The Ove Arup Foundation

Attracting the best and brightest: Broadening the appeal of engineering education

A Report

Professor David Nethercot
Dr David Lloyd Smith

ARUP

THE OVE ARUP FOUNDATION

After Sir Ove Arup died at the age of 92 in February 1988, the Directors of Ove Arup Partnership wished to commemorate his life in an appropriate manner. Many ideas were considered, and the one favoured was an educational trust related specifically to the built environment. The Ove Arup Foundation was formed early in 1989, with Trustees drawn from Sir Ove's partners plus an Arup family representative. For the Foundation's advisory committee, The Royal Academy of Arts, The Royal Academy of Engineering (then the Fellowship of Engineering), the Royal Institute of British Architects, the Chartered Institution of Building Services Engineers, the Institution of Civil Engineers, and the Institution of Structural Engineers were each asked to nominate a member.

The Trustees then considered how to apply the funds. These were subscribed by Ove Arup Partnership over seven years to build resources that would generate about £100 000 pa in real terms. They decided to spend about 70% of the Foundation's income from capital on major self-generated schemes, with the rest used to fund external applications or to deal with smaller ventures. This policy continues, though it is subject to review from time to time.

Now in its second decade, the Foundation has instituted several major initiatives which if replicated should increase the understanding of construction professionals, particularly engineers and architects, of each other's talents and potential contribution to projects. The Foundation has also supported numerous local initiatives which, whether through education or practice, it felt promised to enhance awareness and knowledge of the crucial role played by buildings and places in all our lives.

Major Schemes

At a Conference arranged by the Foundation in 1991 the need for a post-graduate course which would enable practitioners of the various disciplines to work together in a studio environment was identified. The University of Cambridge Architecture and Engineering Departments together proposed an Interdisciplinary Design for the Built Environment course, and this was duly launched in 1994 with 15 students. The course requires two years' part-time study with several residential periods. The Foundation provided funding to help launch the course and then provided two scholarships a year for some years. Students graduate with a Master of Studies (MSt) degree.

The Trustees, with the support of the Royal Academy of Engineering, initiated a scheme to locate Visiting Professors of Design in University Engineering Schools. Whilst continuing to spend most of their time in their own practice, the intention is that the Professors will devote about 30 days a year to an agreed academic agenda. The first such Professor funded by the Foundation is Chris Wise. Appointed in the Department of Civil Engineering at Imperial College, London, he is responsible for giving students a thorough understanding of the multidisciplinary nature of design, and for bringing into the design studio practitioners of other relevant disciplines. His work and approach have considerably influenced the department in which he serves. Both staff and students feel that the learning experience and their appreciation of the art of engineering have been much improved. It is hoped that this lead will be copied elsewhere.

The third major scheme stemmed from the London School of Economics, who sought support for the establishment of a new department - unique to the UK - bringing together architecture / planning, engineering and sociology in addressing the problems of the built environment. This initiative, entitled The Cities Programme, launched an MSc course on Cities, Architecture and Engineering in 1998 which has generated a great deal of interest, particularly from overseas. The Foundation provided much of the funding to enable the School to establish this Programme. Subsequently we have extended our funding to support a Visiting Professorship and other developments.

Other initiatives

The Trustees were instrumental in initiating the Edge, a forum in which members of the RIBA and ICE debate matters of national importance and common interest. The two institutions host evenings when invited speakers address a particular topic, followed by discussion.

Ove Arup's interest in the environment, particularly in his latter years, was well known. In 1994 Mansfield College Oxford requested the Foundation's support for the Oxford Centre for the Environment, Ethics and Society. The trustees sponsored a fellowship in Environmental Risk for a three-year term.

The Scoping Study 'Interdisciplinary Skills for Built Environment Professionals' by Professor David Gann and Dr Ammon Salter of Science Policy Research Unit at Sussex University, published in 1999, resulted from proposals made at a second educational conference, held at the Institution of Civil Engineers late in 1996. The present report carries further the exploration of options for tackling the decline in built environment education.

Donations

Many smaller donations are given. Details may be found in the Annual Reports, published on our website. Our total financial support to date is well over £1M. The administrative costs are minimal because Arup Group (formerly Ove Arup Partnership) donates the services of the secretary and financial advisor to the Foundation.

Background photograph courtesy of Imperial College of Science and Technology
Front cover: A sustainable design for education in the 21st century: Jubilee Campus, University of Nottingham (Photo: Paul McMullin)

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The Ove Arup Foundation, London, November 2001

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Foreword

The Trustees of the Ove Arup Foundation published in 1999 a report prepared for them by Prof David Gann and Dr Ammon Salter entitled 'Interdisciplinary Skills For Built Environment Professionals'. It highlighted the serious decline in applications from bright young people to study engineering in general, and built environment courses in particular. A particularly serious skill shortage lies within the building services specialities. The 'Gann Report' received wide attention, and has helped raise awareness of the seriousness of the situation. It draws particular attention to the fact that courses that encourage a high level of interdisciplinary thinking and project work seem to attract better students.

