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An Investigation of the Potential Use of Thermography for Building Air Leakage Measurements.

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Synopsis

The heat loss associated with the external fabric of a building has been greatly reduced by the increased levels of modern insulation, but heating losses associated with cold external air flowing into a building via leakage points in the external facade are still a major problem. Some ventilation is necessary but a detailed knowledge of this leakage would enable the major heat loss routes to be blocked.

A crack has been studied which has hot air of a known temperature and flowrate passing over it. This has been modelled using a finite element analysis enabling the flowrate to be calculated from the measured temperatures. Additional cracks made from various building materials have been studied using infra-red thermography in order to establish the flowrate and therefore quantify the air leakage.

A more extensive mathematical model is now being developed using computational fluid dynamics to predict the airflow based upon a knowledge of surface and air temperatures.

1. Introduction

Heat losses associated with the external fabric of a building have been greatly reduced by the increased levels of modern insulation now required by Building Regulations. This insulation has minimised the heat loss through walls, windows, floors and roofs. The primary source of heat loss is now through leakage points or cracks in the external facade allowing cold external air to flow into the building. A completely sealed building is not desirable due to ventilation requirements to provide fresh air, remove pollutants and control condensation. It would therefore be practical to quantify this air leakage in order to optimize the ventilation.

2. The Preliminary Investigation

Before commiting time and money to the study of airflow via temperature measurements it was considered prudent to carry out a preliminary test to verify whether this method would give a reliable answer, or if it would have no correlation whatsoever. To prevent the possible unnecessry building of a test rig this preliminary experiment was carried out using a vent grille in a domestic central heating system. The pumping of hot air to rooms is a popular method of incorporating a central heating system into a newly built house. This method gives a constant flow of hot air of a known temperature over a metal grille. The temperature of the air was set at 42°C, and the temperature of the grille then measured at intervals of 30 seconds. The airflow velocity was measured to be $2.0ms^{-1}$.

To try and interpret this data a finite element analysis procedure was adopted. This took into consideration the thermal conductivity of the grille, the velocity and temperature of the airflow, and the dimensions of the grille to calculate the surface heat transfer coefficients. The results of this analysis for various airflow velocities along with the actual measurements are shown in figure 1.

