IPENZ
ENGINEERS NEW ZEALAND

Standards and Regulation for Building Construction in New Zealand

Contents

1. Executive Summary

This report sets out:

- The legislative context and requirements for registering professional engineers as an occupational group. The corresponding required education and qualifications are explained as are the Chartered Engineers' competence progression and assessment systems.
- The qualifications and competence assessment standards are shown to demonstrate strong links to international good practice.
- The building regulatory system as it applies to structural engineering, emphasising features of the changing regimes before and after the 1991 and 2004 Building Acts.
- There are outstanding issues on the role of Standards as compliance documents, and the involvement of engineers through the construction process.
- The role of Chartered Engineers and self-regulation in the statutory occupational regulatory system.
- The regulatory system does not recognise engineers at different levels or fields of competence; however there is insufficient evidence to show this has caused any significant difficulties. The self-regulated disciplinary process is well regarded by the regulator and this is demonstrated by the low numbers of complaints upheld against structural engineers.
- The way in which research, learned society activities in independent technical societies and the professional body and knowledge codification by collegial debate have led to standards, codes of practice and guidance material.
- There are concerns about the way standards are developed and funded, and gaps between innovative practice and codification and regulation.
- The findings of the 2003 Structural Engineering Taskforce, which provides an overarching summary of the views of the expert panel asked to consider the state of structural engineering practice.
- Concerns about consent authorities' administration of the Building Act 2004 and the earthquake prone building policies' management, and suggests alternatives to the present occupational regulatory system for engineering.

2. Context for this Report

The Royal Commission inquiring into building failure caused by the Canterbury earthquakes has asked IPENZ write to this report on the following matters:

- The legislation and other rules governing the engineering profession (including those imposed by the profession itself) since 1924 to the present day, including comparisons to other countries
- The sequential development of standards for building construction in New Zealand from 1935 to present day, and the processes by which the developments occurred
- The manner in which building controls are managed by building consent authorities and the ways this might be improved
- Any matters that logically arise from the above.

In reporting on the first of these, IPENZ also outlines the nature of professional formation through structural engineers' career-long education and professional development and how that has changed since 1924.

3. Legislation and Rules regarding the Engineering Profession

3.1 INTRODUCTION

The legislation and regulatory system affecting engineering works in building construction has had two components:

- The acquisition of a title which might give access to certain types of work, the relevant titles being Registered Engineer (until 2003) and Chartered Professional Engineer (from 2003).
- Direct regulation of performance in a particular application area, eg building construction.

Section 3 of the report sets out the operation of the regulation of restricted titles, and Section 4 covers how the quality of engineering work is directly regulated.

3.2 OCCUPATIONAL REGULATION

3.2.1 Engineers Registration Act 1924

The Engineers Registration Act 1924 was established arising from concerns about ensuring good engineering standards in public works. The Engineers Registration Act established what would now be called a Crown entity as a separate and independent, Engineers Registration Board with statutory powers set out under the Engineers Registration Act. The purpose of the Engineers Registration Act was to create a list of people entitled to be called a "Registered Engineer" who had demonstrated through education and experience that they met the standard for registration.

The Engineers Registration Act included requirements of a minimum age and being of good character and reputation. The standard was what is now termed "input-based" or process equivalence. There was no explicit competence standard, rather candidates were registered after they had gained an engineering qualification at a specific level and gained suitable experience over a specified period of time and presented well at an assessment by interview.

Once registered, there were no specific requirements to maintain registration other than the payment of an annual fee. The title was sought after for many years up until the 1980s as it provided access to promotion and remuneration increase in the government sector. From 1944 the expenditure of public money on engineering works over a certain limit needed to be under the supervision of a Registered Engineer. Local authorities were required to employ at least one Registered Engineer, although registration was not required for building privately owned structures, nor was it widely adopted by the commercial sector as a quality mark.

The Engineers Registration Board was administered by a Registrar who was associated with a relevant government department. Immediately prior to repeal of the Engineers Registration Act at the end of 2003, the relevant department was the Ministry of Economic Development.

At the date of repeal there were approximately 5,000 Registered Engineers with a number were being retired. There was no requirement to undergo any further assessment of retained competence or Continuity Professional Development undertaken to maintain registration. The available grounds for discipline were criminal conviction (rendering the person unsuitable to be registered) or bringing the profession into disrepute.

In terms of the standard and its application, in the early days the Engineers' Registration Board recognised the examinations and professional interviews conducted through major United Kingdom -based engineering institutions. It also set its own examination in this period but later obtained permission to use the United Kingdom institution's examinations in New Zealand. This seemed to be the predominant arrangement prior to World War II.

3.2.2 IPENZ Professional Membership

Throughout its existence (from 1914) IPENZ has maintained a competence standard for entry to competence-graded Membership at the professional level. The entry standard has always been the ability to practice independently as a professional engineer.

Prior to World War II, an arrangement was made by the Engineers' Registration Board to cooperate with IPENZ from an administrative viewpoint. For example, the first Registrar later became the President of the New Zealand Institution of Engineers, (as IPENZ was then called).

In 1946 this was extended by the Engineers Registration Board recognising the competence assessment process performed by IPENZ as meeting its needs, and it seems this arrangement replaced the setting of examinations by the Engineers Registration Board. The new arrangement stayed in place until 2003. By the end of this period the arrangement was that the Engineers Registration Board paid IPENZ a fee and IPENZ would conduct its assessments, and then forward the outcomes of the assessment to the Engineers Registration Board, if the candidate had applied for registration. The Engineers Registration Board would examine the report of the assessment panel and quality assurance of the assessment by IPENZ and decide which candidates to grant registration, based on its judgement of the engineer's ability to practice in New Zealand. (Note engineers did not always need to be practising in New Zealand to gain Professional Membership of IPENZ).