The decision by the Trustees to commission this further report from Prof David Nethercot and Dr David Lloyd Smith of Imperial College, London, drew together several strains of thought, informed by insights from the Gann Report. Put simply, the Trustees wanted to examine how a course could be constructed that encourages greater interdisciplinarity, that further develops creative thinking, and could be accredited together by the Institution of Civil Engineers, the Institution of Structural Engineers, and the Chartered Institution of Building Services Engineers.

Our thoughts ran as follows:

- Many seem attracted by career opportunities where creativity and design are prominent.
- They enjoy technology and are also computer-literate.
- They increasingly care about protecting the environment and the effective use of resources.

These are core characteristics of civil engineering-based degrees, but this seems not to be apparent to bright young people thinking of career opportunities.

The line of thought continued:

- Most intelligent young people at 16, about to start A levels, AS levels or Highers, do not know what they want to be, nor even really what there is to be.
- Increasingly, they do not seek a single career. They seek opportunities. They want to embark on studies which will open up opportunities, not close them off.
- In this context, an engineering degree which achieves such a broadening of horizons should prove attractive, including, as it would, opportunities both within and outside engineering itself.

The Trustees therefore felt that some specific research into how this might be achieved would be of great value and potential. This report sets out a positive and highly encouraging way forward.

Richard Haryott
Chairman of Trustees

November 2001

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Executive Summary

The Ove Arup Foundation first acted on its concerns over the recruitment of professionals to the construction industry in 1996 by commissioning the report 'Interdisciplinary Skills for Built Environment Professionals' from Prof David Gann and Dr Ammon Salter of the Science Policy Research Unit at the University of Sussex. The 'Gann Report' was successful in increasing awareness within industry, professional institutions, and academe of the impending manpower crisis. Its overall conclusion was that declining entry to the various built environment professions is now such that the UK construction sector will be unable to sustain performance at anything like its present levels unless effective corrective action is taken. The Report also advocated some relaxation in the concentration on narrow technical skills, introducing more interdisciplinarity whilst preserving core technical competence. This would address the need for people with specialised professional skills plus a thorough understanding of management, communication, and business processes. Many aspects of 'UK Construction Ltd' require attention, but without more able, motivated, imaginative, and industrious professional staff, other necessary improvements such as enhanced use of IT, more co-operative working, better supply chain integration, etc, cannot be made to work.

Much of the Gann Report makes disquieting reading, but arguably its most pessimistic view is of building services engineering. To quote directly from the concluding 'Policy Suggestions':

- *'In particular it is more important to raise the general level of quality than to expand the number of people being educated for Built Environment professions.'*
- *'There appear to be too many low quality courses in sub-critical departments, particularly in areas such as Building Services.'*
- *'Finally new centres of excellence are needed to champion the weaker areas such as Building Services.'*

Based on these statements, together with deliberations by the Trustees and comments received on the study, the Foundation devised the following proposition:

1. **The demand from prospective students for - and university supply of - traditional building services undergraduate courses is in serious decline.**
2. **Although not buoyant, traditional civil engineering undergraduate courses still recruit worthwhile numbers of students.**
3. **Therefore could some (traditional) civil engineering MEng courses be reconfigured to serve as an additional route into a career in building services?**

To test this hypothesis the Foundation commissioned us to design and conduct a suitable study. However, as the study progressed it became increasingly clear that what started as an exercise for building services engineering was developing into a set of conclusions with potential application across all sectors of engineering. The concerns of senior industry representatives, their descriptions of the types of engineering graduates they need to recruit, and the characteristics required from the cohort expected to develop and operate at the highest levels, seemed equally relevant across engineering. Students of high intellect with an aptitude for problem solving and learning new skills were the universal target. Coverage of a long list of tightly prescribed topics was never mentioned; those employers to whom we spoke saw education as a preparatory and holistic experience – not tightly specified training.

This suggests very strongly that our proposed solution – a course predicated on the need to be attractive to bright students who enjoy technology, are computer literate, and wish to continue their education through a challenging university course that provides wide and varied career opportunities – has similar value across engineering. Such courses should encourage creativity and reflect the increasing concerns of the young for the environment, sustainability, and the 'human' aspects of engineering. Above all they must stimulate the interest and challenge the intellect.

Young people of 16 or thereabouts generally have only vague notions of what they want to be or even what there is to be. Engineering, therefore, must be presented as one of the best degree choices for those seeking a combination of creativity, environment, technology, and plenty of eventual career choice. As long as a sufficient proportion actually do take up careers in engineering, the fact that some see such a course as an interesting university experience and/or a passport to business, finance, administration, politics, etc, should be welcomed, since more of those with whom the engineering world deals will have an affinity with it.

Thus the course ethos is the real objective, and its firm implementation in guiding the detailed teaching of every individual component is the key to its success.

Whilst this report describes the process adopted for the present study, delivers the findings, and suggests how they might be acted upon within the context of the initial brief, we believe that the core messages deserve careful consideration from a far wider audience. In particular, those responsible for the conception, design, delivery, and monitoring of all forms of undergraduate engineering education intended to recruit the most able entrants and prepare them for high level, demanding, but ultimately satisfying engineering careers, should reflect on our main conclusions.

