Hopkins Lecture – Christchurch 21 August 2002

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Consulting Engineering – Serious Fun

1. Introduction

It is a very special honour for me to present the 2002 Hopkins Lecture, not just because of my connection to the late Professor Hopkins. Refer Figure 1. Since the first lecture, given by my father in 1978, there has been a consistent array of distinguished speakers. It is an honour to be in such company.

The fact that the Hopkins Lecture is now established as an annual event is testimony to those such as Toby Richards, David Elms, Bob Park and Brian Wood who helped inaugurate it, and to many others for their support over the years. Their efforts in making the vision of a commemorative lecture a reality are much appreciated by all the family of Harry and Dorothy Hopkins. .

The support of the University and of the Christchurch Branch of IPENZ has been a key to the continuation of the Hopkins Lecture over the last 24 years.

Thank you all.

2. Serious Fun?

The title is derived from my own experience of more than thirty years in consulting engineering work. Work that has been widely varied, has taken me to many different countries, has involved serious responsibilities, has always been challenging and has provided lots of fun.

- Fun in the satisfaction of helping others with one's advice,
- Fun in the professional relationships with colleagues and with clients,
- Fun in the contact with people from other cultures,
- Fun times.

But the title also comes as a result of looking back at some of my father's published papers.

One, titled "Engineering is Fun" published in 1964 [1] concluded with *"I have no doubt that the engineers of the future, like the engineers of the past, will find that engineering is fun, providing that they take their subject and not themselves seriously"*

Another paper, the Newnham Lecture given in February 1976, entitled "Community Leaders and their Engineering Advisers" [2], concluded with almost identical words – *" (graduates) will find that there are still opportunities for fulfilment through single-*

mindedness and that engineering is still fun, provided they take their subject, and not themselves, seriously"

3. Outline

This Hopkins Lecture 2002 covers a range of topics, offering some observations on each and indicating lessons and/or challenges that emerge. Topics are:

- The value of understanding fundamentals
- The value of basic research
- The value of training
- Failures in engineering development
- Earthquake risk mitigation
- Reconstruction issues following earthquake
- Earthquake Risk Buildings in New Zealand
- Globalisation and Consulting Engineering

My objectives in presenting this material are:

- To provide some *insights into the issues* faced by consulting engineers
- To give some idea of the *opportunities and challenges* available to future civil/structural engineers
- To show *some of the seriousness and some of the fun* of being a consulting engineeer.
- To *encourage readers to think* about the issues and relate them to their own experiences and to the future of New Zealand, particularly the future of New Zealand-based professional engineers.

4. Fundamentals

Observations

Harry Hopkins was known for his advocacy of understanding fundamentals, and taking lessons from the past. He was also known for his love of bridges and particularly the Pont du Gard, built by the Roman Marcus Agrippa in 19 B.C.

This magnificent and awe-inspiring structure (Figure 2) was part of a 50 kilometre long aqueduct bringing water from Uzes to Nimes, falling only 17 metres in this distance, or 340mm per kilometre.

At the time of construction it provided 600 litres per day per head of the 50,000 population (About 350 litres per second). In 1989, an American professor, George Hauck [3], with the aid of modern computer technology looked at the hydraulic efficiency of the aqueduct. He found it difficult to make improvements and concluded that the Roman engineers were more sophisticated than generally thought.

Hauck also looked at the structure in relation to wind loading on the 16-storey high bridge, and found the proportions well matched to likely wind pressures, including a factor of safety of about 2.

There are many conclusions that could be drawn from the Pont du Gard, both from its design and its durability. For the present purposes, let us simply recognise that the

Romans' ability to produce an optimum design relied on their understanding of the fundamental principles as based on their observation of natural behaviours, and their recording of such details.

There are immense pressures these days to introduce instruction on the application of computer programmes into university courses. For instance in the field of maintenance management there are sophisticated computer programmes to help organise this activity - lots of spreadsheets ticking off every known maintenance activity. It is helpful to know these programmes. But it is even more helpful to understand the processes which cause assets to leak, rust, erode or wear out.

On occasions when interviewing engineers for registration or employment, I have sought evidence of knowledge of the fundamentals, from which comes that all important quality, insight. An engineer with insight sent to inspect a work under construction will more readily pick up some adverse aspect than someone with less appreciation of the fundamentals.

Lessons / Challenges
Continue to teach and concentrate on fundamentals that build understanding and insight.

Harry Hopkins put it like this in his inaugural address as Professor of Civil Engineering in 1951, entitled "The Academic Engineer"[4]:

"A review of civil engineering practice indicates the necessity for the curriculum of an Engineering School to be determined more by the progress of science than the requirements of present-day practice."

"Ideas, if well taught and firmly held, will not only demand techniques to implement them, but provide the knowledge to build them"

These comments are just as true today.

5. Basic Research

Observations
It is becoming increasingly common for those with the money and influence to require that research be shown to have some forseeable practical benefit, preferably one for which a cost/benefit ratio can be computed.

There can be no doubt that this is a worthwile approach in cases where incremental development is sought to produce a more refined version of an existing product. Incredible achievements have come from this as evidenced by, say, the development of the motor car over the last 100 years.

But what of those basic research results that take time to have their day?
In the 1980's there was a surge in the development of particle board and medium density fibre board plants. The fundamental processes involved in making these products were developed in the 1940's when patents were taken out. It seems that it took 40 years for the market conditions to make the economics right and to resolve the practicalities of manufacture. Does this mean that the fundamental research should have been delayed 40 years?

We have a parallel example much closer to home – in the earthquake engineering field.

In the 1970's, a group of scientists at the DSIR, including Dr Bill Robinson, was working on energy dissipation devices to protect engineering structures from the effects of earthquake ground motions. Many and various devices emerged and were applied by practising engineers, usually involving the yielding of steel.