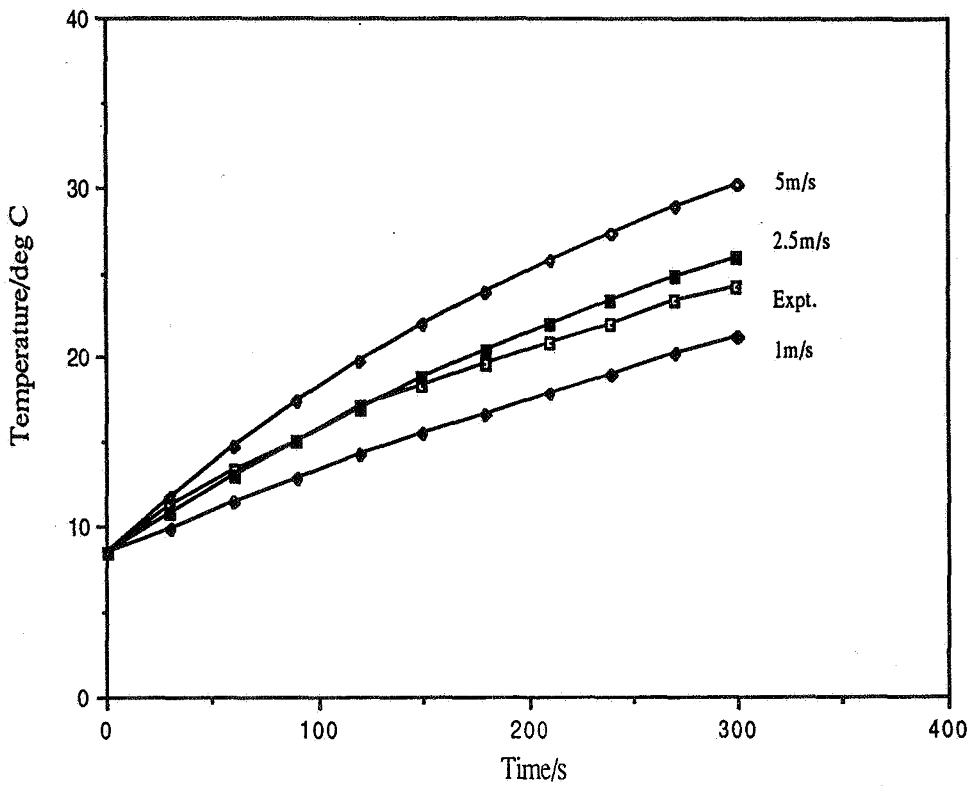

Figure 1: Graph showing preliminary experimental result and finite element calculations.

As can be seen in figure 1 the theoretical predictions are in good agreement with the measured data indicating that calculations of air losses from buildings could be made from a study of temperatures. Obviously when studying the external facade of a large building for heat leakage points the use of a simple temperature probe would be inappropiate. A technique is therefore required that gives quick results and can also be used from a distance so that tall buildings can be studied from ground level. The measurement of the emitted infra-red radiation with a thermography camera would therefore seem to be an ideal method.

3. The Thermographic Method

The initial guidelines for using thermography for air leakage detection were set by Hart [1] in 1986. He stated that the magnitude of the change in temperature depends upon three considerations; the nature and size of the point of leakage, the pressure differential across the construction and the temperature difference between the two sides of the air leakage point which should be at least 5°C.

In this current work these three parameters have all been controlled within the experimental apparatus. Two rooms have been built, each approximately 2m x 2m x 2m, with a partition wall in between allowing the mounting of different cracks at four possible heights. Pre-fabricated cracks have been constructed from typical building materials - hard wood, soft wood and perspex. These cracks all have dimensions of 500 x 50 x 3 mm. In the first stage of the work all the cracks where mounted in turn at a height of 1.75m, with an outlet situated at 1.25m below it to allow the air to circulate.

No pressure differential was set across the crack in this first stage, allowing the only driving force between the two rooms to be the temperature difference. This was achieved by having one room at room temperature, approximately 20°C, and heating the other room to approximately 40°C; thus simulating a building heated to 20°C in winter when the outside temperature is approximately 0°C. The cracks are straight through and constructed to be as smooth [2] as possible on the interior surface.

To use the thermography camera to measure the air temperature, and thus determine the rate of heat loss, the emissivity of the object must be known. The emissivity of a body is defined as the ratio of the spectral radiant power from the body to that from a blackbody at the same temperature and wavelength. The emissivity of the crack material had been measured previously using a known reference and found to be:-

Hard Wood	=	0.90
Soft Wood	=	0.90
Perspex	=	0.96

where a blackbody has emissivity = 1.00.

Thermography utilises the whole of the infa-red spectrum from 0.75 → 100μm and should not be confused with infra-red photography which only utilises 0.75 → 1.2μm - the so-called photographic infra-red spectrum.

The thermography camera was situated 1m from the crack and was connected to a modified video cassette recorder. This enabled a three hour study of the crack to be carried out with time 00:00 defined to be when the crack is opened once the room temperature has reached 40°C. Frozen images were then taken at 10 minute intervals for the whole of the tape using the compatible computer software. This gave 19 images in total. The mean temperature of the crack aperture was then measured and plotted against time, see figure 2.