In almost all cases the Engineers Registration Board's decision in respect of registration and IPENZ's regarding competence-graded Membership were the same. Candidates with less formal education who had learned on the job rather than through degree education generally were expected to undertake a much longer professional experience before applying. Nevertheless, even if accepted for Professional Membership, they were occasionally not accepted, reflecting the Engineers Registration Act's requirement of assessing education and experience rather than competence per se.

Hence, the entry standards to IPENZ Professional Membership and to registration were effectively the same, at least after World War II. IPENZ membership binds the engineer to a code of ethics which requires them to undertake continuing professional development to maintain competence relevant to the work they do and to only work within their area of competence. For a period in the 1990s IPENZ carried out random audits of Continuity Professional Development records, but in practical terms, there is no formal requirement for continuing competence-graded Membership of IPENZ.

3.2.3 Engineering Associates Registration Act 1961

A 1961 Act created the title "Registered Engineering Associate". The normal qualification held by registrants was a New Zealand Certificate of Engineering. To our knowledge, this Act had no direct impact on structural engineering.

3.2.4 Chartered Professional Engineers of New Zealand Act 2002

At various times, engineers had sought to update the 1924 Engineers Registration Act. The importance of updating was emphasised in 1996 with the passing of the Chartered Accountants Act.

At the commencement of the 1999-2002 Parliament, Dr Nick Smith (then a member of the opposition), proposed a Private Member's bill "The Chartered Professional Engineers Bill" which was the first private member's bill drawn in the new Parliament. The Labour-led government decided to use this opportunity to update the legislation, by proposing a supplementary order paper. There were significant discussions with IPENZ, the Engineers Registration Board, and the Association of Consulting Engineers New Zealand (Association of Consulting Engineers New Zealand) and eventually a regulatory framework model was agreed. This was slightly altered after submissions to Select Committee. The Bill passed into law in 2002.

The main features of the CPEng Act were:

- IPENZ was appointed to be the Registration Authority – the CPEng Act sets out powers and functions to be performed as Registration Authority. The Registration Authority is required to maintain rules that prescribe standards of competence for registration and ethical conduct and these rules (CPEng Rules) are regulations and part of New Zealand law.
- A statutory body, the Chartered Professional Engineers Council was created, consisting of up to eight persons appointed by the relevant Minister – three nominated by IPENZ, one by Association of Consulting Engineers New Zealand and the rest being direct Ministerial appointments (on the recommendation of the Department of Building and Housing and its predecessor).
- The statutory body is limited to three functions:
    - to report annually to the Minister and Parliament on the performance of the functions of the Registration Authority
    - to be the first appeals body on both registration and disciplinary matters. (The District Court is the second stage appeal body)
    - to approve standards prepared by the Registration Authority, but such approval must be given if the Council has reasonable grounds to be satisfied that the Authority has prepared the standard by a correct process.

- The CPEng Act does not set competence standards. IPENZ, as Registration Authority, is required to prepare suitable standards in accordance with the process prescribed in the CPEng Act. This involves consultation and taking into account international best practice. The proposed rules must go through the Council approval process before the IPENZ Board can make them Rules. There are four standards (special rules) required by the CPEng Act:
  - a standard of competence for admission
  - a standard for demonstrating current competence for continued registration
  - a standard for the maximum allowable time between assessments for current competence
  - a code of ethical conduct.
- There was no automatic transfer of registrants from the old Registered Engineer register – rather all candidates must demonstrate they meet the new standard. As a consequence both the old and new registers existed during the 2003 calendar year to allow for transition.
- IPENZ is also required to have Rules setting out the processes for assessment against the standard, management of the register, reassessment of candidates, and the receiving and hearing of complaints.

The Rules that contain standards were approved in late 2002 and have not been changed since.
A change in the maximum allowable interval between re-assessments is proposed for 2012 and beyond – lengthening from five to six years.

The Rules approved in late 2002 (other than competence standards) were updated in 2004 and 2005, and further minor updating is being proposed in 2011.

The Registration Authority registers engineers and undertakes discipline but it is not compulsory to be a member of the professional body. Around 80 of around 2,800 Chartered Professional Engineers are not members of IPENZ.

The initial assessment to become registered under the CPEng Act is the same standard as that to become a Professional Member of IPENZ, maintaining the longstanding alignment between registration and Professional Membership. The requirements to continue to be a Professional Member of IPENZ are much less onerous than those to continue registration as a Chartered Professional Engineer because of the periodic reassessments for continued registration.

The CPEng Act requires outcomes-based standards of competence (including standards of knowledge and skills). Education and experience were seen as means to develop competence and could form part of the evidence, but the standard requires the candidates to demonstrate they are able to do the things to the standard expected of a reasonable professional engineer.

IPENZ was fortunate that, commencing in 2001 at what is now termed the “International Engineering Alliance Meetings”, there was work being undertaken towards development of an exemplar competence profile. Throughout 2001 and 2002 the international working group and the working group set up by the IPENZ Standards and Accreditation Board were in close communication, drawing on each other. The 2002 CPEng competence standard was therefore leading edge at the time it was adopted.

The international working group continued work on its exemplar competence profile beyond 2002, and its final output was adopted in 2005. It is still a very close match to the New Zealand CPEng (and MIPENZ) entry standard (see Appendix 1).

3.3 EVALUATION OF ENGINEERING EDUCATION AND QUALIFICATIONS

Until 2003, the educational requirement for both registration and Professional Membership was always met by holding a suitable engineering degree (from 1980 this would normally be an accredited degree). Registration for those not holding degrees was possible but required demonstration of knowledge equivalent to that gained by a degree assessed on a case by case basis.