Bill Robinson discovered some remarkable properties of lead, that metal best known for taking fish bait to the sea bottom. Dr Robinson noted that if you deform lead in a confined space, it changes its crystalline structure and that it takes considerable energy to effect this change. More remarkably, it turned out that when the pressure was released, the crystalline transformation was reversed almost immediately, so that the same energy absorption capacity was available for a reverse cycle of deformation.

These discoveries, coupled with the existence and use of rubber bridge bearings, led to the idea of a seismic isolation bearing made of alternate layers of rubber and steel with a lead core.

It is fair to say that at the time it was first mooted, the idea of sitting large buildings on these devices was seen to be fascinating but impractical. But time moved on and knowledge of earthquake ground motions and the ability to analyse them improved.

In 1978 the Ministry of Works designed a building [5](William Clayton Building near Wellington Fault) with seismic isolation bearings – the first application of the technology. The incorporation of the bearings reduced the expected forces in the building to about 50% of normal values, which was good news for both the structure and its contents.

In New Zealand the technology has been applied in several buildings, some retrofitted and others new. These include Parliament Buildings and Te Papa.
But the success of this technology in reducing earthquake risk is best measured by its application internationally. Japan has over 100 hundred seismically isolated buildings, USA over 50, and China more than 50. There are others in seismic countries around the world.

New Zealand engineers are presently looking for opportunities to apply this technology internationally, including in developing countries.

Looking back, one could lament the fact that commercial applications were not more strongly developed from New Zealand. One would like to think that the present availability of venture capital and the skills needed to promote such ventures puts NZ in a better position to capitalise on the products of original research, than was the case in the 1970's.

But the benefits of this research have taken over 30 years to come to fruition.

Lessons / Challenges

We should continue to support fundamental research in all fields and be patient regarding the benefits. We must develop the ability and attitude to capitalise on new inventions so that more benefits accrue to New Zealand.

6. Training of Consulting Engineers

Observations

Price competition amongst consulting engineers is the order of the day and has been for over 20 years. While in principle this is perceived as a good thing by the community, there are some disturbing trends that put undue pressure on engineering consultants. It is they who take the serious responsibility for the design and construction of our built environment.

It is hard to believe that less than 30 years ago, engineering consultants had what was known as a minimum scale of fees. In addition, they were prohibited from advertising or promoting their services.

The scale of fees for larger jobs worked on a percentage basis, with a defined minimum % depending on the value of the work. The scale was based on the amount of input usually necessary to address all the issues in design and construction, as well as to take care of client changes to a reasonable extent.

The situation now, with competitive pricing, is that firms feel compelled to bid low to secure a project in order to obtain ongoing work for their company and experience for their employees.

Those reviewing proposals from engineering consultants rarely show proper appreciation of the contribution made and challenges faced by engineering consultants. The tendency is to accept the lowest price rather than looking at the suitability of the skills and experience of the consultant for the task in hand.

Few client managers appreciate that in most cases the consultant is required to assess a physical situation, devise an original solution to fit what are unique circumstances and take responsibility for the adequacy of their design to meet a range of possible scenarios.

A barrister colleague recently commented to me that "Engineers look forward. Lawyers look back." This is not always the case but there is a lot of truth in the statement. A structural design engineer aims to foresee all reasonable events that could affect a structure during its life. Earthquake, wind, fire, gravity, corrosion and so on. When something goes wrong, it is the lawyer who looks back at who didn't do what. That invaluable quality, wisdom of hindsight, is then available to help judge if the actions of the designer were reasonable.

Not only must engineers provide for future events in making what is a unique design, they are frequently required to work to excessively optimistic programmes. Often this pressure is compounded by a request to make up for delays in decision making by speeding up the design and documentation process. Or it may be to meet a bonus deadline for a client manager.

Happily there have always been some clients of engineering consultants who recognise the value of relationships and the need for skill, experience and time to create a successful project. May there numbers increase – to the benefit of the client, the consultant, and the community.

The end result of this pressure to work with unrealistic financial and time constraints is pressure on consultant profit margins, with an over-emphasis on performance to fee budget.

This means less emphasis on innovation, technical development and training.
It is not unknown for consulting firms to budget less than 2% of salary on training, while struggling to keep promotional and bidding costs below 10% of salary. There are many in the profession who feel trapped by this situation, and are all too aware of the possibly serious consequences in the longer term.

Consulting engineering firms now prefer to buy in experienced staff rather than take on the responsibility of training them. Requests then go to the universities to turn out graduates who are more immediately useful – i.e. are trained in applications rather than fundamentals.

Interestingly, there are a few firms, usually small ones with niche skills, who spend very little on promoting themselves, other than through the quality of their work.

In this context it is interesting to observe that the giants of civil engineering's past, including Marcus Agrippa, Thomas Telford and John Roebling had a strong ethic of providing training and passing on skills and experiences to the following generation of professionals. [6]

Lessons / Challenges
Recognise that consulting engineers face serious responsibilities. Give them adequate time and resources to safeguard your interests. Allow them time to understand your real problems and so come up with innovative cost-saving solutions. This will help them make the time available to train the next generation in the art.

It is important that consultants and their clients find a way to redress the imbalance that currently exists between training and promotion. There is already evidence that lack of proper training is resulting in inferior products – leaking buildings being one example.

7. Engineering Failures

Observations
Engineering failures make great headlines. Such publicity for engineers is not good. But failures do provide a valuable source of lessons.

They remind us that civil engineering structures, at least, are usually one-off prototypes, not mass produced items. Designs are based on experience with similar but not identical projects. The process of design and construction is done once only. While it is fun to address the challenges, the consequences of failure are almost always serious.

