserts). Dynamic three-dimensional finite-difference computer models were developed for each considered wall assembly. The results from the three-dimensional models (response factors, together with resistances and capacities) were used as ‘inputs’ to generate the equivalent wall models.

The equivalent wall model gives, in general, very good results in reproducing dynamic thermal properties of complex wall assemblies with thermal bridges. Test simulations, performed for continuously varying outdoor temperatures, show very good compatibility of the heat flux calculated using 3-D response factors, 3-D z-transfer function coefficients and z-transfer function coefficients for the equivalent wall.

This report presents an easy to implement procedure for incorporating the equivalent wall approach to account for three-dimensional heat transfer effects in whole building energy simulation programs. In DOE-2.1, it simply involves substituting the original wall assembly with the equivalent wall homogenous materials and their prescribed thermo-physical properties.