IPENZ and the Engineers Registration Board gave recognition to systems run by United Kingdom institutions where candidates without a degree sat a qualifying examination administered by the United Kingdom institution. Over time those examinations dropped out of vogue (probably by about the 1960s) and the primary means for establishing knowledge equivalent to a degree was through the engineering report, defended orally to an assessment panel. The professional engineering experience requirement tended to take longer for these candidates and attracted greater scrutiny by the Engineers Registration Board.

Since 2003 the requirement is to demonstrate knowledge, and holding a relevant qualification is now seen as evidence towards meeting the standard. Because qualifications were directly part of the standard prior to 2003, the progressive development of qualifications does have a bearing on the registration standard. For this reason a summary of relevant changes in engineering education and its accreditation are set out in Appendix 2.

3.4 DEVELOPMENT OF "EXPERIENCE" (PRE-2003) AND COMPETENCE (POST-2003)

In line with common practice in other similar countries, the engineering profession in New Zealand regards the point of entry to the profession (at which registration may be achieved) as being when a candidate demonstrates competence for "independent practice". This point is normally reached four to eight years after graduation, depending on the variety and quality of work experience. At no time has there been a compulsory formal development or training programme for engineers, such as used by parts of the medical profession.

3.4.1 Pre-1990

The period to 1990 was characterised by three dominant employment paths for civil engineers – in central government, local government and private practice. Structural engineering design might be performed in central government of the private sector, and local government had a role in building regulation enforcement.

In central and local government, as well as some private engineering consultancies there was investment in graduate development. Those employers recognised that graduates had a grounding in engineering principles but were not proficient in applications of standards and codes of practice, nor had developed their engineering judgement. Those employers also recognised the need for developing proficiency in important skill areas, like determining a design philosophy and recognising load paths, through undertaking such work a number of times under supervision.

Engineers working in the government sector gained experience through scheduled rotation through different work areas within their organisations. For example, there is evidence of a six year Public Works Department cadetship scheme in operation prior to World War II. In the private sector, the better employers gave graduates greater experience by consultants and contractors “swapping” graduates on a secondment basis.

Other private sector employers, and particularly smaller companies were unwilling or unable to develop structured programmes; these employers wanted useful outputs from day one, and tended to use the graduate more as a technician – generally resulting in delayed or repeated assessments until sufficient relevant work experience was achieved.

3.4.2 Between 1990 and 2003

The restructuring of the New Zealand economy during the late 1980s and early 1990s resulted in a dramatic shift to the way engineers were employed. Prior to this period some 80per cent of engineers were employed in the public sector where there was an embedded culture of personal development and systems for training graduate engineers through to registration.

Over the relatively short period of restructuring from 1987 to the early 1990s, many of the engineering roles within the public sector were relinquished to private sector organisations, resulting in a reversal of the ratio of public sector engineers to private sector engineers. The private sector was ill-prepared for training graduates – there was insufficient culture or embedded infrastructure facilitating graduate development towards registration. In the relatively free-market environment the total number of competence assessments across all disciplines dropped below 100 per year.

IPENZ responded by developing self-administered graduate development programmes, and assisted graduates who were professionally isolated to find mentors.

In the late 1990s IPENZ introduced an “Endorsed Employer” scheme, to recognise those employers running good practice graduate development programmes. Nevertheless, many engineering graduates were not placed in environments that facilitated good development.

3.4.3 After 2003

Since 2003, the adoption of an outcomes-based standard has required a different approach. Candidates must now provide evidence of their ability to competently perform each of the skills described in the competence standard. Inputs-based evidence (qualifications, time performing work etc.) is no guarantee of competence – what is critical is how well an engineer is able to acquire and apply knowledge skilfully in the performance of his or her everyday engineering activities.

Candidates are therefore encouraged to record what are sometimes called “career episodes” or work samples in which they believe they demonstrate the competence required against one or more elements of the standard. While they are encouraged to discuss their performance with a mentor, there is no requirement for the mentor (or referee or supervisor) to sign off work samples if used as evidence.

With the skills shortages between 2005 and 2009, graduates had more power to demand better development and were encouraged to do so by IPENZ. If all went well, the graduate was placed in a mentoring arrangement with an experienced engineer and worked under supervision, being exposed to a variety of work place issues. Large employers have generally created structured programmes for recent graduates; in other cases there could be individual programmes for graduates.

The Endorsed Employer scheme was updated to "Professional Development Partner" in 2008.The number of companies involved is still a minority of those employing significant numbers of engineering graduates but is steadily increasing. Most large engineering consultancy companies and a number of contracting companies now actively consider graduate development.

3.5 ASSESSMENTS

3.5.1 Assessments 1946 to 1990

After World War II, the criteria for registration were a suitable degree, satisfactory experience, the production of an engineering report, and an oral defence of this to an assessment panel.

The candidate was required to show at least four years total experience including 12 months of "office" (eg design) and 12 months of "works" (eg practical implementation) experience. Candidates were expected to log their experience, discuss it with their supervising engineer, and record the periods of their experience spent carrying out either office or works activities at the level expected of a practitioner conducting independent practice. Some of the experience could be under supervision, but for some of it the candidate had to demonstrate the taking of responsibility. The supervising engineer would sign off this record, verifying the accuracy of the claim and stating the experience was in his/her view suitable.