One of my first jobs was to assist in the reconstruction of a major steel box girder bridge that collapsed during construction. Refer Figure 3.

The climate of scrutiny of technical and managerial detail provided invaluable insights into the workings of major projects. It also produced a strong interest in engineering failures and the lessons that can be derived from them.

A consistent lesson from engineering failures is that normally no single factor is the cause. Each project has vital supporting strands. Refer Figure 4

Whatever fun there is in designing structures to serve the community and resist the forces of nature there is a corresponding seriousness in the responsibility taken. There can be no fudging the issues. It is impossible to draw parallels between the technical work of engineering firms and accounting or business firms such as Arthur Andersen, Enron and Worldcom. A structural designer can not pretend that gravity acts upwards, or at some discounted, tax-deductible rate.

Most people are familiar with the failure of Tacoma Narrows suspension bridge – galloping Gertie. This resulted amongst other things through not having a stiff enough deck structure. But how stiff is stiff enough?

Some years ago a researcher produced a diagram to show the depth of suspension bridge girders over time. A representation of this is given in Figure 5. The saw-tooth shape is remarkable. It shows an overall downward trend punctuated by sudden jumps. Well, guess what, the sudden jumps follow notable failures. More fascinating still, the gap between the failures is around 30 years – about the living memory of an engineer!

This graph points to the propensity for engineers and human beings to progressively refine things. In this case there was a set back each time there was a failure. But the long term trend was down. This propensity to refine was a contributory factor to the collapses of steel box girder bridges in the 1970's. With each successful construction, came the thought that the factor of safety allowed in construction, or some other aspect could be trimmed. This was fine until an adverse combination of construction dimensions, led to dramatic collapses, and then a close examination of all the factors involved.

Lessons / Challenges
Failures result from a variety of factors.

Avoidance of structural failures requires imagination and a holistic view of the context of the structure and the forces to which it may be subjected. The understanding of fundamental principles must be highly developed. Attention to detail is vital at all stages. First class technical skills and insights are essential. All activities require careful and proper organisation. Exemplary communication throughout is necessary if the efforts in other areas are to be translated into practice.

Above all, full use must be made of available experience, through use of experienced personnel and research into past examples.

8. Earthquake Risk Mitigation

Observations

New Zealand has an enviable reputation in the field of earthquake engineering. In the structural field this is due in no small measure to the influence of Professors Tom Paulay and Bob Park who gave their students remarkable insights into structural behaviour and the importance of both concept and detail. Others in research and in practice have reinforced this through the years.

There is something in the pioneering heritage of New Zealanders that causes them to want to understand the fundamentals and to address them as economically and effectively as possible. This has resulted in development of earthquake codes and legislation which, although drawing on international and especially US experience, have their own unique New Zealand flavour. Concepts such as capacity design, in which columns of multi-storey buildings are designed to be stronger than the beams, were developed here and have found ready acceptance in other parts of the world.

For four or five decades after the 1931 Napier earthquake, much of the focus of earthquake engineering was on structures. But the last twenty years have seen an enormous broadening of what is recognised as earthquake "engineering". Failing structures still account for most of the deaths in a major earthquake and much of the mayhem, but the viewpoint has now shifted towards that of building resilient communities.

No longer is it seen as acceptable to consider only what happens to physical assets. The impact on the community is the key issue to be addressed. This has brought in many other professionals under the banner of earthquake "engineering". This includes lifeline managers, social scientists, risk analysts, insurers, emergency management professionals, and business continuance planners.

Research in geology and seismology has provided increasing knowledge and understanding of the earthquake phenomenon. Geographical Information Systems (GIS) have exploded in their range of application over the last two decades and particularly in the last decade. The ability to assemble and display data in pictorial and map form has aided the dissemination of new knowledge. More importantly GIS technology has allowed information to be presented in ways that bring the message home to those needing the knowledge for planning, design or other purposes. An example of this is the combined earthquake hazard maps for Wellington produced by the Wellington Regional Council [7]. Refer Figure 6.

But the power of GIS is not limited to the ability simply to present information. The assembly and visual representation of information provides researchers and practitioners with fresh insights into the issues involved. These in turn lead to fresh ideas on what new knowledge should be sought. It also can make for speedy solutions of problems.

This was graphically illustrated during the Wellington Lifelines in Earthquake project in 1990. [8] For the first time graphical information on the hazards was laid over the assets at risk. Lifeline managers gained a much better appreciation of the risks their assets faced, and a ready means to communicate that to their councils and boards of directors.

As a result, the last decade has seen a significant number of developments in making Wellington's lifelines more resilient in earthquake. It has also seen 17 other lifelines projects initiated around the country with a remarkable building of awareness of the risk to the community. Christchurch went one better than Wellington by covering all hazards, including snow and flooding. Auckland has done likewise (except for the snow!) and made significant progress in defining its volcanic risk.

An unexpected by-product of the Wellington Lifelines Project and others is that the examination by managers of earthquake vulnerability resulted in improvements in handling more common risks encountered in the day-to-day operation. Not least of these spin-offs was a better knowledge of their assets and their general condition. Perhaps more significant was the bringing together of lifeline managers to meet each other and share their ideas, approaches and concerns.

Recognition of these benefits has led to the formation of lifelines groups in Wellington, Auckland, Christchurch, Wairarapa, Hawke Bay, Dunedin and elsewhere. There can be no doubt that these communities will benefit from the efforts of those involved when the hazard event occurs. But they are already benefiting through improved interaction amongst lifeline managers.

The lifelines projects have led naturally to considerations of Civil Defence and Emergency Management. Examination of vulnerabilities required consideration of the time required for restoration of water, gas, sewerage, power, roads, power and telecoms.

