Dick Fenner
Editorial Advisory Panel

Editorial

R. A. Fenner PhD, CEng, MICE, FCIWEM

ROMANS, INCAS AND THE YOUNG ENGINEER

Having been involved with the journal since its inception and launch in 2003, I am delighted to write this editorial before I step down from the Editorial Panel later this year. My career has largely been spent in engineering education and research, and I have been involved for nearly 30 years in introducing environmental awareness and latterly sustainable development issues to both civil engineering undergraduates and postgraduates, especially through the MPhil in Engineering for Sustainable Development, at the University of Cambridge. In that time the seriousness with which these issues are taken has gradually improved.

It is now a fundamental requirement that all civil engineering degrees provide a good understanding of a broad range of inter-related social, economic and environmental issues, with 'sustainable development integrated into existing teaching and pervasive throughout the engineering education programme'.¹ Indeed on a very recent accreditation visit to my department the first question asked by those representing the Joint Board of Moderators (JBM) was: 'What are you doing about sustainability?' What was more important was the spirit behind the question: the desire to see sustainability issues embedded naturally across the whole curriculum, and not just as a bolt-on extra module or two which might be chosen as a specialism by only a subset of students. Much progress has been made in this direction, and there are some excellent examples of good practice in many civil engineering departments, yet there are still fundamental challenges which need to be addressed in relation to how young engineers, just starting out on their professional careers, are equipped to deal with these concepts and the additional constraints they represent.

Engineers generally divide work into tightly defined jobs and narrowly organised work units, with communication or joint consultation across these units being uncommon.² This tendency to compartmentalise work, knowledge and skills can be an obstacle by restricting broader perspectives and integrated solutions. Sustainable development requires decisions to be more encompassing of the factors considered, and engineers to be more broadly educated and more conversant with non-technical and non-engineering influences over decisions. While retaining a robust approach to problem solving, engineers are increasingly being called upon to work closely with the social sciences and humanities.

Much has already been written about the skills which will be necessary for engineers to meet the challenges required for sustainable development. For example the Institution of Civil Engineers' task group has suggested that engineers should have the ability to work with complex/ill-defined problems. Initiatives such as the Royal Academy of Engineering (RAE) scheme to fund visiting professors in engineering design for sustainable development in universities across the UK is making steps towards this aim. Since it began in 1998 the scheme has enabled senior engineering practitioners from industry to contribute significantly to the activities of academia in respect of curriculum development in this area and has produced a variety of outcomes.³ These include a set of principles⁴ which help illustrate the importance of sustainable development and what can be achieved in a practical context. One of the outputs of the scheme is a collection of case studies that demonstrate the much useful good practice that is already being achieved. These highlight the need to recognise that a class of problems exist where there is simply not enough information and there are no objectively right answers. A further consideration in modern engineering education is recognition that ethics and values are as important as scientific advance.⁵

The Engineering Education for Sustainable Development conference series (EESD 2002, 2004, 2006)⁶ also has identified the need for a more integrated multi-disciplinary style to develop bridges between the technical and physical sciences and the humanities together with an appreciation by engineers that there are limits to what can be achieved through technology alone. In this respect it is important to understand that singular prescribed technical solutions may not be capable of addressing real needs. Value judgements also play an important role and engineering education should not be exclusively about facts and empiricism, but should embrace ethics, creativity and social responsibility.

Perhaps the best way these objectives can be achieved is by using sustainable development as a way of exploring the context in which engineering services are delivered. This implies providing more breadth in engineering education. It remains an essential requirement that engineers develop a rigorous understanding of the physical and mathematical principles through which their designs will function, but engineering design is only a part of a spectrum of skills needed in the delivery of projects, products and services. Engineering is affected by, and affects, other issues that are not so easily defined. So while engineers frequently see

ourselves as 'problem solvers', much greater attention needs to be placed at an earlier stage in the process through careful 'problem definition' to ensure that the real needs underlying an issue are actually met. This requires dealing with non-technical details and young engineers must have an understanding of the qualitative as well as the quantitative aspects of their practice.

Roland Clift and his colleagues at Surrey University⁷ have developed an interesting distinction in which they prefer to see engineers as 'honest brokers' who recognise that the knowledge needed to reach an accepted decision does not reside solely with technical experts. Honest brokers use their special skills to ensure that the scientific and technical information is presented clearly and without bias, especially when appraising the technical merits in a range of alternative options. This differs from 'technical advocates' who may press for predetermined solutions, in the more traditional 'decide—announce—defend' approach, in which there is only a preferred 'right answer'.

A colleague at the Massachusetts Institute of Technology in the USA, John Oschendorf, uses a comparison of Roman arch bridges and Inca grass bridges to explore very effectively a range of sustainability issues, including the wider context in which the bridge is required to function.⁸ He compares the specification for a Roman arch bridge which is designed for longevity and which requires very high quality workmanship and the use of materials which can be reused in future construction, with the temporary Inca structure which is less expensive, having a short life span using low impact materials, mostly based on grass ropes. Which is the most sustainable?

The Roman arch bridge is characterised by low stresses, low maintenance, long lifetime, high initial cost, reusable materials and a high load capacity. It is perfectly suited to an expanding empire, in which the bridge demonstrates permanence, suggesting to local populations that the Roman Empire is here to stay. The Inca bridge is rebuilt annually from ropes made from local plants or grass fibres to a design that has lasted at least 500 years. This rope bridge is characterised by high stresses, high maintenance, short lifetime, low initial cost, renewable materials and low load capacity. Both not only fill their engineering function well, but also serve the wider context in which they must operate. In particular the Inca bridge uses environmentally sound materials which are locally available, and the maintenance plan is fundamentally tied to the social fabric of the community. Each year the bridge is reconstructed as part of an important annual festival of renewal which provides an important focus for the community where every member of the society makes a contribution to the effort involved, thus providing a focus and purpose for the society and adding to the glue of social cohesion. The context of both of these bridges therefore extends beyond merely the engineering brief of crossing a river or ravine, to the surrounding society for which the service is provided.