- **Recognise and broadcast the challenge, excitement, and potential rewards inherent within top quality engineering and the taste for this that can be developed through the pursuit of an appropriate undergraduate engineering course.**
- **Configure MEng level courses to stimulate interest and challenge the intellect.**
- **Present such courses as the most desirable scheme of study for able, ambitious young people interested in creativity, technology and contributing to a better world.**
- **Accept that course ethos - not detailed technical content - must underpin the design, delivery and accreditation of high level undergraduate engineering education.**

Approach 1

Since the essence of the study is to test the feasibility of a reconfigured civil engineering course, consultation with interested parties is a key feature. The core of the project may therefore be restated in a rather more precise form as:

- Could some (traditional) civil engineering MEng courses be reconfigured to serve as an additional route into a career in building services by:
- meeting the needs of employers
- meeting the needs of professional accreditation
- providing an attractive educational opportunity for students
- being practical in terms of teaching, scheduling, etc.

It was also expected that such a reconfigured scheme would continue as a route into a civil/structural career.

It was therefore necessary: to identify the needs of employers for graduates intending a career in building services, to check the requirements of the relevant professional institutions so as to ensure accreditation for the courses, and then to devise schemes that were both practical in terms of university provision and potentially attractive to students. Clearly, this required consultation with representatives of each of these four groups.

Task	Activity
1	Identify employer requirements
2	Assess accreditation constraints
3	Devise outline course structure and content
4	Solicit views of: • employer • professional bodies • students • academics
5	Refine and flesh out proposals
6	Report

Table 1 - Main tasks in the study

A particular point to emerge from early discussions with the Trustees was that, should the proposed course prove feasible, it ought to be possible to mount it in a number of different universities. Of course, certain features would need to be present in those universities in order for them to be capable of providing the appropriate subject mix.

The scheme by which the project was to be run therefore adopted the form of the six tasks listed in Table 1.

Industry views

2

Consultations were conducted with each of the organisations listed in Table 2. These took the form of a discussion, lasting for at least one hour, with one or more representatives. It was left to the company to decide exactly who should represent them; usually a Senior Director, together with the Director responsible for building services engineering, was present. The agenda was deliberately not tightly specified but normally started with a discussion of the company's needs for building services professionals, together with an indication of the way in which these needs were serviced at present, followed by their views on the sort of people and the type of educational background needed to successfully pursue building services within their organisation. No company that was approached refused to see us; virtually all found the proposition of sufficient interest to arrive well prepared, and were enthusiastic and helpful in the discussion.

Contact	Organisation	Date
Prof. Mike Barnes	University of Bath	10/2/00
Mr Arthur Austin	The Waterman Partnership	17/2/00
Mr R Chantrelle	Ove Arup Partnership (Training)	18/2/00
Mr Mike Farrell	CIBSE	21/2/00
Mr Peter Shears	Oscar Faber	24/2/00
Mr Ron Slade	WSP	24/2/00
Prof. Max Fordham	Max Fordham & Partners	03/3/00
Mr Peter Head	G Maunsell & Partners	03/3/00
Mr Tony Trinick	Tritone Partnership	06/3/00
Mr Mark Whitby	Whitby Bird & Partners	13/3/00
Mr Ron Moncrieff	Gibb & Partners	13/3/00
Mr Jim Read	Ove Arup Partnership (Arup Communications)	10/4/00
Mr Alan Jefcoat	Ove Arup Partnership (Building Engineering)	10/4/00
Mr Alan Rowell	Ove Arup Partnership (Building Engineering)	10/4/00
Mr John Rushton	Peter Brett Associates	12/4/00
Mr Michael Dickson	Buro Happold	18/4/00
Dr Richard Lamb	Pell Frischman Engineering Ltd	16/5/00
Mr Patrick Bellew	Atelier 10	16/5/00
Mr Guy Battle	Battle McCarthy	16/5/00
Mr Klaus Bode	BDSP	16/5/00
Prof. Quentin Leiper	Carillion Infrastructure Management	16/6/00

Table 2 - Consultation

Every organisation we met agreed that 'building services is in crisis', with increasing industry demand and a lack of recruits, particularly the 'brightest and best'. The individual companies had developed a range of means of recruiting that included early engagement with students on existing courses, recruitment from mechanical, electrical and engineering science courses, sponsoring selected students in mechanical, electrical and engineering science courses, recruitment of MSc graduates irrespective of first degree subject, and recruitment from overseas universities. Although some were very happy with their own arrangements, they noted that these were expensive in terms of money (paying for sponsorships) and time (making contact with and selecting suitable people).

As discussions proceeded, it became clear that there were two 'schools of views':

1. *'Building services is straightforward. We need people able to do the basic tasks (meet a specified requirement competently). Beyond this our company would engage specialist assistance.'*

2. *'We need (some) people who can contribute to early, conceptual discussions from the building services viewpoint, helping to identify the key issues, consider alternative solutions, and discuss these comfortably with some appreciation of their interaction with other professional contributions.'*

Providing that the existing building services courses could supply graduates in sufficient numbers, it was thought that the first requirement could be largely satisfied from this source. The second category, however, was the major concern, with many companies commenting on the continually increasing level of challenge for this form of contribution and the increasing difficulty of fielding staff capable of meeting it.