The 4 R's of emergency management - Reduction, Readiness, Response and Recovery- have become clearly recognised as being interdependent when looking at earthquake risk holistically. As the representation in Figure 7 shows, actions on all four must be integrated and co-ordinated to obtain optimum results.

Application of GIS has provided the means to measure the earthquake risk to communities. The City Aware project in Wellington [9] provides some insight into this field and the intricacies involved. It starts with modelling an earthquake event in terms of ground acceleration or movement. Next, the building stock is added, in this case building by building, noting the generic type of each and the daytime and nighttime occupancy. Characteristics are then added defining the earthquake performance of each building in terms of damage to it and the likely injuries and deaths at each level of shaking intensity.

When this mix is integrated over the whole city, it is possible to draw maps of the intensities of damage, injury, deaths or even social deprivation. Refer Figure 8.

These studies do not provide a prediction, but a possible scenario following a major earthquake. In advance of the event, the information can be used in many ways, including for planning of hospitals, securing of emergency services premises, recognising the need to improve the performance of key assets and so on. Immediately after the event they same techniques can be used to identify the likely nature, extent and location of the worst damage. This is valuable in planning the response.

City Aware gives and indication of the sophistication involved in the analysis. There are many examples of greater sophistication, especially in the US and Japan. The results are wondrous to behold and could give us in New Zealand an inferiority complex were it not for that the key value in these exercises is the overall process of analysis - and in doing something with the information.
We hold our own on that front. Detailed US-developed methodologies such as HAZUS [10] allow for an incredible amount of detail to be put in to the analysis, and this is all helpful. But in New Zealand we take some comfort in recognising that it is all too easy

to mistake the precision of the calculation process for the accuracy of the answer – and they are not the same.

Assumptions on the relationship between earthquake shaking and damage to a particular building type are by no means matters of great accuracy.

Nevertheless, the analysis exercise itself provides meaningful insights into the issues involved and leads to more cost effective earthquake risk mitigation.
This sophistication in the analysis of earthquake risk is largely the preserve of developed countries. Analyses of risk have been carried out for some cities in developing countries, usually as part of a research project funded by an aid agency.

Many developing countries have more fundamental engineering issues to deal with, notably the effective application of design principles to structural design and the establishment of effective legislation and monitoring regimes to achieve design intentions during construction. Different cultural and economic circumstances lead to different perspectives on risk and the priorities for mitigation. People who can barely afford to feed themselves each day, or who can afford only the most basic of dwellings are unlikely to be responsive to fine tuning of earthquake risk. One's daily risk regime must have some bearing on how one perceives earthquake risk.

Even so, there is much that is being done in and for developing countries. This promotes a better understanding of the earthquake risks they face. It includes taking steps to improve legislation and codes, and more importantly, improving the quality of design and construction.

Whatever is done must recognise the social, cultural and economic environmental context in which it is applied. Even in developed countries maintaining a perspective on earthquake risk is difficult. Damaging earthquakes are low probability high consequence events that occur very infrequently in any one community. But it is something that each of us has a responsibility to address.

The question is what to do now for an event that may not occur in our lifetime. Organisations and individuals must ask themselves:

> *"Given the state of knowledge of earthquake risk and the likely expectations of the community, are we in a* ***defensible position*** *should a major earthquake occur?"*

To illustrate this point, consider the case of the Cypress freeway collapse in San Francisco in the Loma Prieta earthquake in 1989 [11]. Caltrans engineers were responsible for the earthquake performance of all of California's bridges. The dramatic collapse of a major section of elevated freeway, with attendant injuries, loss of life and disruption to transport networks, could on the face of it be seen as a failure on their part to address known risks.

However, it emerged that Caltrans had done a survey of all bridges, identified the vulnerabilities, determined the nature and cost of repairs, and on the basis of this and the importance of the bridges overall, had prioritised the repairs in a comprehensive programme of strengthening. Each year they had sought funds to implement the programme, and each year they carried out the work according to the assigned priorities. Unfortunately the earthquake came before they reached the Cypress freeway. Maybe they got their priorities wrong, and maybe they should have pressed for more funds to speed the programme up.

But the key point in their ***defensible position*** is that they had recognised the risk, had taken steps to assess the consequences, had established a prioritised programme of repair, and were implementing it according to funds available. In establishing the programme they communicated the risk to those community decision makers responsible for allocating funds. That request for funds no doubt needed to be balanced with other community needs on the basis of the perceived relative importance of earthquake risk.

However, addressing the question above represents a valuable first step in deciding what, if anything, should be done to put an organisation in a defensible position. If the decision is to do nothing, then let the reasons for that decision be recorded as part of the defensible position.

This principle can be extended to much smaller, but still important issues. If I do not take steps to secure, at minimal expense, a tall bookcase in my house, I will not be in ***defensible position*** after the earthquake if someone gets hurt by it toppling.

Overall, thanks to researchers in geology, seismology and engineering, our knowledge of earthquake risk is increasing. This is driving up community expectations on the extent to which this risk should be addressed. At the present time there is much more that could and should be done to respond to this knowledge with reasonable action to reduce the risk.

Lessons /Challenges

- All organisations should take a serious look at the earthquake risks they face.
- Organisations and individuals should take action sufficient to put them in a ***defensible position*** should a major earthquake occur soon. This means doing what the community expects of them to prepare. This may not be much, but it will probably not be nothing.

