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Making of an engineer

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The term 'Engineer' is often used to describe people belonging to many trades, for example, any household appliance installer or repairer. On the contrary, legal systems in some countries of Continental Europe and Latin America restrict the use of this title only for people with engineering degrees. However, completion of a degree education is not enough on its own for a prospective professional engineer. This paper describes various basic aspects that are vital for making of an engineer, including initial affinity to sciences such as mathematics and physics that has to be reinforced with training, experience and self development.

Introduction

The popular encyclopaedic definition of engineering considers it as the link between art and science. An engineer should be trained to develop safe, elegant, efficient and economical solutions to practical problems, by applying scientific knowledge, for example mathematics and physics, while considering technical constraints. It follows, therefore, that the engineering profession is suitable for a person with natural inclination towards physics and mathematics, and a better than average educational achievement. After completion of university education, a graduate would normally undergo rigorous training for some four or five years before he or she can become a professional engineer. At this stage, many engineers may receive remunerations that could be less attractive than those available to young people of the same age group in other lines of work, for example, salesmen, dealers in money market, etc. It may seem difficult to understand, therefore, why a young person, talented and intelligent, should persevere with a choice to become an engineer. In some cases, some engineers do move over to management after two-three years of gaining their academic qualifications, some move over to positions in financial institutions, where their sharp minds and problem-solving skills could bring much higher rewards. However, some good engineers continue with their profession, perhaps because their work on structures and buildings brings them such sense of achievement and satisfaction that could not be matched by greater financial rewards. The writer believes that engineering becomes a way of life, an experience that is common to genuine engineers irrespective of their different circumstances, for example, religion, language, nationality, etc.

Historical background

Engineering came to the help of mankind when human beings could not depend only on the limited number of caves for protection from the elements. A set of trees leaning against each other may have inspired the construction of early shelters from rain and a tree fallen across a rivulet may have given birth to the concept of bridging over openings. Rolling of round shaped stones could have promoted the development of wheeled carriages.

C.V. Kand[1] has given an account of the ancient Indian science of building *(Vastushastra)*, which goes back to some 7000 BC. There were places for learning (*Ashramas)*, where the sages *(Rishis)* researched and taught science and technology along with classical subjects. Mr. Kand's paper on *Vastushastra* includes some fascinating illustrations of protection of buildings from elements with conical roof shapes, planning of buildings including their location and orientation, old concepts of developing cities on riverside, etc.

In Europe, there are examples of outstanding structures like the Tower of Pisa in Italy, St. Paul's Cathedral in London and many large palaces and places of worship built during the past centuries. In parts of England, 'experienced' master-builders would build churches on the basis of thumb rules. There are instances of collapse caused as a result of a variety of reasons. For example, Selby Abbey in Yorkshire was built originally as a Benedictine monastery. The building that stands today, albeit restored after part of the tower collapsed in 1690, was started in the 12th century. The abbey sits just three feet above the water table and during building, as everything started to settle, subsidence and cracking became apparent. Eventually, when the tower seemed to be stabilised, the work recommenced and the building was completed, although in all it took about 130 years to finish.

By the end of the 19th Century, there were developments to formulate some rules to assist pre-planning of buildings before the construction started. Codes of practice came about later in the beginning of 20th Century. The engineering approach has rapidly progressed over the past hundred years, with research and development in construction materials and techniques of assembling various products to construct building frameworks and the cladding, including various services and amenities essential for the users.

Basis of engineering – Mathematics and physics

It is essential that a student of engineering should have understanding of basic principles of mathematics and not just the mechanical skills of multiplying and dividing with the use of memorised tables or calculators, and he or she should not depend only on computers for the analyses. In olden days, one would learn by heart multiplication tables up to 29 and fractions up to 3¾. The writer believes that one should learn by heart only a few tables, say up to twenty. No one should cram up and memorise numbers like parrots. On the contrary, one should try to work out some basic problems for oneself. For example, many students would not bother to know why (-3) x (+2) should be (-6) and (-3) x (-2) should be (+6). Many adults would be content to press the buttons of the calculator and get the answer. The simplest way to understand this is to give meanings to the signs, with reference to the present position. 'Plus' sign should mean 'forward' or 'in future' or 'in credit' or 'better off'. 'Minus' sign should indicate 'backwards' or 'in the past' or 'in debit' or 'worse off'. Then the multiplication of numbers with signs becomes a statement, for example, the result of giving away £3.00 every day after two days. Here, the sum of £3.00 has a minus sign (in debit) and the period of two days has a plus sign (in future). The right answer is -£6.00, which means that one will be £6.00 worse off in two days time compared with his or her present position. Similarly, with the rate of giving away £3.00 per day (-3), one should have been £6.00 better off (+ £6.00) two days ago or in the past (-2), compared with what he or she has at present.