There is, therefore, a widely held view that what matters most in recruitment is intellect - rather than the detailed scheme of study that has been followed - and an aptitude for problem solving and the learning of new skills. A better understanding of the organisation of the construction industry and the different roles and contributors to it was often mentioned. There is general agreement that it is the 'heat and fluids' area of building services plus the associated control systems that is central. Beyond certain basic material in acoustics, lighting, etc, these subjects were seen as specialised. Much of this basic material - but not its application - might well be found in A-level physics. A more thorough grounding in heat transfer, computational fluid dynamics, etc, would however often prove helpful. For the electrical building services, the rather unfashionable topics of power generation and transmission were regarded as the most important. Much of the general 'construction' material within a conventional civil engineering course was felt to be generally beneficial to a building services education.

Thus the general views on the sort of educational preparation required were most encouraging. Nowhere was it stated that coverage of a long list of tightly prescribed topics was essential. Indeed, the overall impression given was very much to the contrary, with employers seeing education as a preparatory and holistic experience - rather than tightly specified training.

There was a very strong feeling from the discussion that graduates from well run and respected civil engineering/building services courses would be extremely attractive to the industry. There was also a recognition and acceptance that whilst universities should be able to teach the underpinning topics for building services, for applications-related teaching the active and committed assistance of practitioners was essential. Those consulted were willing to contribute.

Professional (accreditation) view

3

The responsibility for the professional accreditation of courses in building services engineering rests with the Joint Board of Moderators (JBM) of the Institutions of Civil and Structural Engineers, and the Chartered Institution of Building Services Engineers (CIBSE). Thus there is already uniformity of the overall approach to and method of conducting accreditation within the civil/structural and building services sectors. Where the processes differ is in some aspects of the detail of individual subjects and areas of study listed in the JBM Guidelines.

Initial discussions with CIBSE (Lynn Beattie and Mike Farrell) were designed to elicit a general view on the extent to which that Institution required certain courses of study to be present in an accredited degree scheme. A most important outcome from these discussions was that the core building services material was relatively small, that much of the engineering science and supporting skills, eg mathematics, drawing, computing and communications, was common, that material on management and the organisation of construction and the construction industry was essentially common, and that it ought to be possible to reconfigure design work so as to include an appropriate building services component without undue difficulty. Thus, from the point of professional accreditation a four-year MEng course targeted at able students should have no difficulty in accommodating the requirements of CIBSE alongside an acceptable civil engineering content. As a result, accreditation on behalf of both the specialist CIBSE and the more general ICE/IStructE partners of the JBM appears feasible.

Outline course structure

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The development of four-year Master of Engineering courses has been much influenced by the Finniston Report (1980)[2], which records an official inquiry into the engineering profession. Its committee affirmed the need for a cadre of engineers capable of exercising leadership in the development of new technology and the operational management of engineering. It advocated that their education, rather than following the normal three-year course, should be directed through a new four-year MEng course, heavily oriented towards design, systems and applications. One outcome was that a few universities felt encouraged to set up four-year courses, and initially did so by adding an extra year of design, in the form of large-scale interdisciplinary projects and supporting seminar studies, to their existing three-year courses. A somewhat prior influence, the Dainton Report (1968)[3], had emphasised the need to attract more top quality young people into university degree courses in engineering and technology as potential industrial high-flyers. It argued that, for such as these to progress to full industrial leadership, they would need to be educated in a manner that would foster the acquisition of managerial skills and the development of business acumen. The University Grants Committee then made some funds available for instituting a few Dainton-style courses in which the normal engineering content was enhanced by the inclusion of substantial elements of business and management, linked to industrial practice.

In the intervening years, the four-year course has evolved by further development of the design and management enhancements. A greater depth of study in the technical subjects has also been sought, usually by incorporating a menu of advanced option subjects in the third and fourth years of the course, as would be found in the best Engineering Higher Diploma courses in continental Europe. This provides the foundation for the model MEng course in civil engineering employed in the current study. With slight variations, it will be found to provide the MEng course structure at many of the UK universities able to recruit an appropriately high-quality intake of students. This format is consistent with the requirements of the Engineering Council's SARTOR97 provisions.

An underlying principle is that the course should be attractive to bright students who enjoy technology, are computer-literate, and wish to continue their education through a challenging university course that provides wide and varied career opportunities. It should encourage creativity and reflect the increasing concerns of the young for protecting the environment. Above all it should stimulate their interest and challenge their intellect.

Young people of 16 or thereabouts have, at best, only vague notions of what they want to be or even what there is to be. So, present civil engineering as one of the best degree choices for those seeking a combination of creativity, environment, technology, and plenty of eventual career choice. Providing a sufficient fraction take up careers in construction, the fact that some see a civil engineering course as an interesting university experience and/or a passport to business, finance, administration, travel, etc, should be welcomed, since more of those with whom the construction sector deals will have an affinity with it.

Thus the ethos of how the course is taught and not simply its content is seen as vital.