9. Post- Earthquake Reconstruction

Observations

Major earthquake events overseas have shown that it takes many years for a community to recover and rebuild. Recent studies [12],[13] for Wellington assumed a four year period to carry out $5b worth of rebuilding. On this basis the demands on existing resources would be stretched, but perhaps not overwhelmed. Local resources would be insufficient and the ability to reconstruct in reasonable time would depend on the availability of the requisite skills and resources from elsewhere in NZ and overseas.

An indication of the extent of demand is given in Figure 9.

This shows the demand over the four year period compared with local capacity and with national capacity.

Such studies may be regarded as a contribution to earthquake risk mitigation, in that they promote understanding of the nature and extent of consequences of a major earthquake.

Key issues to emerge were:

- *The importance of the 4 R's – Reduction, Readiness, Response and Recovery* – and the fact that they need to be considered as a complete set, not individually.

In analysing what actions to take for, say, reduction, it is helpful to analyse what the consequences of inaction may be. For example, it might be more economic to be ready with spare parts than to make replacements now.

- *Development of mutual aid contracts or prior agreements.* These are starting to be put in place in New Zealand. For instance, in water supply restoration after an earthquake, a speedy and effective response is paramount. This is greatly helped if a prior agreement is signed between kindred organisations in neighbouring regions to send qualified teams to assist. All the organisational and funding arrangements are made in advance.
- *Funding Arrangements* - $5b of work in four years, on top of ongoing work, is a tall order. Special funding arrangements may be needed.
- *Special Legislation* – There may be a need to have special legislation to allow for the special circumstances. For example, dispensations under the Resource Management Act or special provisions under the Building Act.
- *Logistics of access and supply* – Wellington's restricted access and steep topography represent a considerable challenge to bring the materials, plant and labour to the places where they are needed.
- *Availability of resources* – the demand for resources of all types is far greater than exists day-to-day. The Earthquake Commission has made careful studies of its likely workload in processing claims following a major earthquake, and has made special arrangements to cope in the event of a major earthquake. At EQC's instigation, two conferences have been held to promote a parallel approach in the construction industry. It is to be hoped that this issue will be taken up more strongly than it has been to date.

Lessons / Challenges

- At the very least the major contractors should consider how to meet possible requirements. This could include establishment of prior agreements with other New Zealand contractors in other centres and overseas.
- This will help the industry to be ready to meet the challenges of the reconstruction effort and to maximise the New Zealand content of it.
- Others who may be involved in reconstruction should familiarise themselves with the scale and nature of the challenge and its relevance to them.

10. Earthquake Risk Buildings in New Zealand

Observations

Since 1968 New Zealand has had legislation covering unreinforced masonry (URM) buildings. Powers available to local authorities have been taken up to varying degrees over the intervening period. The NZSEE has produced three sets of guidelines, the most recent in 1995. These have helped Territorial Authorities take consistent approaches countrywide when assessing performance against legislative criteria, and to set standards and timetables for required strengthening or demolition.

There are some who blame this legislation for the loss of many of New Zealand's older buildings. To some extent this is true, but most of those demolished were past their use-by date in economic and functional terms. On the other hand, the application of earthquake engineering technology has saved many notable buildings and made them safer.

Every time there is a major earthquake in a city overseas, we see spectacular and sickening building collapses. More often than not, the prime cause is a critical structural weakness such as a soft storey or plan irregularity. Regular buildings, particularly those with shear walls consistently perform well.

These overseas failures are a reminder that the same could happen in New Zealand. Yes, we have good codes and a design and construction industry with a strong record of compliance. But we still have buildings that will not perform well in earthquake because of critical structural weaknesses.

Building codes in NZ have developed over the years and it only since 1976 that codes made what is now regarded as proper provision for structural detailing and hierarchy of failure of beams and columns. Thus there are numerous buildings that do not comply with the current loadings standard. Even those built after 1976 cannot be automatically exempted. Pressures to create open spaces, to provide garages, to allow panoramic views, to meet budget constraints and/or simply to maximise profit from the construction can result in buildings with the same critical structural weaknesses that exist in buildings overseas.

Over recent years this issue has been addressed by a Study Group of NZSEE that has developed:

- A method for quick and easy assessment of structural performance in earthquake.[14]
- Detailed guidelines and recommendations on improving the structural performance in earthquake. [In preparation]
- Studies of the cost benefit of improving the structural performance of buildings in various parts of the country. [15],[16].
- A proposed grading scheme to be applied to all buildings [17]. The aim is to increase awareness of earthquake risk generally and to underpin legislation with a market-forces approach.

This work has been in response to NZSEE initiatives to examine the issue, and the development of new legislation extending coverage to all buildings (other than small residential ones). The proposed legislation would require all buildings with less than 33% of the strength (performance capacity) of a new building to be improved or demolished.

The proposed Grading Scheme is shown in Figure 10.

The idea is to have this grading on the title of a building, or readily available through a LIM or PIM so that awareness of earthquake risk is developed in the community. Market forces could then, to some extent, drive earthquake risk mitigation. If an owner of a building of Grade D found that tenants were shying away, there could be a case for upgrading the building. This would only happen if the owner saw it as a worthwhile investment.

It is important to realise that the 33% figure represents only the worst of non-complying buildings in New Zealand. For buildings of 33% strength of new ones, the risk is approximately 20 times that for a building complying with the new building standard. This means that even with the new legislation, there will be many buildings that do not comply with new building standard, but which will not be legally required to have their structural performance improved.

The cost benefit studies involved looking at building types, the code to which they were (most probably) designed, and the seismicity of their location. The latter varies considerably around New Zealand, and the more research is done, it seems, the more refined the variations. The net result is that computed benefit-to-cost ratios for improving structural performance vary widely. For the particular assumptions used the ratios range up to 6.0, on the basis of annual probability.

Benefit-to-cost ratios climb considerably when conditional probability is taken into account. What if the earthquake happens in the first year after structural improvement?