The candidate for professional interview provided their work history, including records of office and works experience and an engineering report. Two assessors would require the candidate to defend these documents orally in an interview. Assessors were drawn largely from the public sector with the government sector essentially dictating the standards for registration. Assessors were drawn from the same field of engineering as the candidate as far as was practicable. The panel would ask questions about the claimed periods of office and work experience to ensure the work was suitable. They would examine the content of the engineering report, seeking verification that suitable judgement had been applied, the analysis was correct and so on. They would then ask the candidate questions about his/her knowledge of engineering more generally. At the end of the interview (about an hour) they might set an essay topic for the candidate to complete as a "closed book" exercise in three hours. The purpose of the essay was to check communication skills and test any area of perceived weakness.

Assessment panels were not formally trained except by the rub-off of a new assessor being placed with an experienced one. However, the shared implicit understanding of the standard in government engineering circles probably ensured both a good standard and sufficient moderation between assessment panels.

3.5.2 Transition Period 1990 to 2003

During this period IPENZ started the shift towards competence-based assessment – developing an assessment made with greater transparency and creating a quality mark likely to be of value to the private sector to promote the quality of engineering staff in a company. Such a change required a paradigm shift not just for candidates but for assessors too – requiring investment in up-skilling assessors.

IPENZ started to change its assessment process from the mid-1990s. A standards-based assessment model was introduced which provided greater transparency in the process. A programme of up-skilling assessors in the use of these new tools was also implemented, and over the late 1990s and early 2000s, the profession became more attuned to the concepts and benefits of competence based assessment.

During the 1990s a moderation process was put in place because the implicit shared understanding of the standard that had occurred in government was progressively eroding. This type of process for moderation is still used by some other professions. Assessment results were collated, and regional moderators would review these, and hold face to face meetings at which the panels were all invited to be present. Marginal cases were discussed and collegial decisions taken. This process was also considered necessary to deal with an increasing number of alternative pathway candidates without engineering degrees. This pathway was actively promoted by IPENZ from 1993.

3.5.3 Assessments Post 2003

With the introduction of the CPEng Act a generic competence standard, consisting of 12 elements, was developed and candidates are assessed against the standard in their practice area. Candidates are required to state their practice area as part of their portfolio of evidence, and this description, along with the supporting evidence, forms the context in which assessments are conducted. A practice area is usually narrower than a full field of engineering such as “structural engineering”.

Assessments during 2003-2010 have generally been of three types:

- Previously proven candidates (previously assessed to the equivalent standard, for example current MIPENZ or formerly Registered Engineers) – these were assessed by a two person panel which considers a written self-review, work samples, written and sometimes verbal referee statements. Panels did not normally require interactive assessments unless the case was considered marginal. This so-called desk-check was international good practice in 2003 when instigated.
- Candidates who were not previously assessed but hold a recognised degree – these also have generally involved interactive assessments with work samples normally being required.
- Candidates not holding a recognised qualification (for example, science or geology degree graduates with extensive experience in an engineering context) – in addition to all the above, candidates go through a knowledge assessment process to show they hold knowledge equivalent to a recognised engineering degree. This requires the addition of a third assessor to the panel who is a specialist in this form of assessment.

The assessment panel decisions are passed as recommendations to the Competence Assessment Board (CAB). The Competence Assessment Board may approve recommendations and send the report back to the panel for reconsideration, or after considering advice from the panel change the recommendation. In effect Competence Assessment Board has the moderation role.

To undertake outcomes-based competence assessments IPENZ needs trained assessors. There are two types – Staff Assessors who are more expert in the assessment methodology, and document the assessment, and Practice Area Assessors who are expert in the candidate's field of engineering. Normally, a structural engineering candidate is assessed by a staff assessor with structural knowledge and a practice area assessor with strong competence in the same field of engineering as the candidate, although on occasions two competent structural Practice Area Assessors have been used where the Staff Assessor does not have a structural background.

IPENZ has drawn on learned societies to identify good assessors and to develop guidelines to be read in conjunction with the competence standard to assist candidates and assessors. In preparing guidelines on structural engineering during the period 2007-2009, a working group consisting of the Structural Engineering Society of New Zealand members and assessors with a structural background developed examples of work that would be good evidence for assessment, drawing typical activities or problems that a competent structural engineer would encounter in his or her engineering practice.

IPENZ has invested heavily on assessor training – using experts in competence assessment to lead training sessions and assist in the preparation of reference manuals. Two such reference manuals (one for candidates preparing their portfolios of evidence, and the other for assessors) are currently posted on the IPENZ website and readily accessible. The guidelines for assessors also includes Competence Assessment Board advice for assessors based on the Competence Assessment Board's experience since 2003 as the final decision making body on assessments, with both positive and negative outcomes.

Moderation remains an issue. The standard is an "entry level" standard for independent practice. However, some structural engineering assessors would prefer if it were set higher and regard candidates demonstrating entry-level competence as "marginal" because their design skills are insufficient for complex building structures.

In 2009/2010 IPENZ commissioned a major review of the competence assessment process first instigated in 2003. The review concluded that whilst it was unlikely that poor quality decisions had been made (i.e. persons registered who had not demonstrated sufficient competence) improvements to moderation should be made. The recommendations of this review are being put in place in 2011. In addition, changes are being made to the assessment process to reduce the time requirements for candidates preparing for assessment, and to make greater use of face to face evidence verification. More detail can be provided on request.

3.6 INTERNATIONAL BENCHMARKING AND MUTUAL RECOGNITION

3.6.1 Pre-1990

In the 1920s the New Zealand Society of Civil Engineers (the predecessor of IPENZ) conducted a major piece of work considering the United Kingdom, Ireland and Australia and proposed a unified registration system for the Commonwealth. This does not appear to have gained traction, but probably led to the first benchmarking of the standards in the various countries.

Under the 1924 Engineers Registration Act there was no requirement for taking into account international best practice. Nevertheless processes evolved that were a close match to practices in Australia and the United Kingdom, probably as a consequence of the earlier initiative. This was probably almost inevitable due to the international movement of engineers, many of whom worked for a period in the United Kingdom and were assessed there, and also through inter-institutional arrangements. These linkages were almost certainly initiated more through IPENZ than the Engineers Registration Board directly.