Table 3 (overleaf) displays the model four-year course, taught in traditional full-year blocks. The following features have been identified as being of particular importance in guiding the construction of a new-style 'Engineering for the Construction Sector' course, one that remains securely founded upon the more conventional civil engineering material but now also embraces an appropriate building services / building physics content:

- Much of the first year must already contain introductory / preparatory material that, with very modest broadening of content, would be eminently suitable as the new style course.
- Properly conceived and supervised projects provide an excellent vehicle for including building services issues alongside conventional challenges.
- Relatively little specialist 'engineering science' from the building services area appears necessary. It does not seem reasonable (nor necessary on the basis of the view of practitioners) to require a fundamental understanding of such topics as electric motors, pumps, heat exchangers, etc. It is the operation of such equipment and its role in controlling internal environments that is seen as essential.
- Heat transfer and fluid flow are seen as the key topics requiring appropriate theoretical treatment; in the case of the latter much of the basic work may already be present in existing hydraulics courses.

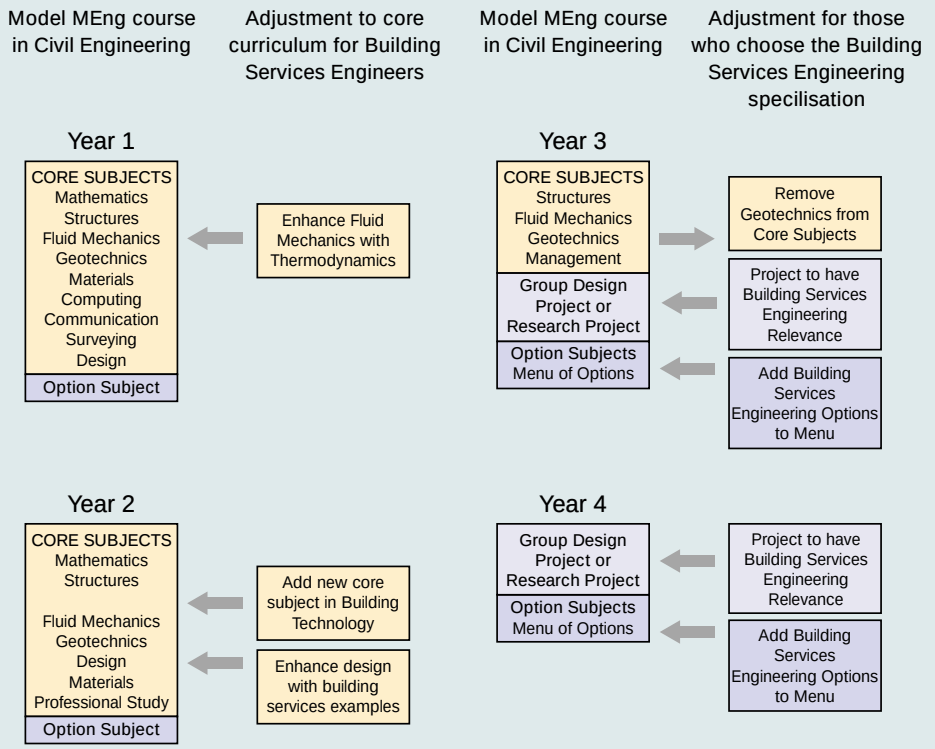

Table 3 - Model MEng course in Civil Engineering - Adjustment for Building Services Engineering

Subject descriptions

MATHEMATICS should be seen as a medium for communicating concepts, ideas, and information in a parallel way to text - and not as the mastery of a series of abstract processes with little or no linkage to physical understanding and application. It should instil disciplined thinking and rigour in the development of arguments based on assumption and simplification in modelling, should teach the importance of controlled approximation, and, above all, impress upon students its value as a tool to be invoked when quantitative evidence is needed to underpin assertion, hypothesis, or sheer physical intuition.

STRUCTURES should focus on how civil engineering constructions resist load through the mechanics of deformation and the development of internal stresses. It should recognise the central role of the computer in removing the tedium of actual calculation, thereby increasing opportunities to explore variations and to study cause and effect. Whilst being firmly founded on the principles of mechanics, it must enthuse the student by linking the fundamental behaviour of components to their role in imaginative, adventurous, yet practical and cost-effective structural forms.

FLUID MECHANICS should explore the properties of air and water and the principles governing these real fluids at rest and in motion, starting from basic mechanics but essaying the different applications to be found in civil engineering. An understanding of temperature, heat flow and the basics of thermodynamics, as encountered in the design of internal environments for buildings, should be accomplished.

GEOTECHNICS is about the engineering of the ground, soil properties, and the methods needed to build safely on the variety of conditions met in practice. In common with structures, teaching should foster an understanding of how different types of soil resist and transfer load, recognising the importance of special features such as changes with time, interaction with the flow of water, and disturbances caused by the actual construction.

MATERIALS should seek to furnish the civil engineer with the knowledge needed to make informed choices of appropriate materials for use in a range of practical situations, having regard to their abrasive, acoustic, corrosive, structural, and thermal properties. Whilst an appreciation of the role of chemistry in determining these properties is important, the focus should be on developing the ability to use materials appropriately in the knowledge that reference to specialists will normally be required for novel, unusual, and particularly challenging applications.