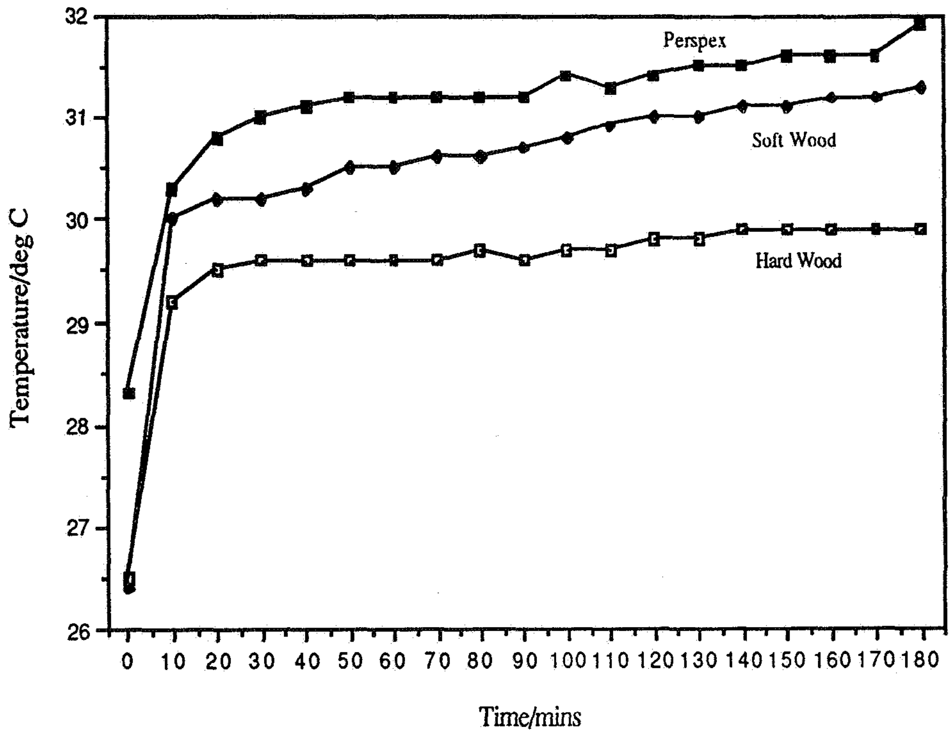

Figure 2: Graph showing temperature change of airflow through various cracks over a three hour period.

4. Results

The heating up curves in figure 2 are similar to those measured with a temperature probe and calculated using the finite element analysis in figure 1. It must be noted that the time scale for the two experiments is different; the temperature of the grille being only measured for 5 minutes whereas the temperature of the pre-fabricated crack is measured over 3 hours. As figure 2 shows, the temperature rises sharply in the first 10 minutes then does not rise by a comparable amount in the next 170 minutes. This tends to suggest that the heat loss is dependant on the dimensions and material of the crack, not on the temperature differential.

To compliment this experimental study and in an attempt to gain a fuller unsterstanding of the air/heat flow a theoretical simulation has been started using the computational fluid dynamics package Fluent®.

5. The CFD Study

Fluent is a complex interactive modelling package that enables various fluid dynamics problems to be studied. The region to be modelled is split into a specified number of cells and then these cells are solved individually according to the initial parameters chosen. An example of the grid of cells for a simple crack is shown in figure 3.