Some further evidence of these linkages is available. For example, in 1927 the Engineers Registration Board confirmed its recognition of the United Kingdom's Institution of Civil Engineers qualifications as meeting the qualification requirement for registration in New Zealand. In 1931 the New Zealand Public Works cadetship (which is presumed to be a graduate development scheme towards New Zealand registration) was recognised by the Institution of Civil Engineers as equivalent to its own system. Also at that time, the Institution of Civil Engineers reported acceptance of the University of New Zealand engineering degree from Canterbury College as meeting its educational requirements for membership. The degree taught through the Auckland College of the University of New Zealand was pending for recognition at that time. IPENZ understands this may have been because this was the time when the previous system of Auckland students being taught the final year by Canterbury was being phased out, but we cannot be certain of this.

In 1947 there was acceptance of the direct equivalence of the professional interview (which we now call competence assessment) between the New Zealand system and the Institution of Civil Engineers

3.6.2 1990 to 2003

In 1989 the Washington Accord agreement, recognising substantial equivalence of engineering qualifications, was signed, and IPENZ was a founding signatory. A natural progression was to identify equivalence in competence standards for registration as well. IPENZ subsequently signed a series of "like for like" mutual recognition agreements with professional engineering bodies in Australia, Hong Kong, Ireland and several United Kingdom -based engineering institutions. The earliest of these were signed in 1993 with the majority being set-up during the late 1990s. Most were open-ended but the Australian agreement had a renewable three-year term.

The general basis was that a person holding professional membership (in those days called corporate membership) of one body could transfer to the other at the same level. A person arriving in New Zealand under these arrangements would obtain Professional Membership of IPENZ. If they applied for registration under the Engineers Registration Act they had to demonstrate that they were familiar with New Zealand good professional engineering practice, and this normally involved a period of adaptation through working in New Zealand (usually for a period of not less than 12 months). The New Zealand engineer reaching the United Kingdom was able to access the Chartered Engineer quality mark in a similar way.

The arrangement with the Institution of Structural Engineers was different. The title Chartered Structural Engineer is managed by the Institution of Structural Engineers. To obtain the title and access the Member grade with the postnominal MIStructE candidates must pass a seven hour written examination and a professional interview. The exam is a commercial/industrial structural engineering design exercise. As such, it tests for one very specific skill – one of 12 contained in the CPEng competence standard. Obtaining CEng in the United Kingdom or meeting the New Zealand registration standard of the day generally exempts the professional interview. The Institution of Structural Engineers is of the view that the design standard set for MIStructE is higher than the United Kingdom -wide CEng standard. However, IPENZ is not aware of the need to establish any formal benchmarking of the examination if there is a gap.

The arrangement with Australia is complicated by the fact that occupational regulation in Australia is generally a State issue. Queensland's Professional Engineers Act 2002 requires engineers to be licensed to practice in Queensland, but otherwise there are only voluntary industry-based registers. The National Professional Engineers register was established in 1994, and was based on using the standards and processes of the Institution of Engineers Australia (trading as "Engineers Australia"). The title Chartered Professional Engineer is administered by Engineers Australia (using its Royal Charter as the mandate) as a private quality mark of competence-graded membership.

An agreement between the New Zealand and Australian Governments covering occupational regulation (formalised in legislation by the Trans-Tasman Mutual Recognition Act 1997) meant that a registered occupation in one jurisdiction was deemed to be registered in the other so long as "occupational equivalence" was established. "Occupational equivalence" was determined by the nature of the engineering activities a registered person was authorised to carry out. Handling structural engineers under this agreement prior to 2003 was difficult and decisions were dealt with on a case by case basis as there were few such cases occurring prior to 2003.

There has been regular interaction between the Australian and New Zealand professional bodies, and in the period prior to 2003 this led to sufficient confidence to recognise equivalence.

IPENZ was a founding signatory to two further international agreements within the International Engineering Alliance the Engineers' Mobility Forum's "International Professional Engineers' Register" agreement (1997) and the APEC Engineer agreement (2000). The need for an internationally recognised competence profile exemplar was driven by these international agreements. In 1999 the APEC Engineer agreement conducted a limited and loose benchmarking study based on a desk-top review of about six actual candidates from each participating economy and that concluded there was equivalence of New Zealand to the norm amongst the ten participating APEC economies.

Prior to the introduction of CPEng, in 2001/2002 IPENZ contracted a consultant with an international reputation for expertise in competence assessment to carry out research of international best practice by reviewing assessment processes in the United Kingdom, Ireland, South Africa and Australia, including making visits to some of these countries to observe their systems. This research formed the cornerstone in the development of CPEng assessments in compliance with the CPEng Act requirement that the CPEng registration process take into account international "best practice".

3.6.3 Post 2003

Since the International Engineering Alliance's adoption of the exemplar competence profile, outcomes-based assessment is becoming international best practice. Within the International Engineering Alliance, IPENZ is a full member of two agreements – the APEC Engineer Framework, and the Engineers Mobility Forum. In 2006 these agreements carried out a review of IPENZ procedures, and found they corresponded to the agreed benchmark standard. This study involved IPENZ supplying twelve actual candidates portfolios, including three marginal cases which were demonstrated to show the actual minimum standard being applied. The twelve cases were perused by an international panel of three persons nominated by other members of the Engineers' Mobility Forum and APEC Engineer Agreements. The panel of experts compared the standard and procedures to those being used in their own jurisdictions and reported they were satisfied that substantial equivalence was demonstrated. A further such review is scheduled for 2012/2013.