COMPUTING is an increasingly important tool for the civil engineer. However, whilst some exposure to programming teaches the importance of logical thought and precision, the civil engineer is far more likely to encounter computing as a service that underpins his mainstream activities. Thus the emphasis should be on developing the confidence to utilise appropriate software to support the engineering subjects - including, in the latter parts of the course, topics such as finance and management.

COMMUNICATION teaches the importance of conveying concepts, ideas, information, and images through speaking, writing, drawing, sketching, and whatever other (electronic) medium is appropriate to the task in hand. It should develop the qualities of clarity, brevity, appropriateness, variety and interest, and should seek to enhance the students' skills and confidence to engage with audiences of different types.

SURVEYING teaches the importance of measurement and positioning, linked to the need to transfer information from site to office and vice versa (setting out). It should enhance the students' appreciation of error and the need for appropriate levels of precision, introduce them to the concept of organising and planning tasks, and increase their spatial awareness. It must recognise the rapidly growing use of ever more powerful instrument systems, eg GPS, without losing sight of the essential principles of basic surveying, eg line and level.

DESIGN introduces the students to the creative process, linking this to the need to support choices with engineering and other knowledge. It must be taught in a way that recognises the open-ended nature of design, explains how seemingly contradictory constraints may be reconciled, and assists the students to form judgements. Above all it should stimulate imagination and adventure, tempering these with practicality and realism as appropriate so as to assist in the development of a balanced attitude towards ensuring 'fitness for purpose'.

PROFESSIONAL STUDY raises awareness of how a civil engineer operates in terms of the professional, environmental, legal, economic, and social context within which construction must function. The aim should be to ensure that students learn how to balance the scientific part of their education against the wider social issues, so that they emerge with a rounded view of the practice of civil engineering.

BUILDING TECHNOLOGY should explain how fundamental knowledge of heat transfer and fluid flow permits the design of internal environments that deliver appropriate levels of comfort. Some awareness of sound transmission, illumination, energy efficiency, and control systems should also feature.

MANAGEMENT introduces students to the science and practice of how individuals, groups, and organisations function when working towards the achievement of goals. Although focused on the particular issues associated with delivering construction projects, it should compare and contrast this with relevant insights from other industries.

GROUP DESIGN PROJECT provides the students with an opportunity to contribute as part of a team towards the design of a substantial multi-faceted constructed facility. It provides an opportunity to utilise knowledge and experiences from all parts of the course in an environment of challenge, operating against pressures of time and limited information.

INDIVIDUAL INVESTIGATIVE PROJECT provides the student with an opportunity to study in depth a topic not currently fully understood. The emphasis should be on seeking out information, adding some elements of personal contribution and presentation of the findings in a mature and usable form.

- Whilst 'first thoughts' might imply that students on the new course(s) would concentrate on building construction, reflection suggests that since they would develop a better appreciation of the operation of constructed facilities, their broadened expertise would find equally appropriate application in other areas of infrastructure, eg tunnels, power stations, chemical plant, mining, etc. As the civil engineering profession moves increasingly from 'designing and constructing' to embrace 'operating and maintaining', a better knowledge of operational requirements in general becomes more important.

Well-structured 'traditional' courses should be able to accommodate the necessary additional engineering science within the first two Years and should be able to permit a significant proportion of the final two Years to develop a varied building services engineering flavour - much of which could be integrated with more traditional civil engineering material. Both the investigative project and the group design required by SARTOR 3 provide vehicles for doing this.

A suggested structure for a course of this nature is provided in diagrammatic form as Table 3. It quite deliberately presents a 'minimum change' solution. Some departments may wish to respond more adventurously by drawing on particularly favourable resources. Encouragement is given in the next section on course content, where some of the possible variations of the 'minimum change' solution are suggested. Although first reading of Table 3 might indicate extra material being added to an existing course, it is the intention that the total amount of study not be increased. Indeed, since a frequent comment in JBM Reports on Accreditation visits is that present courses are overcrowded, some reduction in overall volume would probably be appropriate. Where adjustments require the insertion of new topics, it is expected that equal or greater reductions to certain of the existing topics would be made. Experience suggests that when academic staff take a pragmatic view of the content of individual courses and consider this against both the educational objectives and the requirements / expectations of employers, there is always some scope for making economies.

The rationale for the course suggested consists of the following. Suitable basic building services material in the form of appropriate 'heat and fluids' is introduced in Year 1, enhanced with further instruction in Year 2, complemented by some building services project work in design. The investment of reflection and effort in the way the first two Years of the course are delivered is key to inspiring interest in building services amongst a group of able students. In the final two Years, those so inspired are provided with more substantial building services opportunities through the investigative project, group design, and a programme of option subjects. It would, of course, be for individual departments, recognising their own particular characteristics, to decide on the details of their own scheme.