Mathematics has a strong link with the basis of engineering. Engineering is an applied science or an approximation of physics and physics is an approximation of mathematics brought about by the 17th century mathematicians. Mathematics is about facts that are absolute and limitless, which appear to exist only in theory. For example, a curve given by a mathematical relationship between 'x' and 'y' can extend to infinite values of 'y'.

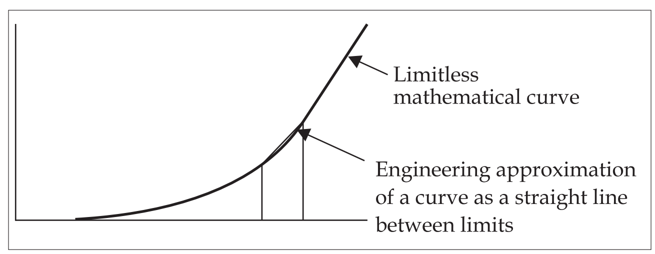

Figure 1. Engineering approximation of rules of mathematics and physics

The curve given in Figure 1 shows emergence of engineering rules, with their origin in the abstract and limitless ideas involving mathematical expressions. Physics makes use of approximated mathematical expressions for derivation of rules, for example, Hooke's Law applicable to elastic deformation of an element. Such laws and principles are then applied to formulate engineering design rules and methods of analyses, with further approximations that are justifiable for a particular construction material within certain limits, for example treating part of the curve as a straight line. Furthermore, Hooke's Law features in estimating response of members to applied loading, even if they are made with material that may not be truly elastic, for example reinforced concrete. Such design rules are validated with sufficient number of tests on specimens with variations in key parameters. Factors of safety are then used to provide against any uncertainties in modelling, potential difference between test conditions and real life situations, etc.

Sources of knowledge and development of a professional

Knowledge is gained and developed through some well known sources; for example, tuition, reading, thinking, observation, discussion, etc. Tuition is generally for the young age, provided by teachers in schools and by parents at home, and its usefulness diminishes as the person gets older and experiences circumstances different to those prevalent during the lives of his or her teachers and predecessors. Most discerning teachers and parents realise that spoon-feeding or prescriptive teaching should not continue for very long. It would appear that the 'A' level stage of education in the UK does this and the self-development instinct is promoted in an appropriate manner at about 16 years of age, quite different to the earlier stage of direct teaching. Success at 'A' levels, therefore, forms a suitable basis for engineering education, not just because the 'A' level stage is difficult but mainly because it can prepare an aspiring student well in his or her future training and work as an engineer.

There is one significant difference between engineering and some other forms of education. Engineering education has to undergo a continuous further development through thinking, observation and discussion. While thinking and observation could result from work on various projects and the associated problem-solving, development through reading and discussion requires special effort on the part of an individual. In this context, organisations like the professional institutions (i.e. the Institution of Structural Engineers) provide invaluable services to their members, in the form of journals, seminars, libraries, technical presentations, etc. Such development has to be continuous, a part of what is commonly known as Continuing Professional Development or CPD. Those members who do not attend any technical meetings or take any active part in the work of their Institution, or keep the journals in their wrappings or flick only through the job advertisements, are really doing themselves a disservice. There is no real sense in the argument whether CPD should or should not be mandatory. Members must believe in it and take steps on their own to keep themselves up-to-date.

The economical climate in the UK has resulted in general reduction of training available to young graduates. One has to be fortunate and academically exceptional to get employment with the top engineering consultants and contractors, where they groom young engineers to cope with the high-tech world of specialist design and construction. Medium or small consultants and builders perhaps cannot afford such activities, on account of circumstances resulting from fee competitions and work load. The writer's employment with Gammon India Ltd goes back to the period from 1960 to 1967 and he would not know first hand about the experience and training available to all young graduates in India today. Gammons required that a graduate, aspiring to become a design engineer, should work on drawings for at least six months and then do quantity surveying for some time before he or she could attempt any modest design of a structure like a water tower. Training of contract personnel and site engineers was equally rigorous and systematic. It is understood that some firms like Ambuja Cement do hold regular courses in design and concrete technology for their staff. It also seems that some institutions have started training construction operatives. However, it could take some years to see any significant improvement in the level of workmanship on construction sites in India.

