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A Simulation Model to Determine Energy Savings in an Air Conditioning Office Building

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Abstract

Energy saving and energy efficient equipment are attracting a lot of attention due to the escalating energy costs world wide. Selection of Heating, Ventilation and Air-Conditioning (HVAC) system for buildings is considered to play a vital role in energy consumption. However, proper selection of such a system depends primarily on an accurate cooling load calculation method. ASHRAE has developed different methods to estimate the accuracy of cooling load calculations. In this paper a method based on the finite difference technique is implemented to estimate the cooling load in an office building. The office building is cooled by a ceiling radiant cooling panel (CRCP) coupled with fan coil unit (FCU) using 100% fresh air. The simulation model of the office building showed that significant energy reduction could be obtained when using a ceiling radiant cooling panel.

Keywords: Air conditioning, Ceiling radiant cooling panel, Chilled water, Ventilation system, fan coil unit

1. Application of Explicit Method

To apply an explicit method in practice, consider the nodal subvolume of Figure 1. denotes to the rate of heat addition (external or internal) to the node. This element can be considered as an arbitrary subvolume of outer part of a building wall. Assume one dimensional flow and node i represents the subvolume having thermal capacity C_i, and connected by resistance R_{ij1} and R_{ij2} which stand for convective and conductive resistances respectively. If the node i is exposed to the solar heat input q_i and has a temperature T_t at time t, then for a time interval Δt the quantity of heat Q entering the node i is expressed as [1]:

$$Q = q_i \Delta t + \left(\frac{T_{j1}^t - T_i^t}{R_{ij1}} + \frac{T_{j2}^t - T_i^t}{R_{ij2}} \right) \Delta t \qquad (1)$$

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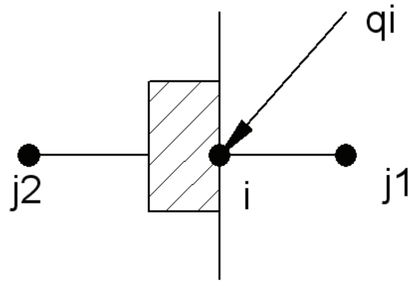

Figure 1. The rate of heat addition (external or internal) to the node

From first law of thermodynamics, this heat must give a rise in temperature of the node such as:

$$Q = C_i \left(T_i^{t+\Delta} - T_i^t\right) \tag{2}$$

As Combining equations 1, 2 and designating t + Δt as t + 1

$$T_i^{t+1} = \frac{\Delta t}{C_i}\left((q_i + \frac{T_{j1}^t}{R_{ij1}} + \frac{T_{j2}^t}{R_{ij2}}) - T_i^t (\frac{1}{R_{ij1}} + \frac{1}{R_{ij2}}) \right) + T_i^t \tag{3}$$

If node i is connected to n number of nods, then equation 3 becomes:

$$T_i^{t+1} = \frac{\Delta t}{C_i}\left(q_i + \sum_{j=1}^{n} \frac{T_i^t}{R_{ij}} - T_i^t \sum_{j=1}^{n} \frac{1}{R_{ij}} \right) + T_i^t \tag{4}$$

Equation 4 is explicit in T_i^{t+1} and is equivalent to the first forward differencing scheme for the time derivative [1]. Explicit methods are unstable; therefore, equation 9 is used for stability condition [2].

2. Building Thermal Network

The space conditioned under the physical test is selected as small office which has dimensions of 4.22 m x 2 m with height of 3.056 m. All walls of the office consist of common brick (24 cm thick). The ceiling is made of 12 cm concrete, 2 cm air gap, 2 cm polyethylene insulation foam and 0.4 cm plywood. The floor is constructed of 39 cm concrete; 3 cm cement mortar and 3 cm tile. The 0.95 cm x 0.76 cm is made of a single clear glass with thickness of 3 mm where the door has dimensions of 1.95 m x 0.82 m soft wood (4 cm thick).

The building under investigation should be represented based on one or more of the above method. Figure2: illustrates thermal network of a single wall (T lumping method) for the office building. Thermal network for the ceiling, floor, door and window can be determined in the same pattern. A complete view of the whole office building is shown in Figure 3. that composed of 8 parallel circuits, each of the will be ended at node (66) which represents the room air temperature node.

To evaluate the transient heat response of the office thermal network which is explained in Figure 3, the following assumptions are constructed:

- One dimensional conduction heat transfer through the office structure.
- Explicit method is used to solve transient heat conduction.
- Thermal properties of all materials are constant.
- All inside surfaces radiate and reflect thermal radiation.
- Inside temperature of the space is remained constant.