There is thus strong evidence that New Zealand adheres to international good practice in terms of the entry level standard to the profession.

Within the international agreements, the countries most strongly using outcomes based assessment are Australia, Ireland, South Africa, the United Kingdom and New Zealand. The format for assessment in these countries generally mirrors the IPENZ process – requiring a portfolio of evidence of written evidence, referees (or sponsors), interactive assessments and trained assessors.

Ireland, Australia and South Africa are similar to New Zealand in that there is a single registration body that sets the standard and conducts assessments. The Engineering Council (United Kingdom), EC(UK), "owns" the Chartered Engineer (CEng) quality mark in the United Kingdom, but it licenses 37 professional engineering bodies to assess candidates for registration. The competence standard is specified as the United Kingdom Standard for Professional Engineering Competence, with licensees being required to implement systems to ensure assessments are carried out in accordance with the specification. Regular audits along with formal and informal reporting are used to monitor compliance.

Two notable exceptions are Canada and the United States where entry to the registration systems is by passes in standardised written examinations, set according to the engineer's discipline.

3.6.4 Ongoing Requirements to Continue Registration

Before 1990 it was rare for there to be a requirement, other than payment of an annual fee, for registration to continue. In the late 1990s as the international agreements began to form, the international profession recognised that continued competence should be more formally assured.

Most countries now have a requirement for candidates to undertake sufficient continuing professional development to maintain their competence. Registrants provide statements of their continuity professional development activity and it is checked for suitability. This may be done on volume only (enough hours of participation) or by ensuring there is a fit between the types of activity and the type of engineering practice of the candidate. From 2010, Australia introduced one of the more rigorous systems of this type, 20 per cent of registrants are audited annually, but prior to that the audit was not mandatory. An auditor checks the candidate's statement of recent work experience against the continuity professional development undertaken and approves or not that the requirement is met. From 2011 the United Kingdom -based Institution of Civil Engineers (Institution of Civil Engineers) also audits 10 per cent of members to check that they have an up to date Development Action Plan as part of the continuity professional development requirements.

To our knowledge, New Zealand was the first to adopt requirements that go well beyond continuity professional development. In 2002, the New Zealand standard for continued registration was in two parts – the first part requires the candidate to demonstrate that he or she has taken reasonable steps to maintain the currency of his/her knowledge and skills. This is equivalent to the overseas continuity professional development-based systems. We focus on ensuring the candidate has identified important new knowledge in their field, has accessed continuity professional development to learn about it, and has used the knowledge rather than on the volume of continuity professional development undertaken. The second part, which no other jurisdiction presently requires, is that we require candidates to demonstrate they are still able to practise competently. This is done though evidence from recent work samples.

3.6.5 How New Zealand Compares

New Zealand is, to the best of our knowledge, the only country that comprehensively reassesses for current competency (but very few engineers undertook this reassessment prior to 2008). In all other countries the registration body relies solely on monitoring the suitability of continuity professional development as a proxy for ensuring the candidate is still competent.

All the international benchmarking is at the New Zealand CPEng or equivalent level, ie an entry level of competence. It would be expected that engineers develop competence on an ongoing basis, and thus if they remain in technical roles they may practise at a level of competence well above the CPEng standard. These candidates complete the regular reassessments with few concerns.

3.7 HIGHER LEVEL COMPETENCE

There is no specific quality mark in New Zealand for high levels of competence –IPENZ Fellowship is granted for contribution to the profession, although candidates are required to be of above average competence.

Under the Building Act a register of “Recognised Engineers” is created. The requirements are to be as Chartered Professional Engineer whose area of practice in which the assessment was made includes dam safety. Given that most Recognised Engineers are experienced engineers the register of Recognised Engineers may be mainly composed of individuals significantly above the minimum CPEng standard, but that is not by design.

In other nations, particularly amongst those in East Asia there are examinations for structural engineers to become registered. These tend to be set in the local language and IPENZ is not aware of any benchmarking exercise against the International Engineering Alliance exemplar.

As set out above, the Part III examination of the Institution of Structural Engineers (United Kingdom), whilst narrow in nature, may be above the CPEng/CEng standard for “design”.

3.8 OTHER ALTERNATIVES

IPENZ's perception of the general view on the New Zealand engineering profession is that:

- The outcomes-based competence standard and means of assessment are appropriate and sufficiently rigorous, although the time required to prepare for assessment is a concern.
- Although onerous, the regularly scheduled re-assessments of competence do add rigour to the system, above that achieved in other countries.

If changes were to be made to occupational regulation, possibilities IPENZ has advocated include:

- Allowing for multiple registers at different internationally-benchmarked competence levels under a single Registration Act, administered by a single registration authority. (There is consensus that this should include the engineering technician and engineering technologist competence levels below chartered professional engineer, but no consensus about a higher competence level – part of the structural engineering community has argued there should be a higher competence level than CPEng for designers of complex structures; others believe that self-certification under the code of ethics is sufficient means of differentiation).
- Improving the quality of evaluation of overseas engineering qualifications. The assessment by the New Zealand Qualifications Authority lacks rigour from an engineering viewpoint. A single engineering qualification assessment system undertaken by the registration authority would be preferred.

3.9 SUMMARY

Until 1990 the competence standard applied was both ensured and moderated through central government involvement, and benchmarked through maintenance of strong institutional linkages to the United Kingdom, but was relatively inaccessible to non-degree holders.

From 1990 to 2003, with the growth of alternate pathways, moderation was a challenge and whilst the overall standard was internationally benchmarked, greater variability may have arisen. However, there is little evidence to suggest that engineers were registered who did not meet the minimum standard. The post-2003 standard is strongly benchmarked internationally. Moderation remains an issue which is progressively being tackled.

