Visiting Professor – Department of Civil and Building Engineering – University of Loughborough

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Introduction

The Royal Academy of Engineering Visiting Professors Scheme has enabled nine Professors to provide a range of different inputs to the learning, teaching and research activity of the Faculty of Engineering at Loughborough. These persons have contributed to all six departments through a range of activities bringing their knowledge and experience from a number of organisations including: Arup R&D, British Aerospace, British Gas, ERA Technology Ltd., Cosworth, JCB, and Nortel Networks. Not all the Visiting Professors have engaged in engineering design teaching. This paper outlines the input to the teaching within the Civil and Building Engineering Department, by Professor Mike Holmes, the lead author and our Visiting Professor. It includes a short discussion on the nature of engineering design together with the manner in which this has been embraced within our research-led institution. In particular, the interlinking of research and teaching is highlighted, since teaching incorporates the findings of research and research depends upon a sound foundation of both general and specific knowledge within the subject area.

The paper describes how the Visiting Professor works with the Building Services Engineering Group at Loughborough (a world leader in its field). The group is within the Department of Civil and Building Engineering, and the aim of this collaboration is to develop and enhance the design process related to building services engineering. In this context, design is more akin to an analytical process resulting in the selection of systems and controls as opposed to the romantic notion of an artist working through inspiration. This 'interaction' falls under the following broad categories:

Lectures for elements of a vocational MSc Course;
Specialist lectures;
General guidance and collaboration on EPSRC funded research;
Collaborative research;
Raising the International profile of the Department.

The underlying objective is to link the work of the department to the needs of industry and in doing so to introduce improved tools and understanding of physical processes into the industry. To do this, it is essential to take a 'world view'. This is made easier because Arup is an International company and Arup Research and Development have strong links with academic institutions throughout the world.

Before discussing the detail of the 'interaction,' it may be helpful to show how this relationship developed. About 20 years ago, Mike Holmes presented a paper at a conference in Liege describing research work related to the performance of cooling coils. The performance of HVAC plant was, and still is, an area in which the Building Services Engineering Group within the Department at Loughborough can be considered as international experts. Loughborough was leading the UK input to an International research project related to the simulation of HVAC Plant[1]. This joint interest developed and we collaborated on a number of similar projects and general discussions on the work of the Department. The basis for the present method of working was therefore developed over many years, resulting in a friendly and professional relationship.

1. Teaching

The development of a vocational MSc course in Building Services Engineering provided the opportunity to introduce some of the successful, low energy, design techniques developed in Arup

[1] International Energy Agency – Annex 10. Project lead by Professor Vic Hanby (now of DeMontfort University).

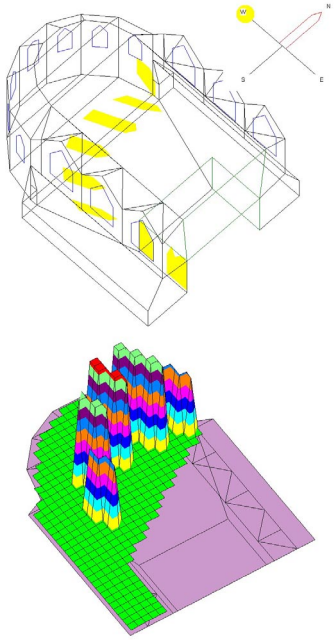
Research and Development to the students. These are associated with the prediction of thermal comfort and ventilation[2], both activities being carried out using software, the lectures are targeted at demonstrating the application of that software. Experience has shown that unless the user has a good understanding of what is being done and how, it is difficult to produce meaningful results. To this end, the lectures also introduce the following concepts:

Computer programs contain models;
Models are not the real world they are someone's version of the world;
The problem as described to the program is a model.

The objective is therefore to show what the software can do as an aid to design and to explain how it does so. In addition, issues associated with the selection of appropriate software are introduced. In the context of design, the programs demonstrate two approaches:

A broad overview of strategy – ventilation analysis;
A detailed analysis of the performance of a single space – thermal comfort prediction.

Furthermore the output from each differs in the way results are presented. Ventilation analysis provides tabulated data describing flow rates of air between spaces whereas the thermal comfort predictions are in an attractive, graphical format. The use of strong visual images is seen as an essential means of communication with the client with the unfortunate side effect, on some, of the engineer becoming more interested in the presentation than the content.



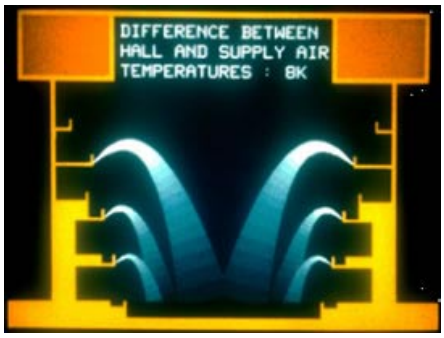
The adjacent figure illustrates two ways to display similar information. The upper figure shows a frame diagram of a building. The objective of the study is to investigate the thermal comfort of occupants within the space and also to explain the need for both a qualitative and a quantitative approach to 'analytical design'. To this end, the upper figure clearly shows where solar radiation passing through the windows falls within the space. Alone, while of interest, it tells the engineer very little about conditions within the space. It is, however, an excellent way to communicate with the client. A numerical simulation of the space can be used to predict temperatures and - of more interest, quantify the thermal occupant comfort. The lower diagram presents the output in pictorial form. The flat area shows that people will generally feel comfortable, whereas the peaks indicate the heating effect of radiation transmitted through the windows. This approach is used to demonstrate the need for good communication within the design team and the need to select the most appropriate techniques. Thermal comfort is a major research area within the Department and this particular tool (developed by Arup R&D) has been made available to both researchers and students.