Course content

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Notwithstanding the benefits of diversity implied by the last sentence, we have been encouraged - largely by the responses to a draft version of this report received from a significant proportion of the organisations named in Table 2 - to put forward some thoughts about desirable subject matter. It should be emphasised that these comments are offered for reflection and are not intended to be at all prescriptive about the content of the new type of course that would meet with accreditation approval from CIBSE.

Year 1 and Year 2

Many of the Year 1 and Year 2 fluid mechanics and hydraulics programmes in civil engineering degree courses would need modification to encompass the basic heat transfer and thermodynamics aspects appropriate to buildings. Moreover, it is clearly advisable that, perhaps through 'Structures' and 'Design' or otherwise, early core knowledge of building form and building construction should be planted. Ideally, the opportunity should also be taken to begin the development of awareness of architecture in design, of precedent, and of the role of architects in building, clearly a part of the ethos that should evolve throughout the course.

Within the proposed core subject of 'Building Technology', in addition to the expected building physics and human responses to the internal environment, there is scope for covering the basic electrical, mechanical, and transportation aspects of building services, emphasising the interdependence between structure and services. Although this is an additional subject for most traditional MEng courses, there should be room for it in the Year 2 curriculum, possibly by means of a little judicious pruning of other material. In the first two Years, most civil engineering MEng degree courses include an introduction to environmental engineering: it would be highly appropriate for it to include specific reference to the building environment - in relation to climate, energy consumption, and sustainability.

Year 3 and Year 4

There is a widespread opinion that Year 3 'Geotechnics' should not be compulsory for those who opt for the building services engineering specialisation, thus freeing more time for an additional and relevant elective subject.

Both Year 3 core courses in 'Structures' and 'Fluid Mechanics' are traditionally quite analytical in their focus. They do have relevance to building services, although to establish that relevance they might benefit from some refocusing. On the other hand, it may be possible to argue that, for some MEng courses, all the core elements should be completed by the commencement of Year 3. This would offer the prospect of a substantial variation of the model MEng course from the 'minimum change' solution.

In Year 3 and Year 4 of the new course, there is very considerable scope for constructing an elective programme in building services engineering that would draw on specific skills and expertise from within the university and, particularly, from practitioners in local industry. It might be envisaged that a student could be allowed to choose up to 50% of the required elective subjects from the specialisation in building services engineering, thus conforming to the notion that a UK undergraduate course should not be overly specialised. On the other hand, many of the best continental European Higher Diploma courses in engineering are structured to permit a single specialisation in the final year. For that in building services, sufficient breadth might be gained by linking building services electives to further studies in architecture and structural engineering. Again, this would open the prospect for a further variation in the 'minimum change' solution.

The elective subjects for building services engineering might be packaged in many ways. The following list neither proposes a preferred grouping, nor is it necessarily complete.

Applied Heat Transfer: heating of buildings; natural and power-assisted airflow
Energy Usage: low-energy design; energy storage, conversion and control; sustainability
Internal Environment: psychrometrics, comfort; lighting; acoustics, noise and vibration
External Environment: climate and climate change; wind; daylighting
Electrical Engineering of Buildings: power; lighting; safety and control
Communication Systems: telecoms; IT and control networks; system integration
Building Systems: heating; cooling; fire & safety; transportation; waste disposal; integration of services
Façade Engineering: the building envelope
Facilities Management.

With the current environmental concern over issues of sustainability, there has been an understandable burgeoning of interest in energy use in the engineering of buildings.

Motivation of students to study building services engineering

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The obvious premise is that nearly all students who would be likely to enter the proposed MEng course would do so principally from an attraction to civil engineering. However, if the highlighted point in Section 5 regarding course ethos is properly followed, such courses should be attractive to a far wider range of young people - especially those looking for a broadly-based challenge at university that provides entry to many later career choices. With effective guidance and example, many of those that enter for these more general reasons will be persuaded that the construction sector can meet their career expectations.

At the more specific level of 'marketing' the building services route, some positive action is called for to ensure the successful uptake of the building services engineering option scheme in the third and fourth years of the course. In the first and second years, two lines of action in particular are almost self-recommending:

- The properly conceived and supervised projects into which building services engineering issues are integrated, especially when related to real and topical projects, form an excellent means of advertising the later option theme.
- Appropriately constructed vacation training in the building services sector has proved to be a valuable element of the recruitment strategy practised very effectively by some firms.

Building services engineering education in continental Europe

7

As is well known, the traditional style of higher education for engineering in continental Europe involves two types of courses. Some universities offer diploma courses, which are typically concerned with a thorough but essentially practical coverage of current technology. Such courses are nominally of three years' duration but may take perhaps four years to complete. In addition to awarding the diploma to successful participants, these same universities may also be authorised to confer the professional title of Technician-Engineer, or its equivalent. A mostly different group of universities offer higher diploma courses, which aim to provide that deeper level of understanding appropriate for graduates who will in the future direct the industry and advance the technology. These courses are nominally of five years' duration, although they may perhaps take seven years to complete; graduates may then be awarded the title of Engineer, together with the higher diploma, by universities invested with national authorisation to do so.