Engineering judgement

It is often said that engineering design requires sound judgement and appreciation of various parameters that are important for design of a building. The aim is to plan a building that will be fit for the purpose, with an acceptable level of reduction in risks that may be encountered during the life of the building. Some common design procedures may give loading or actions on structures that may not have any real scientific basis and assume properties of materials that may not be clearly understood. Budding engineers should not feel down-hearted because of any such apparent imperfections. After all, many things in life are not fully understood in an absolute sense. There are many examples of this phenomenon, for example insufficient knowledge of the space, environment and human body, and uncertainty about human behaviour and reaction to various circumstances. Engineers must appreciate that common methods of engineering design do require approximations but they are expected to be used by those with sound judgement acquired through knowledge and experience. Most importantly, they must be aware of the scientific basis of design methods and the rules, and they must clearly understand the limits within which the rules would apply in their approximated form.

In this context, one must really appreciate the work engineers do. They have to design and build structures that should have a useful service life, say sixty years or more, and withstand actions and hazards that can be foreseen at the time of designing them. This task cannot be speculative in any sense but it must rely on judgement, past experience and tried and tested application of science. Much of the design process, typically for common building situations, appears to rely on Codes of Practice, which may have been prepared by experts with knowledge and experience. However, the design rules may have been based on experiments carried out some years ago, using materials common at the time of drafting the codes. Such guidance may become out-of-date with rapidly developing construction practice and with the use of innovative construction materials. Reliance on Codes of Practice, therefore, must be supported by an engineer's sound sense of design and ability to apply his or her own knowledge and individual skills.

Sound sense of design comes after varied experience coupled with knowledge and individual flair. Experience is often quoted in number of years, which is misleading if not meaningless. One may have experience of working in a limited field and under someone with opinionated and rigid ideas. Such layer of experience may provide a short-term reward but it could be a hindrance when adapting to changing practices, and it may deprive an engineer of the ability to consider a change on its merit and manage it to suit. There are many examples of such narrow experience, for example, recent discussion on emerging Eurocodes in the UK and resistance to Limit State Codes in the past.

Professional training tends to give engineers certain single-mindedness, which may be different in character to people in other walks of life. Mrs Usha Tambe[2] has described the reaction of her husband, an eminent engineer, at the end of an Indian film. They were watching the film in company of their friends, which was full of high drama. The film ended with a scene depicting the beautiful heroine, a common girl, being encased alive with brickwork as a form of capital punishment for falling in love with the Crown Prince of the *Mughal* Empire. As it happened, some caring and humanitarian stalwarts in the Court of the Emperor had planned her rescue through a secret tunnel to take her away to safety. At the end of the film, the engineer's wife and friends were full of praise for the story, acting, music and artistic scenes of the *Mughal* court. Our engineer, however, calmly commented - "The director has made a mistake in showing wrong type of bricks for the time in North India, that is at the end of the 16th century!"

Presentation of work of an engineer

In the present-day world, it is not enough to have single-minded excellence and an inward-looking vision about the engineering profession. Engineers are often criticised for their inability to communicate with words, having been brainwashed into believing that drawing is their language. An engineer is quite likely to take out a pencil and a sketch pad, even when a simple question is asked! Quite often, the older engineers may project an image of self-rightousness whereby they appear to consider others incapable of understanding their work.

In the year 1991, the writer changed his work from project engineering to a policy division of the UK Government. One of the tasks was to provide written answers to Parliamentary Questions. The writer politely asked a senior officer whether a small sketch would be in order. The senior man was horrified and swiftly ruled out the crazy idea of presenting the Minister with anything other than words! Apparently, there was a blockage in the writer's mind that caused a problem when converting thoughts into words without drawings. The senior officer believed that such blockage could be cleared by writing something, even non-technical articles, first in one's mother tongue and then in English. According to him, all powers of expression should start with the use of one's mother-tongue and people with good grasp of their mother-tongue would be more likely to master other languages. Many people in the UK, and even in Mumbai, should consider this advice seriously and not boast about their children unable to speak their own language.

