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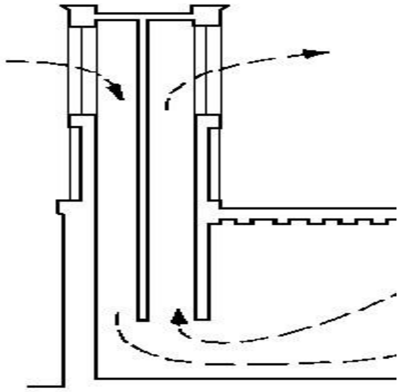

Iranian wind towers

Wind towers are designed to introduce cool outside air, driven by positive wind pressure. The internal partition allows the low pressure on the lee side of the tower to suck air from inside the building

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Architectural fluid dynamics concerns the flow in and around buildings. This flow is responsible for the ventilation of buildings and the quality of the indoor air. The linkage of the interior flow with the complex flow outside is achieved either through natural ventilation or by introducing the air mechanically. Once inside the building it is delivered to the various spaces again either mechanically or as a result of flows through openings between spaces. The flows, both internal and external, generally turbulent and often strongly affected by buoyancy forces caused by temperature differences.

Architectural fluid dynamics concerns the dynamics of these flows and, as such, is a cross between classical engineering fluid dynamics and geophysical fluid dynamics. Most engineering flows, such as in an internal combustion engine, or around a vehicle are dominated by the geometry. They need to be calculated for the specific boundary conditions that the geometry imposes. Geophysical fluid dynamics, on the other hand, is a study of flows for which boundaries usually only play a minor role. The flows are governed by internal dynamics associated with buoyancy and Coriolis forces. In both cases methods have been developed for making these calculations. For engineering flows by including the geometry explicitly and for GFD by simplifying the geometry and considering, for example, periodic domains.

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In AFD the flows are determined both by the geometry and by the internal dynamics in about equal measure. The flow through a building is determined both by the internal geometry and the location and sizes of openings and also by pressure and buoyancy forces. This combination makes computation especially difficult. In addition, it is often desirable to make calculations of flows in the design phase when the building geometry is evolving – often quite radically.

The challenge is to develop ways of making calculations of these flows that are relatively simple and yet robust. Architects and designers need to be able to evaluate how their buildings will ventilate, how they will affect (and be affected by) the local external flow, and what the implications for air quality and energy consumption. They need to make these calculations for weather variations experienced over a typical year, so many cases often need to be run. Our research is aimed at developing this methodology and improving understanding of how buildings operate and perform.

According to the Energy Information Administration, in 1997 over 5% of the total annual energy consumption of the United States (i.e. 5.6 quadrillion BTU or ``quads'', at a total cost of over $50 billion per annum) is consumed by the heating and cooling of domestic buildings. Indeed, domestic buildings as a whole are responsible for over 15% of the total emissions of greenhouse gases in this country. Heating and cooling constitutes a significant part of the ongoing monthly cost of the building. Conventional modern building practice is to design heating and (increasingly with economic growth in hotter regions) cooling systems to moderate internal air temperature within strictly defined limits. However, such systems can have significant energy demands, particularly during periods of extreme weather conditions. Similar remarks apply to commercial and industrial buildings.

Therefore, it is vitally important to develop and apply innovative design strategies and technologies to the built environment to reduce the amount of energy consumed by the heating and cooling of buildings. Also, in the light of increased stress on energy supply mechanisms (as recently evidenced in California in particular) and concern for stewardship and conservation of environmental resources, there is a clear need to provide professional engineers with the skills and knowledge necessary for the design and construction of environmentally friendly, energy-efficient buildings.

Natural ventilation – ventilation driven by the natural forces of wind and temperature – is a reliable, low-maintenance and energy-efficient method to keep air quality and temperature inside buildings within safe and comfortable limits. Motion of air within a building is induced naturally (i.e. without a mechanical driving mechanism) when air masses of different density or pressure come into contact. Such density changes arise from variations in temperature or composition (due for example to varying gas content).

Over the past few years there has been considerable research effort aimed at improving understanding of natural ventilation of buildings (see [121] for a recent review). We have developed analogue laboratory systems, in which density differences may be represented by several different methods. Most commonly, saline solutions with different concentrations have been used, although it is also possible to vary the temperature, and hence density of the water. By varying the density contrasts and the geometry of the laboratory systems, dynamic similarity

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between the laboratory and air flow within a real building may be achieved. It is then possible to isolate and study in detail various aspects of the full-scale flow.

Such experimental investigations have two principal benefits. Firstly, using modern visualization and data acquisition equipment, high-quality data and flow visualization may be obtained, avoiding many of the inherent difficulties of data acquisition in full-scale rooms. Visualizations can shed light on the qualitative aspects of the behaviour of real flows, and help to identify processes which may not be easy to observe in real buildings or numerical simulations. Secondly, the high-quality quantitative data obtained in the laboratory experiments may be used to formulate and test quantitative models of natural and mixed-mode ventilation using both natural and mechanical ventilation systems in various circumstances. These simple, experimentally based models may be used to parameterize and validate numerical simulations of the flows within buildings.

Underfloor air distribution (UFAD)

UFAD is a relatively new approach to the delivery of air in an air conditioned building. Air is supplied to the space through ‘diffusers’ located in the floor, rather than from registers in the ceiling as in conventional overhead systems. The floor is raised above the slab and supported on columns to provide a supply plenum. The height of the plenum is typically 0.30 m and it is pressurized to about 0.1 cm water. This pressure drives the conditioned air through the diffusers into the space above, The return is usually in the ceiling.