With these thoughts in mind, it is encouraging to see young engineers at the beginning of their careers rising to these challenges. The first piece in this issue is an edited summary of short responses by the 13 'Telford Apprentices', currently assisting the President with his duties, to the question: *what can young engineers do to best promote and deliver the sustainability agenda?* In their own way they have each embraced

the spirit of sustainability, and demonstrated very good understanding of the modern context in which engineering services must be provided. While each short piece has its own individual flavour and theme, collectively they reinforce the sustainability message well. This suggests that those just starting out in the profession do have a very good understanding of the issues that need to be faced and share a common vision of how engineering sustainability can be achieved.

Some of the ideas which emerge are worth highlighting here: including a recognition that it is not good enough to add environmental performance as an afterthought in the delivery of any project, the need to accept (personal) responsibility and to ensure a multidisciplinary perspective and encourage strong communication between all parties. Concepts such as life cycle analysis, the precautionary principle approach to risk, whole life costing, the global impact of some engineering decisions and the need to look at a bigger and long term picture are also key themes. Some of the pieces take as their focus topics such as infrastructure maintenance, design, bridges and transport, climate change and social issues while several of the apprentices point to Telford's foresight and the need to seek integrated solutions. Not all the essays are purely idealistic, recognising that there are real difficulties of implementing sustainability principles at the grass roots level. However the drivers for change are increasingly seen as being led by clients, funders and planning authorities. Perhaps Sally Walters provides the best summary when she says 'the biggest challenge facing modern engineers is to balance the needs of a continually developing, fast paced world, with changing global conditions, while considering the needs of our future generations'.

The first briefing note, by Vicki Mistry, provides an excellent summary of BREEAM—BRE's long-established environmental assessment method for buildings. BREEAM's credit-based system is clearly explained and well illustrated by a description of how four contrasting buildings (all winners under the annual BREEAM awards scheme) achieved their scores. A second briefing note by Lucy Goldring reviews the recently re-launched regional sustainable development framework for the south west of England, and provides details of a web-based online forum in which user feedback can be provided, for sharing experiences in using the new 'Sustainability Shaper' tool.

The first full paper is by Derek Carder, Les Hawker and Tony Parry and describes a study looking at the feasibility of generating renewable energy on motorways and trunk roads, in this case by using noise barriers as solar power generators. A series of detailed trials in a cutting to the east of Junction 9 on the M27 are described. These include an assessment of the performance of the photovoltaic installations as well as their impact on driver distraction. A whole life cost of a larger installation was estimated so the potential value for money of more widespread use of solar panel noise barriers could be determined. The paper concludes that the installation costs are not covered by the electricity generated over 30 years (at current values), and any financial benefits will need the environmental benefits of using renewable energy to be monetised and included, or subsidies or changes in electricity pricing to be introduced.

Stephen Ison and Tim Ryley's paper is also related to transport and considers options for sustainable mobility. The authors

propose a simple economic model which sets the problem in context and focuses on demonstrating pollution effects. They examine three approaches, namely: market-based solutions, technological change and the promotion of sustainable modes of transport. The paper makes good use of data from the Office for National Statistics and argues that each option has distinct advantages, with no 'one solution fits all' and therefore recommends all options should be actively progressed.

The final paper by Watson and Shaw provides a technical appraisal of the energy generation potential from a Severn Barrage prior to full commissioning. Making comparisons with the existing scheme on the Rance Estuary in northern France, the study illustrates the output patterns of the Severn Barrage once the barrage is closed but before project completion, with electricity generation possible during the construction phase.

All of these papers address key issues of energy generation and transport, and demonstrate both the scale and difficulty of the problems we face, as well as the ingenuity with which engineering solutions can be developed. It is this joint capacity both to recognise the nature of the problem (and all its constraints) and to strive for technically elegant and robust solutions that are the skills needed by current and future generations of young engineers. In concluding, I am reminded of a remark from one of my own recent students who said 'we are

not simply educating the minds of the future, but educating the minds that will ensure there is a future'.

REFERENCES

1. http://www.ice.org.uk/JBM/docs/h_AnnexC-Sustainability.doc
2. CROFTON F. S. Engineering on and off the road: sustainable development policies and practice. *Developing Ideas Digest*, 2004. See <http://www.iisd.org/didigest/special/crofton0.htm>.
3. See <http://www.raeng.org.uk/education/vps/sustdev/default.htm>.
4. DODDS R. and VENABLES R. *Engineering for Sustainable Development: Guiding Principles*. Royal Academy of Engineering, London, 2005.
5. PARKIN S., JOHNSTON A., BUCKLAND H., BROOKES F. and WHITE E. *Learning and Skills for Sustainable Development—Developing a Sustainability Literate Society. Guidance for Higher Education Institutions*. Higher Education Partnership for Sustainability/Forum for the Future, London, 2004.
6. See <http://www.eesd2006.net/>.
7. AZAPAGIC A., PERDAN S. and CLIFT R. (eds) *Sustainable Development in Practice: Case Studies for Engineers and Scientists*. John Wiley and Sons Ltd, Chichester, 2004.
8. OCHSENDORF J. *The Role of Bridges in the Inca Empire*. Harvard Department of Anthropology, Graduate Seminar in Andean Studies, March 2003.