As far as the professional work of an engineer is concerned, the first important aspect should be confidence in his or her work, as a result of education and training. It is inadmissible to give an answer about safety of a structure in any way other than "Yes, it is safe!" This is in contrast with a politician who may use the words "May be, all things being equal, under the right circumstances, etc. etc." A senior supervisor in Gammon India Ltd used to ask young graduates to check their own design ten times to be sure that the bridge would be safe for use. For example, one must spare a thought for the thousands of trusting worshippers, who may pull the chariot of *Jagannath* over a bridge one day, with their full faith in the engineer!

Secondly, the design presentation has to be suitable for a peer review. It is a common concept in most quality assurance systems that one person presents the design for another person to carry out an independent examination. This makes it essential that the presentation is clear. The following list contains some common expectations from a well presented design, although this may not be exclusive:

1. The written work must be with good margins and clear hand-writing. The best advice could be to 'print' it, as if the text were to be the same as manuscript notes on a handmade drawing. Sketches must be clear and complementary to the calculations.

2. The presentation must have a statement of methodology and design assumptions to start with, along with the scope of the project. Proposed use of the structure, choice of construction, exposure conditions and various loadings and their combinations should be clearly stated.

3. There must be clear references to formulae and figures in the right hand margin. Codes of practice, guidance documents and any other references should be quoted against any rules used in the design. Quite often a figure is shown, say 'Point load of 80 kN' without any indication of its origin. This makes a peer review very difficult.

4. In the days of computer outputs, it is not desirable to give large and unnecessary print-outs of calculations, say with a twenty point bending moment diagram for a simply supported beam. A computer output should be preceded by clear manuscript statement of the input and it should be followed by a summary of salient results.

5. Properties of the foundation strata must be ascertained through soil investigation. Soil is an important structural element for the stability of the structure and safe transfer of the loads to the ground without excessive settlement or differential settlement of any kind.

Perception of life from engineering point of view

Pure mathematics is about numbers but they are of no real use on their own. For example, '1' and '10' are numbers that mean something only when one uses them to describe quantities , say one bag and ten apples. Addition, subtraction and multiplication are commonly understood operations but one can only divide a quantity (numerator) by another (denominator) as long as the denominator is not 'zero'. A division by zero would tend to produce a limitless quantity described as 'infinity', which can only exist as a concept and not as a number. Students of science would have experienced this as the immeasurable size of an image produced by placing a tiny object at the focal point of a convex lens or as countless reflections of an object placed in between two parallel mirrors. In a practical sense, it is impossible to quote the smallest number next to zero or to work out the largest of all numbers. One has to accept simplifications, such as one pence being small enough as an amount and 10 million pounds being a very large sum. Users of computer-aided drafting software will know that the 'model space' is equivalent to an infinite space and the 'paper space' enables us to pick up an object in a 'view-port' to a scale of our choice, just as a camera captures an image on the film through its aperture, with size and orientation as chosen by the photographer.

This idealisation of the 'absolute' is at the heart of engineering, evident in treating structures as simplied models, adoption of design loads on buildings based on experience and statistics and assessing properties of construction materials through testing. None of these procedures are perfect and the lack of perfection is covered by suitable factors of safety, which are meant to ensure that the structures will have sufficient resistance to withstand the foreseeable actions or hazards. This process is closely associated with assessment of risk. Such assessment must be based on a realistically estimated magnitude of the hazard and probability of its occurrence, as derived from judgement, experience and statistical data.

It is indeed very difficult to design a structure on the basis of a perfectly meaningful and individual risk analysis, in the absence of a large enough statistical data and experience of many critical parameters associated with the project. The term 'Risk Analysis' is commonly mentioned in some cases, for example, in the context of Health and Safety File as a hand-over document where a designer is really meant to identify residual hazards and not analyse any risk as such. In case of common building construction, risk assessment is embodied in solutions recommended in the Statutory Guidance Documents (or Approved Documents in England and Wales) or the rules given in Codes of Practice. Such recommendations are based on past experience of limited types of buildings and tests on specimens with limitations on their attributes, for example size, constituents, strength of material, etc. It is essential, therefore, that such recommendations are used strictly within their limitations that are stipulated as conditional for their application. These rules are meant to be reviewed regularly, for example, to account for new information or outcome of research, to allow for changes in construction practice, to accommodate usage of new products and their assemblies, etc.