4. Building Regulatory System – Overview

There are four New Zealand building regulation phases – pre-1936, 1936 to 1991, 1991 to 2004 and 2004 onward. IPENZ is unable to comment on the first of these.

4.1 1936 to 1991

After the Hawke's Bay earthquake in 1931, building regulations changed. 1936 is seen as the pivotal date for this.

Two parallel regulatory systems were in place until the mid-1980s. All central Government buildings went through the Ministry of Works (Ministry of Works) system. The Ministry established internally its own standards and systems for sign-off of work through an engineer's certificate system. Whether the work was undertaken directly by the Ministry or contracted out to private sector consultants, the required standards to be followed were prescribed by the Ministry and quality assurance was to the satisfaction of its supervising engineers. The Ministry made its standards readily available (eg they could be purchased from the Government printer).

Other buildings were regulated through local government. Prior to 1931 it seems there were not consistent systems. After the Hawke's Bay earthquake the precursor to the New Zealand Standards was established to develop building standards as its first purpose. Standards New Zealand developed "model by-laws" (the first of which was NZS – 95 in 1936); and local authorities largely picked up on these and used them. National consistency occurred only in so far as local authorities used the model by-laws or chose to share good practice amongst themselves.

In practice the two systems were linked. Through strong contribution from the Ministry of Works, as well as engineers from consulting companies to Standards Committees it is likely that there were strong crosslinks between the Ministry standards and the model by-laws.

A registered engineer was required to sign-off public work (central or local) over a certain value. This gave a further regulatory check on quality. However, there does not seem to have been a standard form of engineer's certificate during this period, although towards the end a form was recommended by the Association of Consulting Engineers New Zealand.

During the period from 1936 to 1991, major regulatory changes could occur if either the relevant central government design guide or the equivalent New Zealand Standard was updated.

The central government design guide was designated PW 81/10/1 and known as the Ministry of Works Building Code. During the 1960s Ministry of Works also created a grading system for government buildings which may be regarded as an early form of "earthquake prone buildings" policy.

The standards included:

- NZS 95 – 1936 Model *Building By-Law* incorporating loading and materials clauses
- NZSS 95 – 1939 *New Zealand Standard Code of Building By-Laws*
- NZSS 95 – 1955 *New Zealand Standard Model Building By-Law*
- NZS 1900.8:1965 *Model Building Bylaw*, which raised for the first time the desirability of adequate ductility

- A greatly shortened NZSS 1900.8:1976 to include only general performance requirements, recognising the then new NZS 4203 as a means of compliance. It provided considerable guidance on the design of plastic hinges
- NZS 4203:1976 *General structural design and design loadings for buildings*, which began the process of replacing the "working stress" method of the earlier Standards with what was becoming described in the literature as "capacity design"
- NZS 4203:1984 *General structural design and design loadings for building*s, which gave more guidance on "ductility factors" for materials and made minor changes.

From 1936 until 1965 the provisions for loadings and materials were incorporated in different parts of the same by-law, but after 1976 the loadings and materials standards were published separately.

It is also worth noting that in Wellington in the 1960s there was considerable debate between the private structural engineering community and the City Council as to whether local variations to the model by-laws could be made. Leading edge practitioners wanted to apply new knowledge and push outside the scope of the standards or by-law. For example, the Standard allowed buildings to rise to 160 feet, but the Wellington City Council wished to be more conservative by following the Japanese example of 102 feet or 10 storeys.

4.2 1991 to 2004

As set out above, in 1991 under the Building Act 1991 the first national *Building Code* was established, and Standards became only one means to give effect to it. The need for a smooth transition from prescriptive standards to a performance-based regime was, in hindsight, not well understood and no proper preparation occurred. Local authorities were required to grant consents and code compliance certificates to the national *Building Code*, but there were no checks on the consistency of their performance. The Act also allowed for private building certifiers, but their involvement with commercial building structures was limited. These private certifiers disappeared as a consequence of the 2004 Act.

The central regulator was the Building Industry Authority. It had the statutory powers now ascribed to the Department of Building and Housing. It could approve acceptable solutions, approve verification methods, issue compliance documents, and perform determinations.

Of particular importance was Building Industry Authority's citing Of NZS 4203:1992 *Loadings Standard* as a means of complying with the performance requirements of the new *Building Code*.

Many commentators formed the view that the Building Industry Authority took too passive a role during the ten-year period of its existence. This may have been due to the limited resources (the Authority depended on the Building Levy); or restrictions imposed by the governing Statute.

Both the Building Act 1991 and Building Act 2004 are based on the premise of a performance-based national *Building Code*, expressed in terms of desired outcomes, largely on a qualitative basis. Building owners may apply for a building consent by demonstrating that a building design complies with the *Building Code*. After construction the owner may apply for a code compliance certificate. In the 2004 Act, the construction must comply with the consent documents, in the 1991 Act construction had to comply with the *Building Code*.

Two types of solution are recognised: acceptable solutions and alternative solutions. Acceptable solutions are fully described ways of complying with the *Building Code* and where provided and properly adhered to, consent must be given. Alternative solutions put the onus on the applicant to provide sufficient evidence to the Building Consent Authority that the *Building Code* has been met (based on a reasonable grounds test).

The *Building Code* is therefore supported by two sets of compliance documents:

- Those documenting acceptable solutions which may include New Zealand Standards in part or in full
- Verification methods – these are prescribed ways to evaluate the suitability of certain types of design approach, which may also include New Zealand Standards.

This is also a need for an effective system for validating alternative solutions, proposed by professional designers and quality assured by peer review (ie designer producer statements).