2. Specialist Lectures

These lectures are delivered to staff, researchers and students and are intended to cover areas that are either new or outside of the normal Building Services Engineering curriculum. For example, Arup Research and Development was commissioned by the Chartered Institution of Building Services Engineers (CIBSE) to re-write the section of the CIBSE guide that deals with the calculation of static and dynamic heat flows in buildings. A description of this work, together with the major revisions in other sections, was presented.

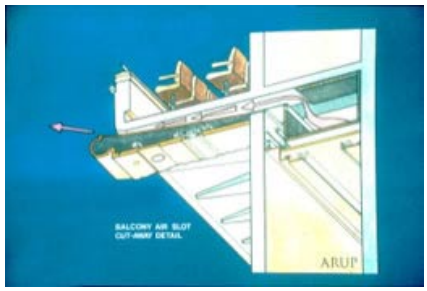
[2] Both topics are also closely related to research within the department and so this provides an excellent opportunity to demonstrate the advantages of links between research and industry.

Mike Holmes spent his early working life at the Building Services Research and Information Association (BSRIA). In addition to the research on the static and dynamic performance of cooling coils, he spent some time investigating airflows within rooms. This lead to the development of empirical methods for the prediction of the characteristics of jets in confined spaces and the velocities generated within those spaces. It is now common practice within the industry to use complex software (Computational Fluid Dynamics) to predict he movement of air within buildings. This is not, however, a very cost effective way to carry out design since it requires specialist users and significant amounts of computer time. One of the specialist lectures covers alternative 'design approaches' using the results from the BSRIA research work. An example used was the development of the design for the air distribution system in the concert hall at the Birmingham Convention Centre.



In this case acoustic performance is an overriding consideration. The simplest and probably the most satisfactory way to supply air to a concert hall is beneath the seats, failing that by nozzles in the ceiling. Unfortunately, the acoustic consultants would not accept perforations in either the floor or the ceiling. This lead to the scheme shown in the adjacent diagram. The jet trajectories were calculated using the empirical approach to room air movement design developed at BSRIA. In order to achieve the required performance, supply air velocities of about 3m/s were necessary.

The solution is a demonstration of design integration. The detail on the right shows the concept. The structure supporting the balcony reduces in width towards the edge of the balcony providing a smooth expansion passage for the supply air. The 'nose' at the point of air discharge serves three functions in that it sets the discharge angle, provides the appropriate nozzle characteristics for low noise and is a significant architectural feature. It was, of course, still necessary to 'prove' the design in terms of both acoustic and aerodynamic performance. This was done using a scale model of the auditorium and full-scale models of the airflow distribution system.



The importance of this example is that it shows that design does not necessarily require highly sophisticated software. What is required is a good understanding of the physical processes involved and of the engineering principles. In order to achieve this, all those involved required knowledge of:

- Room aerodynamics;
- Airflow - generated noise;
- Structural design;
- Physical modelling techniques.

thus demonstrating the broad range of skills that must be acquired by the building services engineer.

3. Other Activities

High quality research is the cornerstone of the Building Services Engineering Group and it is natural that research should be a major component of the relationship between the Visiting Professor and the Department. The Group holds regular meetings where the research programme is discussed. These are an ideal opportunity to look at the relevance of the projects to industry and to see how collaboration might be arranged. Clearly it is not feasible for Arup Research and Development to be

involved in all research projects, however, it is possible to provide encouragement and as in one case offer advice on industrial relevance and obtain the assistance of an equipment manufacturer. One EPSRC-funded project being carried out by the Group investigated conditions for thermal comfort in offices when cooling is provided by a combination of a radiant ceiling and air supplied at low velocity close to the ground (displacement ventilation). Major industrial interest in this project helped the Loughborough group to win the research funds and also enabled the Department to obtain a proprietary ceiling at a modest cost. The research then involved placing subjects in a test room and obtaining their response to a range of environmental conditions. On other occasions design input has been introduced by arranging meetings between a number of design engineers and the researchers, in one case to look at the relevance of work aimed to investigate optimal design solutions. This particular project was being carried out for the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) and the Visiting Professor was also able to provide support at a client meeting in the USA.

The design of sustainable buildings often involves natural ventilation. Modern naturally ventilated buildings usually have some form of automatic control of the ventilation openings. Another of the Group's EPSRC-funded research projects has looked at the application of fuzzy logic to ventilation control. In order to do this, it was necessary to develop a simple method to predict airflow patterns in rooms in approximately real time. This therefore excluded the use of CFD. Zonal airflow models offer a simpler approach but have not been validated for this purpose. The VENT program (again developed by Arup R&D and also used in the MSc lecture course) was available to the researchers and an experimental programme was set up. The results are very encouraging in terms of both the quality of control possible and the performance of the ventilation model. Mike Holmes will present a paper, on behalf of the researchers, describing this work at the ASHRAE summer meeting in Honolulu.

Part of the brief for Arup Research and Development is to keep in contact with research organisations throughout the world. This sometimes provides the opportunity to disseminate the work of the Department worldwide. Recently the ventilation research has been presented at the Cooling Frontiers conference held in the Department of Architecture at Arizona State University and also during a set of lectures given at the opening of the Centre for Hybrid Ventilation at the University of Aalborg (Mike Holmes is a member of the International Steering Group).

4. Summing up

The strength of the Department lies in the vigour and quality of its research; our teaching is research-based and provides valuable training in the conversion of graduate engineers to Building Services Engineering - a profession in which there is a great shortage of engineers. The objective for this particular Visiting Professor is to encourage and support research and to assist in the training. A background of research in the Building Services Industry and employment within a leading international company are of great relevance in providing this greatly valued support.

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