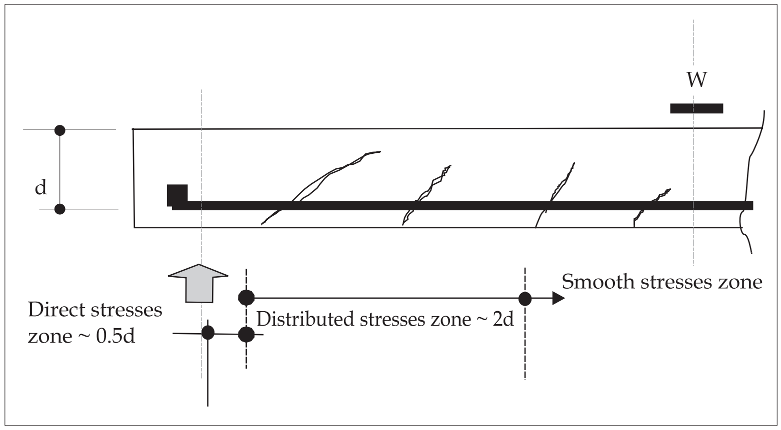

Figure 2. Zones of development of stresses in a reinforced concrete beam

Relationship between the theory according to a pure science like mathematics and any generally accepted guidance on building or a Code of Practice is perhaps analogous to that between the absolute truth (or God) and a local religious practice. An engineer can readily appreciate that a finite and local concept of faith can differ from place to place and that it can be a valid one in the specific circumstances, provided that there is a clear understanding and recognition of existence of the infinite and uniqueness of the absolute truth. Training in engineering should also lead to acceptance of probability of existence of gifted men of extra-ordinary intelligence and perception in various parts of the world and at different times, who may have interpreted the whole truth to suit the environment and life style of the local people. All the same, leaders of highly doctrinated and commercialised religious institutions may find it difficult to review and revise scriptures in the same way as authors of guidance documents and Codes of Practice do, in recognition of various factors, for example, research and development in sciences, changes in the environment and lifestyles of people, knowledge about peoples in other parts of the world and their ways of life, etc.

It is indeed encouraging to see some recent instances of changes in positions and policies in high religious places. For example, in October 1998, Pope John Paul II used Galileo's writing to support his own pronouncements in his 13th encyclical '*Fides et Ratio*', which had the link between faith and reason as its main theme. This happened after some 300 years, when Galileo had been found guilty of heresy, for expressing views in favour the Copernican Sun-centred System, as opposed to the Ptolemic Earth-centred Universe. The verdict of the Church of that time was based on some fabricated evidence, which resulted in Galileo's house arrest for the last eight years of his life in Florence. Pope John Paul II had previously admitted that the Church was wrong to treat Galileo as it did. However, it must have been quite extraordinary for the Pope to quote faith and science as the two truths and that they could not contradict each other. The Pope used his strongest words against theologians who would ignore philosophy and quoted the Second Vatican Council as saying:

> "Methodical research, in all realms of knowledge, if it respects moral norms, will never be genuinely opposed to faith."

One could not have expected the Pope to be more explicit than what he said. However, he was known to have favoured exploring the *why of things* in full harmony of the search for the ultimate answer, which could enable human reason to reach its zenith and to be open to the religious impulse. The Pope had also pointed out that the Church might seem negative about ideas and that it should encourage philosophical enquiry. It is tempting to visualise that, in this Papal plea for union of reason and faith, there may be seeds for more pragmatic reviews of practised religions elsewhere, just as engineers are accustomed to periodical examinations of general guidance documents.