These considerations lead to the conclusion, as far as the NZSEE is concerned, that the legislation and Grading Scheme should be implemented. At the same time it should be recognised that it may take several decades to make significant progress. After all, the 1968 legislation captured 700 unreinforced masonry buildings in Wellington CBD. By 2002, 500 of these had been addressed.

How quickly this issue of earthquake risk is dealt with depends on the community's perception of the risk and willingness to fund it. There are many other demands on public and private funds. Earthquake risk must be set in perspective.

Major earthquakes are high consequence, low probability events that with time slip from living memory. In the Chinese city of Tangshan, a devastating earthquake occurred in 1976, killing more than 250,000 people. It is interesting to calculate that the percentage of Tangshan's present day population that experienced the earthquake is probably below 50%. NZ's last major earthquake in an urban centre was in 1931. Keeping a balanced perspective on the risk can be difficult, especially when a growing proportion of the population has had no direct experience of a major event.

Developments in both hazard identification and risk analysis are advancing quickly. So are community expectations of the scientific and engineering communities. In this and many other fields, delivery of world's best practice is now expected by the community. Unfortunately, this expectation takes little or no account of practical constraints such as the funding needed.

Nevertheless, informing the community view is the job of the engineering and scientific professions and so keep community expectations as realistic as possible.

Lessons / Challenges

The lesson from all these studies is that keeping earthquake risk in balance is difficult. Awareness of earthquake risk in the community needs to be sustained, and the legislation and grading scheme are good ways of ensuring that.

There is also an obligation on the engineering profession to keep the community informed on earthquake hazards and risks, and the means available to address them. From the profession's point of view this is the most important way for it to be in a defensible position after a major earthquake.

The community must be in a position to make informed decisions when deciding what approaches to adopt and what funds to make available for earthquake risk mitigation. Professionals have an obligation to the community to communicate the risks consistently in a way that allows sensible decisions to be made on day-to-day approaches.

11. New Zealand Consulting Engineers Internationally

Observations

NZ engineering consultants are highly respected for their attitude and all round practical knowledge. Most consultants here are exposed to a wide range of activities related to their special interests. The small market does not permit narrow specialisations that exist in larger economies. Such practical breadth is invaluable when technical challenges of a remote village in a developing country have to be met. For example, the engineer who is regarded as a structural design specialist in New Zealand is able to cope with a range of issues from water supply to geotechnical investigations, at least to deal with day-to-day challenges. In addition, there is something in the New Zealand psyche that gives New Zealanders empathy with those in developing countries.

NZ consulting engineers have been involved on the international scene for over 3 decades. The progress of this involvement is shown in Figure 11 from which it can be seen to be about 20% of all business, and still on the rise. Note that this is an overall figure and that some firms will have a much higher percentage of overseas work.

What will this figure rise to? No one knows. But there is plenty of room for it to increase before it becomes unsustainable through the lack of an adequate home base market. Make no mistake, involvement in overseas projects, even with the modern communication technology, takes tremendous effort, funds, human resources (usually of the most senior and experienced personnel) time and patience.

At one stage in the 1980's, architectural and engineering consultant, KRTA Limited, with heavy involvement in geothermal development in the Philippines and elsewhere, as well as with building and civil engineering projects in South East Asia and the Pacific, derived almost 80% of its income from overseas work. This was far too high a percentage for two reasons. Firstly, there is a high risk of cancellation due to vulnerable economic and political situations. Secondly, almost all the energy of the practice was directed away from home base. It is hard to keep a local profile when the energies of almost all key people are directed elsewhere.

So perhaps something around 50% would be a reasonable target. One thing is certain, we must look for ongoing involvement overseas to maintain our skill base and to provide attractive work prospects for younger engineers. The local market is simply not enough to support the quality of skills we produce and need to retain in New Zealand. Putting it more positively, we produce quality skills in New Zealand professionals – we need to make use of them.

Yet it is on the back of this overseas involvement by KRTA, and similar initiatives of other New Zealand consultants, that the growth in overseas engineering consulting work has come. Those who gained experience in the field are now well equipped to push New Zealand's involvement further and wider. They know the organisational, logistical, contractual and cultural demands first hand.

The increasing involvement of New Zealand engineers in overseas work is a reflection of the energy and enterprise of engineering consultants, and particularly of the leading firms and their leaders.

Much, but by no means all, of the work done by New Zealand consulting engineers has been in developing countries, notably Asia and the Pacific. The challenges faced by these nations to improve their standards of living are enormous.

There are two key areas:

- Development of industry and supporting infrastructure
- Development (and in some cases establishment) of viable governance – "institutional strengthening" in the words of the development banks.

It is easy to see that there is a role for consulting engineers in the first. The requirements for energy, roads, ports, airports, water supply, water treatment, housing, hospitals and schools offer huge challenges and opportunities, added to which is the need for engineering in the development of industries. New Zealand consulting engineers are well represented in this development. It takes only a small proportion of the overall market to meet our wildest ambitions.

The second major area requires not just engineers but a full range of advisers – financial, legal, legislative, tax, health, education, insurance, local government, building codes and so on. In these areas, NZ has more to offer than is commonly realised. The government reforms in NZ since 1984 have given many people here experience of putting new structures of ownership and management into place.

In many government agencies and elsewhere there are people who have the potential to provide advice – that is to become consultants. Maybe not full time consultants, but we need to recognise that their skills and experience are saleable and develop a mindset within government circles that allows these key skills to be made available readily.