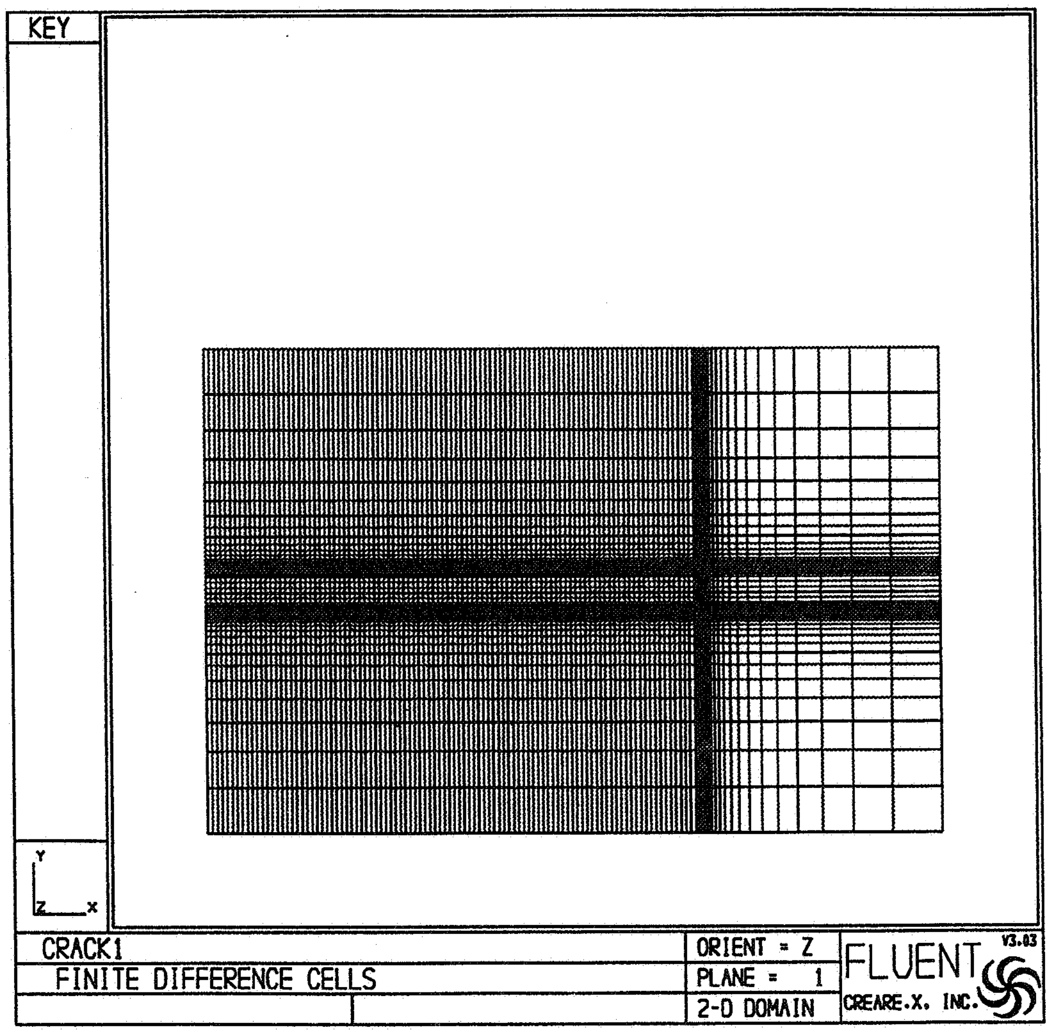

Figure 3: The grid of cells as defined to cover the chosen area .

As a first approximation the grid chosen to study the heatflow through a single crack has dimensions of 150 x 100 cells representing a 50 x 3mm 2-D crack and a 2 x 2m room. To create a temperature differential the room to the right of the crack is set to a temperature of 20°C, and the air entering throught the inlet side of the crack set to a temperature of 40°C. Two outlet cells are defined at the top and bottom of the room to satisfy mass conservation. The calculation is performed on a SunC by an iterative process to produce convergent normalised residuals. These residuals may take over a week to reach the required level of convergence. Figure 4 shows a colour-raster plot converted to grayscale of the temperature profile obtained at steady state conditions.