A parallel for development of an engineer

An interesting parallel can be found between development of an engineer and stresses in a simply supported reinforced concrete beam[3], (Figure 2). The initial development stage, say up to the age of ten, is analogous to the stress development near the support of the beam. The beam has direct stresses near the 'supports', no tension as such and it is a comparatively safe stage. Similarly, a child is generally in a protected environment, in care of its parents (supports) and it would respond to direct instructions and teaching. The next stage, during the teenage years, is quite different. The youngster is experiencing the external world and working out his or her own ways. It is a 'disturbed' state and an excessive parental involvement could often do more harm than good. This is analogous to the zone of the beam where the stresses depend on various circumstances and they are mainly indeterminate or in a disturbed state. Provision has to be made in the form of concrete with sound microstructure (less porous and with stronger binder), so that it would resist 'cracking' by the virtue of its 'inner strength'. Adequate transverse reinforcement does help but, as is well known in flat slabs, it is the 'inner' shear strength of the concrete section itself that counts in determining the ultimate resistance to cracking or failure. In case of human development, the reinforcement should represent education and other means of support, which have to be complemented by 'bond' between the provider and the recipient, just as the bond between reinforcement and concrete that depends on tensile strength of concrete itself. There are some theories whereby tensile strength of concrete is ignored and the provision against shear relies entirely on transverse steel or links. In the writer's opinion, they are comparable to straitjacketing the teen-ager's development through harsh feelings, excessive strictness and discipline of a military nature, and paying scant attention to self-development that must be vital for the youngster's career in the long term.

The next stage for the beam is the flexural zone with 'smooth' and parallel stresses. This stage appears to be similar to the stage for an individual, who has completed his or her education and training and is able to manage his or her further development. It may seem strange but it is a fact that most computer programs deal with the last stage only and leave the design against shear to be carried out separately. In a similar way, analyses and theories on human behaviour and response to specific situations are often related to adults, leaving out the complex development of the adolescent young people.

Concepts of child development would seem to follow a pattern similar to that of treatment of shear design, which might have been rather speculative and some originators have changed their views on this subject drastically in the past. For example, Dr Spock was the most famous paediatrician and the author of the all-time bestseller and classic book, 'Baby and Child Care'. This book had been a standard for parents since its first publication in 1946. Dr Spock had encouraged new parents to use common sense and to treat children with respect. His idea was to let parents know that nothing about raising children was written in stone and to trust themselves and their instincts, rather than any prescriptive general principles. He knew that every child was an individual and that what worked for one might not work for another. This had been misconstrued by some critics, who called him the 'Father of Permissiveness', responsible for a 'Spock-marked' generation of hippies,' in spite of Spock's protests that he had never meant that children should be allowed to be uncooperative or impolite. He had also advised parents that it was better to feed babies when they wanted to eat rather than make both parents and babies unhappy by adhering to a strict schedule. In later years, he said that he was becoming more moralistic and advised parents to give their children strong values and to encourage them to help others. He also made drastic changes in his advice to parents about feeding their children and, in the later edition of his book 'Baby and Child Care' in the 1990s, he rewrote the nutrition sections to recommend mostly vegetarian diet and no dairy products at all for children over the age of two. This is similar to much of the research work on shear design of reinforced concrete members, which has shown uncertainties about a real and definitive solution so far.

The writer believes that the early stages of nurturing and development must determine the extent and the ultimate height of achievements of a human being. There could be various negative or unfavourable circumstances - injustice in the society, neglect on the part of parents, inadequate teaching, lack of encouragement to read, think or discuss matters, etc. At the same time, education does not have to be in a school and self-education has proved to be the key to the success of many great leaders and engineers. In the case of concrete members and structures, their durability and performance could well depend on quality of mix design with appropriate aggregates and cementitious binder, aided by good compaction and curing of concrete. Such concrete members should benefit from good 'inner' microstructure, which is essential for defence against deterioration agents, improved tensile strength, sound resistance against shear, effective bond between reinforcement and concrete, etc.

It must be clarified that the discussion here is mainly about the development of a scientific and technological mind. There are people who use science and engineering education or, really speaking, schooling, simply as a stepping-stone. They soon turn to management or financial side of the business and may succeed in their careers. However, they would remain only mediocre as far as engineering is concerned.

Engineers for the future

The writer has put forward personal observations on some aspects of development of a good engineer, starting with affinity and fundamental knowledge of the sciences that needs to be enhanced with training and self-development of technological skills. The writer's views are mainly based on his experience in the UK and they relate particularly to values expected of an engineer in the UK, which should perhaps be equally valid in rest of the world.

It is apparent, however, that all good engineers should have a positive point of view to absorb all human experiences and learn from examples of their predecessors in their exercise of the art of engineering. They must have a good awareness of the needs of the society and the traditions, for example, preferred types and sizes of buildings, influence of structures on the environment, use of materials with sustainable construction in mind, etc.