Some people would like to put the globalisation genie back in the lamp. But it is out and we must accept it and take advantage of it. New Zealand consulting engineers are well placed to do this. Much of what they sell is expertise and ideas. Communication of ideas around the world in this age of the internet can be achieved at a single key stroke. The ability to send documents and drawings electronically has been around for some years, but with every year the uptake of this technology is increasing. So too is the size and complexity of what can be transmitted and dealt with effectively.

Engineers produce drawings, specifications and contract documents – amongst other things. Most drawings are now done on computer. It is possible for a drafter to produce a drawing in Bombay and send it to Wellington immediately for review by the designer. For some years now, large US architectural and engineering practices have been using drafting firms based in India, Philippines, Indonesia and elsewhere to produce the bulk of the drawings for major projects.

The skills available from these overseas specialist firms are comparable in most respects to what is available locally. But the cost per hour is 25 to 50% of the local rates. For large jobs this cost differential provides ample margin to pay for the additional management, oversight, communication and travel involved in delivering the requisite quality of the overall documentation.

Initially, the problems of distance and additional management proved costly, but as both parties gain experience in the process, it becomes more efficient. Such an approach does not suit all projects. A certain scale is required. But the concept is alive and here to stay.

It is not just drawings and specifications. Imagine the complexity of the structure of a modern Olympic stadium, say in an earthquake prone country. It is possible to send all the geometrical and loading data electronically from UK to New Zealand in order for the earthquake engineering specialists to analyse the structure for earthquake effects and develop design concepts and details for earthquake resistance.

So, we have, at least, a two-way street: - New Zealand firms having drawings done in Malaysia or India where the requisite skills are available at lower cost, and UK firms sending material to New Zealand to take advantage of our specialist knowledge - and our cheaper rates.

This whole approach was clearly evident when buildings group managers of Sinclair Knight Merz (SKM) met in Sydney in 2000. A Malaysian structural engineering firm had just become part of SKM. The Australian and New Zealand based managers were looking forward to the opportunity of using the more competitively priced drafting resources of the new addition to the ranks.

The Malaysian managers welcomed the prospect of the additional work that their new relationship would bring. But they pointed out that, in fact, they were under some pressure from other Malaysian firms who were able to bid lower overall prices for their contracts by employing drafting resources in India.

What are the implications for New Zealand engineers and drafters in all this?
Some people argue that New Zealand (or US or Australian or UK) firms should use resources from their own country in order to keep them employed. But the reality is that if they do not take advantage of the available cost savings, some other firm will - and not just the drafters will be out of work. There is only one way to view the current and ever-changing situation in this area (and in many others) and that is to see it as an opportunity.

New Zealand engineers and drafters can make a considerable contribution through their technical knowledge of the drawing content. For example deciding on what should be or need not be shown on drawings and managing the production of documents. There is also a market for their skills in overseas firms, such as in US and UK, who would see them as a cost-effective resource, even if their rates are not the lowest available. And they would not have to leave New Zealand to service these clients, at least not permanently.

Another insight into opportunities for New Zealand engineers is evident from the use within SKM of the specialist skills in earthquake engineering. It is interesting to note that SKM and other firms see New Zealand as their centre of excellence for earthquake engineering. The global connectivity between the offices of these firms makes it possible for them to offer earthquake engineering skills via London for a stadium for the Athens Olympics without the need to have specialists stationed permanently in London.

This indicates that although the merging of New Zealand based consultants into international practices may lessen some opportunities for New Zealanders to become involved in offshore work, it points to the potential of maintaining and developing key areas of specialist expertise, of which earthquake engineering is but one.

There is a further dimension to this. New Zealand engineers have proved themselves effective and popular in assignments to developing countries. Their previous experience in working in other cultures and legislation regimes, together with their practical approach, makes them a sought-after resource amongst the international firms and agencies. Not everyone is prepared to meet the challenges of travelling to unfamiliar surroundings and applying their technical, managerial and interpersonal skills.

There is definitely a role for NZ in this global economy with its internationally branded firms. But we New Zealanders must work out what that role is. And then work at making it happen. No one else is going to do it for us.

A promising development in this regard is the intitiation by Wellington City Council and TradeNZ of an Earthquake Engineering Technology Business Cluster. This is a group of professionals throughout New Zealand who look to apply their niche skills to overseas work. The focus is to obtain work that would not otherwise be available to the member firms individually. It is a pooling of knowledge and expertise of New Zealanders – both those based here and those offshore. Earthquake Engineering New Zealand we call it. [18]. Refer Figure 12.

EENZ is essentially a marketing network. It does not undertake contracts in its own right. When an opportunity is identified or created, those member firms that can see worthwhile potential business in it, in spite of the efforts necessary to win from a distance, will elect a lead firm and invest their own money and time in pursuit of the prospect.

EENZ acts as a catalyst, clearing house and an incubator/disseminator of ideas. It is not just for engineers. Insurers, emergency management professionals, researchers, scientists, management consultants and any group that can see potential in applying their skills are members.

The potential benefits of this group extend beyond earthquake engineering. New Zealand earthquake engineering skills and expertise are highly regarded internationally and provide ready access to key decision makers in many countries. The goodwill generated and the network of high level contacts can be used to identify and pursue opportunities for other engineering disciplines, and for other New Zealand organisations in general.

Any one who has travelled offshore to market NZ skills quickly becomes aware what a small resource we have to offer. We need to co-operate and help each other as much as possible. Once offshore, our fiercest local competitors become potential associates, and there are many examples of successful collaboration amongst New Zealand engineering consultants – and this is not restricted to offshore contracts.

For all the wonders of international connectivity through the electronic media, the successful pursuit of offshore work requires the development of meaningful relationships with key organisations and people in the countries we wish to work in. Only when these relationships are in place can the benefits of email and extranets be fully effective. Mutual trust and respect are still the cornerstones of the best deals. The first has to be developed and the second earned.