A limited amount of information so far gathered on Germany, Spain, Italy, and the Czech Republic seems to indicate a typical pattern for providing higher education in building services engineering in continental Europe:

- Diploma courses, specifically and wholly in building services engineering, are given at a few universities. Although aimed mainly at serving the more practical needs of 'pipes and wires', the content is often extensive and thoroughly covered in the three- to four-year courses.
- Higher diploma courses associated with certain professional careers may offer building services engineering as one of a number of specialities that may be chosen in the last two or three years of the five-year courses. Such higher diploma courses are mostly in architecture, which in continental educational practice often has a significant engineering content. However a few higher diploma courses in civil engineering and in industrial engineering also have been found to offer building services engineering as a specialist option theme.

Conclusion

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The investigation and study sketched in this report supports the conclusion that traditional MEng courses in civil engineering, constructed in a manner similar to the basic model considered herein, are capable of reconfiguration to serve as an additional route into a career in building services engineering. This career route would be additional to that satisfactorily provided by the traditional undergraduate courses in building services engineering.

Of course, this is not the only possible additional route. The postgraduate conversion course, attracting good quality graduates in electrical and mechanical engineering, general engineering, and physics, has been tried before with undoubted success; yet its viability is always likely to be at risk from the volatility of the postgraduate recruitment market. Again, somewhat akin to the continental higher diploma model of providing a building services speciality within a programme of architecture, there is scope in the UK for a higher-level undergraduate course in architectural engineering in which building services form a major feature.

A particular benefit of the additional route offered by the amended model civil engineering course proposed in this report is that the graduates would be thoroughly steeped in the technology of construction and therefore able to make a broad contribution to engineering the building and its services. Furthermore, for such appropriately amended courses, cogent reasons have been adduced to support the contention that accreditation for building services engineering, in addition to that for civil and structural engineering, would be feasible.

Particular attention is also drawn to the importance of the course ethos, a feature that applies equally strongly to conventional civil engineering courses. Notwithstanding that declining take-up of university courses in science, engineering, and much of the construction sector is the result of a complex interplay between the situation in schools, the public perception of industry, alternative opportunities, etc, any attempt to ensure that university civil engineering courses provide attractive educational opportunities is, of course, only a part of the necessary corrective action. But it is the only aspect specifically addressed by the brief for this report. Thus whilst concerted action on many fronts is undoubtedly required, those responsible for mounting, advising on, or accrediting university civil engineering courses of all types are strongly advised to reflect on the highlighted paragraphs on page 13.

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Prof David A Nethercot

David Nethercot is currently Head of the Department of Civil and Environmental Engineering at the Imperial College of Science, Technology and Medicine. Consisting of some 45 academics, over 150 MSc students, a highly international mix of undergraduates, responsibility for an extensive research portfolio, and frequently involved in advisory work for the construction industry, it is the largest civil engineering department in the UK and has achieved the top rating in every one of the Research Assessment Exercises.

Prior to taking up the position at Imperial College, David Nethercot was for 10 years Professor of Civil Engineering at the University of Nottingham, being Department Head for five. As a member of the Joint Board of Moderators for seven years he has been extensively involved in professional accreditation both in the UK and Overseas. For the three years immediately adjacent to the introduction of SARTOR 97, he was Chairman of the Board. His research interests in structural engineering have provided opportunities to visit universities in more than 50 countries, permitting him to develop an appreciation of the different styles of engineering education on offer worldwide.

Professionally, he has been a member of the Standing Committee on Structural Safety, currently chairs the BSI Committee responsible for BS5950 and is Chairman of the Technical Committee of IABSE. He is presently a Vice President of the Institution of Structural Engineers and a member of the Council of the Royal Academy of Engineering.

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David Lloyd Smith joined the academic staff at the Imperial College of Science, Technology and Medicine, University of London, in 1971, and is Reader in Structural Mechanics. Currently, he is College Tutor - a Dean of Students by another name. For some time previously he was Director of Undergraduate Studies in the Department of Civil and Environmental Engineering. In this role, he led the team responsible for the design, planning, and implementation of the Department's MEng courses, and he established the continental European links and curricular framework upon which the department's MEng courses with a Year Abroad were founded. Although much involved in engineering education at Imperial College, he heads the department's Systems and Mechanics research section and has contributed to almost 70 technical publications, mostly in the computational mechanics of structural plasticity.

Attracting the best and brightest: Broadening the appeal of engineering education

A Report

In 1999 The Trustees of The Ove Arup Foundation published a study entitled 'Interdisciplinary Skills For Built Environment Professionals' - otherwise known as the 'Gann Report'. In it, Prof David Gann and Dr Ammon Salter highlighted the serious decline in applications from bright young people to study engineering in general, and built environment courses in particular. A particularly serious skill shortage was found to lie within the building services specialities.

In the light of this, and observing young people's career ambitions, environmental concerns, and attitudes to technology, the Trustees wanted to explore further how an engineering degree course could be constructed that encourages greater interdisciplinarity, that further develops creative thinking, and could also be accredited together by the responsible UK engineering institutions. The present report, commissioned from Prof David A Nethercot and Dr David Lloyd Smith of Imperial College, sets out a positive and highly encouraging way forward.

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