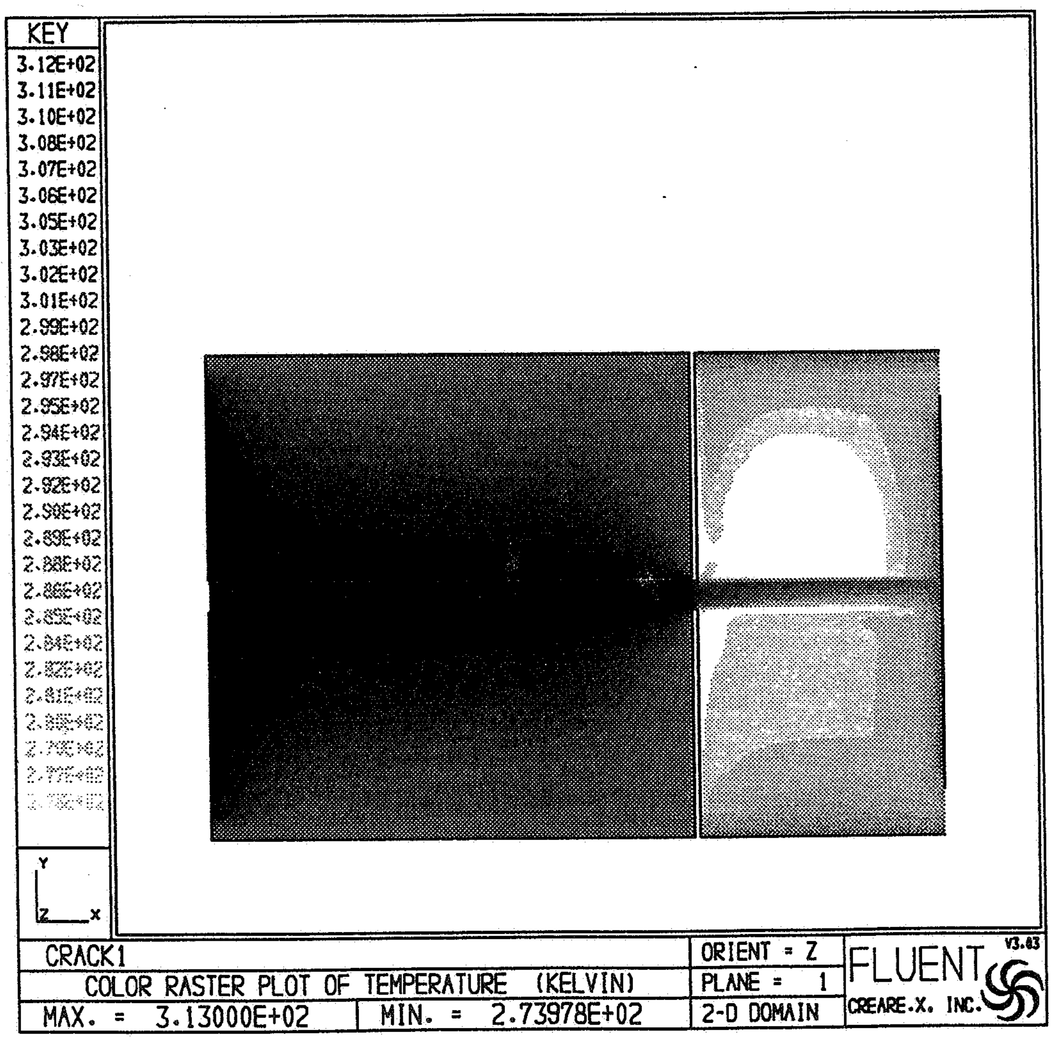

Figure 4: The temperature profile of the crack and room. The key on the left is in Kelvin.

6. Conclusions

Even though this investigation is in its infancy there is enough evidence to suggest that thermography will become an invaluable tool in the study of air leakage measurements. Thermography gives a consistent method of measuring temperatures from a distance, and with our knowledge of how to interpret these as airflow rates it will give a quantatitive method of estimating the heat loss via cracks in buildings.

The application of Fluent to this study will give a greater understanding of the airflow through cracks and will give the limiting situations for convective heat flow to occur.

References

1. Hart, J. M., Building Research Establishment publication, ref. no. PD91/86.
2. Kula, H-G. R., Sharples, S. and Ward, I. C., to be published.