Modern thinking has resulted in a move away from the 19^{th} century industrial revolution's linear processes, leading to inefficient conversion of energy and materials into a limited product with much waste, towards a 'cyclical' process for the 21^{st} Century where much is recycled and reused[4]. This is a shift in thinking from linear or essentially 'physics' based processes, towards non-linear and complex 'biology' based systems, using the advantages of modern technology coupled with a major behavioural change of the users of natural resources. Such considerations produce the 4Rs cycle, a cycle echoing biological processes:

- Reduce use of energy and materials in construction, and minimise wastage on site.
- Refurbish existing buildings and adopt them for any change of use.
- Reuse frameworks of buildings and building components in new build.
- Recycle products of demolition, with due regard to their safe use.

Professional and educational institutions should be able to foresee and plan against any undesirable influence on training of engineers brought about by changes in social, political and economical circumstances. Unfortunately, educationalists in the UK have recently reported falling standards of achievement in mathematics and physics in schools, which may adversely affect the level of engineering education. Furthermore, these are the days of fast-track construction and unhealthy fee competition as the writer has mentioned above. Excessive emphasis on speed and cost has promoted a tendency towards eclipse of appreciation of good values, including merits of training young people, good site supervision and properly planned maintenance of buildings. Merits of making money at any cost and in any way appear to influence the minds of budding professionals. Talented youngsters are tempted to abandon careers in sciences and applied sciences, and work in the City or in managerial capacities. Like everything else, engineering suffers from the symptoms of bad coins replacing the good ones and loss of expertise in the construction industry could be irreplaceable and permanent. The writer has seen instances of design submitted by people, who claim that it is only necessary to learn how to push the computer buttons to get sizes of members, without any regard to stability, robustness, buildability, connections and the load paths to take loads safely to the ground. Perhaps changes to the regulatory framework may help and eliminate such practice, and avoid potential failures.

Help may be at hand through Construction (Design and Management) Regulations (CDM) in the UK and the procedures adopted for compliance with the same. Early collaboration between various disciplines may come about through appointment of a coordinator. Such coordinator should belong to the lead or predominant discipline and not someone coming as an outsider with only a cursory knowledge of various issues associated with the project. Engineers should get well acquainted with these procedures and seek to perform the coordinators' roles, wherever they are best suited. CDM may also encourage good practice of teamwork and early appreciation of hazards and steps essential for their comprehensive elimination or management of any residual risk as appropriate to each profession. Inclusion of such records in the Health and Safety File may enable good planning for the post-construction management and proper use of the building after hand-over.

In spite of all the criticism levelled against Eurocodes and even some resistance to accepting European practices in the UK, it seems that something favourable may come our way with their emergence. Firstly, the codes will have to be used by adequately trained individuals. Secondly, there will be sufficient scope for application of individual solutions, as long as they have the right basis of design or they are positioned within the scope of accepted design principles. In effect, the design process could be ramped up with introduction of new ideas and practices requiring better educated and better trained engineers.

The Institution of Structural Engineers has done sterling work through its review of standards expected from aspiring Chartered Members (CM). Introduction of MEng or an equivalent post-graduate degree as the minimum qualification should raise the standard of the candidates wishing to take the qualifying CM or Part 3 examination. Professional Review Interviews are introduced to assess competence of a candidate in respect of 13 core objectives. This procedure should focus the candidate's attention on issues other than those concerning only the structural design, which are generally covered by preparation for the CM examination. Appreciation of legislation, health and safety and financial aspects are essential for future development of an engineer and knowledge about the Institution, of which he or she wishes to be a part, must be just as important.

It is conceivable, therefore, that the future Chartered Engineers will be better equipped to face the challenges of the changing world, with such contributing standards as higher qualifications, diverse training and early introduction to international practices through European Standards. Engineering appears to have a bright future ahead and it should continue to be a way of life, just as rewarding as it has been for many all over the world.

References

1. Kand, C.V., Structural concepts in vastushastra, *Proceedings of 'FIP Day' Seminar* on 5-7 March 1998, Mumbai, pp. 197-204
2. Tambe, Usha, *Concreteche Kimayagar*, Granthali Prakashan, April 2000, Mumbai, p 13.
3. Hsu, T.C.H., *Unified Theory of Reinforced Concrete*, CRC Press Inc., Boca Raton, Florida, USA, 1003; 1993, pp. 3-5.
4. Dickson, M., Engineering buildings for a small planet: Towards construction without depletion, *The Structural Engineer*, February 2002, Vol. 80, No. 3, 5, 5, pp. 35-43.

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