That is when New Zealand's remoteness hits home. It is costly to travel to and stay in overseas countries. There is a huge investment of time required to assess the market and one's place in it, and above all to develop key relationships.
This process of identifying and creating specific opportunities that look worthwhile to participating firms is the most difficult phase for most firms to justify within the context of their own marketing budget.

At the start there is no relationship, and there is no specific opportunity. Usually there is just an idea that there is potentially a market for New Zealand services. Much can be achieved remotely by way of information about the market, but the time comes when plane trips just have to be made to determine if there are real prospects and to develop relationships.

It is this area that the support of Government through TradeNZ and Industry NZ and MFAT can and do play a significant part. Bhuj Hospital in Gujarat is a worthwhile example to illustrate this point.

On Independence Day, 26 January 2001, Gujarat suffered a strong earthquake, causing over 18,000 deaths, injuring over 160,000 and leaving 100's of thousands homeless. Over 300,000 houses were destroyed [19]. A key 300-bed hospital at Bhuj was destroyed with almost total loss of life of those within the building. By a strange quirk of fate, most of the nurses doctors were outside the building at the time of the earthquake – at a flag raising ceremony.

New Zealand MFAT was moved to donate some aid money to Gujarat for victims of the earthquake. With the help of EENZ, funds were made available by MFAT to bring the designers of the replacement hospital to New Zealand to help them incorporate seismic isolation. MFAT paid for the Indian professionals to come to New Zealand, for the New Zealand engineers to provide design advice and for them to visit the site periodically to monitor the construction process. MFAT's funding has also allowed for some follow-up training of local professionals.

Quite separately, a New Zealand manufacturer of lead-rubber bearings, Robinson Seismic, used their knowledge of the project and their competitive international position to bid for the supply of the bearings for Bhuj Hospital. They obtained the $1M plus contract.

This key hospital is due to be opened on Independence Day 2003 and will be a showcase for NZ EE technology in India and elsewhere. Thus, much has been done to promote New Zealand expertise, and Bhuj Hospital may well provide an example for many other similar projects in earthquake prone areas of India. New Zealanders may participate directly in some, but there will no doubt be many others done by locals building on the experience of Bhuj.

Regardless of the degree of future New Zealand involvement, there is a real possibility that this relatively modest MFAT initiative and contribution will in time be seen as the catalyst for a significant contribution to the reduction of earthquake risk in India. Should that prove to be the case it is something from which all New Zealanders can derive satisfaction.

For the engineers involved in situations like this, there is the satisfaction of having used their skills to help others not just to build something, but to learn a new skill that will have ongoing benefit. To do this requires enterprise, courage, and commitment. It requires successful business skills to stay in business and thus to continue to make their skills available. It requires the serious application of engineering principles and practice. It involves the fun of travel and cultural exchange, even in tragic circumstances such as Bhuj.

Lessons / Challenges

- We must make use of our NZ based skills and sell them internationally
- We must make better use of our expat network – actively
- We must work hard to become more visible internationally
- Adopt the slogan: "Think globally. *Organise locally.* Act internationally."
- Identify and develop NZ as centre of excellence for Earthquake Engineering – through EENZ.

- Extend that to other areas where we have niche skills, including those involved in government.

A final comment:

Former President Clinton of USA visited NZ earlier this year and emphasised the importance of trade and aid in fighting world poverty. It is hard to argue with that. As the various communities of the world become closer through 'globalisation' we each become more aware of the conditions faced by the other six billion people on earth.

If New Zealanders were to plot themselves on the graph of international quality of life they would surely be amongst the most fortunate, even though we are falling behind other developed countries economically. New Zealanders have the resources and skills to assist developing countries - through trade and aid. If this is, as Bill Clinton says, the way of the future, then it points to significant opportunities for New Zealand engineers.

Trade requires industry and development which in turn requires engineering skills and advice to be successful and efficient. Aid will undoubtedly continue to involve the development of infrastructure and industry in developing countries. But there is one other ingredient that perhaps binds them or makes both possible, and that is enterprise. This requires risk taking initiatives to create goods and services and thus wealth.
It will take enterprising individuals and organisations to make the most of the global market place - to set up the industries; to develop natural resources; to trade; to deliver effective aid.

Trade, aid and enterprise offer much through which the New Zealand consulting engineer can contribute to the global community. Organisations like Enterprise NZ Trust with their Young Enterprise Scheme are helping strengthen New Zealand's enterprise culture. So you can expect New Zealanders and especially New Zealand engineers to continue to play their part in all three.

These efforts will contribute to bringing more of the 6 billion a better life and enough to **eat** each day. So perhaps that should be **E**nterprise **A**id and **T**rade – in that order.

Regardless of the order, for consulting engineers this represents a huge challenge and brings many engineering issues to tackle.

The overall challenge is **serious**. But tackling the engineering issues is **fun**.

13. Postscript

Harry Hopkins could not have known that the vernacular of the late 20th century would include the enigmatic term "serious fun". But he would at least have been able to relate to it in an engineering context.

But why use these almost identical words about taking your subject but not yourselves seriously in two papers 12 years apart?

Perhaps his study of the history of engineering showed the march of development, such as of roads and bridges in any country, to be far more important to the community than the individuals who made them a reality. And that is after acknowledging the contribution of some very remarkable individuals.

Could the comment have its roots in my father's wartime activities? As a bomber pilot in the RAF in World War 2, he flew many missions to Germany. Loss of colleagues was an almost everyday occurrence, and it would be hard to take yourself too seriously in such circumstances. But we can be sure that all those involved took what they were trying to achieve very seriously indeed.

Somehow, though, in the midst of this most serious challenge, there had to be fun.

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