When building strengthening work is undertaken the same regulatory system applies. Strengthening work will generally be treated as an alternative solution, and the onus is on the applicant to prove the *Building Code* requirements are met. This is also through evidence generated using verification methods, peer review, physical tests, or special studies.

Under the 1991 Act the bulk of the earthquake engineering part of commercial building work was evaluation via either use of verification methods or the alternative solution route. For some designs there are some recognised verification methods (standardised means to demonstrate compliance), but the default is treatment as an alternative solution with the onus on the applicant to provide sufficient evidence of compliance. The approaches taken by Building Consent Authorities to considering alternative solutions have been variable. Most have required peer review of designs – some do that by contracting their own reviewers, others allow the applicant to choose the peer reviewer. Producer statements (in essence another name for engineers' certificates) were recognised in the 1991 Act as a means to provide evidence in support of the application by the designer and sometimes the reviewer. The New Zealand Institute of Architects, IPENZ and Association of Consulting Engineers New Zealand defined model producer statements known as PS1, PS2 and PS4. These were widely applied by engineers but not architects. The author needed to have suitable competence (for engineers – MIPENZ).

Some consider that the 1989 amendments to the Local Government Act 1974 had an inadvertent impact on the capability of local authorities to perform building controls functions. Prior to that Act most local authorities had a chief engineer who managed the capital works programme, the operation of infrastructure, and regulatory functions such as building, plumbing and drainage. Under the amended Local Government Act the regulatory functions were separated out, and most engineers became infrastructure asset managers. Building controls were usually placed in a different part of Council and sometimes lost their engineering ethos through reporting into the planning function of the Council. There are suggestions that building controls officers with engineering knowledge became rarer. This occurred at the same time as a performance-based *Building Code* was introduced which arguably, requires a higher level of skill in the regulatory agencies than prescriptive regulation.

4.3 2004 to PRESENT

The 2004 Building Act kept the performance-based Building Code but introduced a number of other changes. These included:

- Creation of a means for quality assurance of Building Consent Authorities. However, in 2011 the envisaged systems for quality assurance (accreditation) of Building Consent Authorities have still not been completely implemented.
- Creation of licensed building practitioner (not fully operational until 2012). For structural engineering this has had modest real impact as CPEng are deemed licensed building practitioners and the proposed restricted building work is not intended to include many commercial building structures, and is yet to be implemented.
- Removal of the formal recognition of producer statements. Their use as a form of standardised evidence of compliance is now at the discretion of Building Consent Authorities. Attempts to get national guidelines agreed on producer statements have been made since about 2008 but this is still not achieved. IPENZ and Association of Consulting Engineers New Zealand refined the model producer statements, and by 2011 have persuaded most Building Consent Authorities the model forms are acceptable. These are most often used for geotechnical or structural engineering work.
- Since the CPEng Act came into effect IPENZ and Association of Consulting Engineers New Zealand have recommended that alternative solutions for complex structural engineering work should be certified to Building Consent Authorities through producer statements signed by Chartered Professional Engineers. The signing author may have done or supervised the work, but sometimes in big companies the signatory signs as a manager of the design team on the basis that the team in the company were appropriately selected and competent. Each CPEng signing such a statement states that the work carried out was undertaken by suitably competent engineers.
- Introduction of earthquake-prone buildings policy (minimum of 33 per cent of current Building Code). In 2003 IPENZ backed the New Zealand Society for Earthquake Engineering recommendation that the 2004 Building Act set 67 per cent of current Building Code as the minimum requirement. It was of course set lower and this has been well publicised.

4.4 FURTHER SIGNALLED CHANGES TO THE BUILDING ACT

The Building Amendment Bill Numbers 3 and 4 are expected to further change the Building Act. Key areas that will potentially impact structural engineering include:

- The introduction of risk based consenting where higher risk buildings such as commercial buildings or public buildings will be looked at more stringently than a domestic dwelling. This might manifest as differing levels of evidence required for buildings with a higher risk profile. To provide the higher level of certainty, the question as to whether evidence needs to be provided by engineers of suitably higher skill level might arise. This might suggest a multi-tiered engineers' registration system if a public benefit can be demonstrated over the present practice of self-certification by engineers whether they have the competence to tackle the complexity of the work.

- The future consolidation of Building Consent Authorities. Currently there are around 70 Building Consent Authorities and the Department of Building and Housing is investigating the viability of reducing this number to six or even fewer. The possibility of one, a national service delivered locally, might be considered.
- Distribution of liability. The liability scheme may change incentives, which could have unintended perverse outcomes.

4.5 OUTSTANDING POLICY ISSUES

A major policy issue is clarification of the role of Standards as forms of compliance documents. In the regulatory system it seems historically there has not been delineation of public policy decisions and technical standards. This arose in part from the absence of a single Government policy owner until the Building Industry Authority was established in 1991.

Two of the main policy decisions affecting earthquake design are the selection of return periods of design events for assuring safety and retained building serviceability. Good public policy practice suggests these policy matters should be dealt with in the *Building Code*, and then the Standards development process would allow the minimum requirements to give effect to those policy decisions to be defined (eg minimum earthquake design loads). In practice, the *Building Code* has been a qualitative document, and the Standards development process has filled the policy vacuum. Standards committees made the missing policy decisions in deciding the loads to be designed for. Those loads have always been for protecting life but service levels for building reusability has also been considered. Of recent times the Department of Building and Housing has started to address the policy gap issue but has done so by modifying standards when making them compliance documents under the *Building Code* rather than introducing quantitative elements into the *Building Code*. An example was the change in snow load after the 2006 Southland snowstorms – the 2003 snow loading standard was overwritten by the Department of Building and Housing in 2008.

A common complaint from engineers is they have insufficient involvement through the construction process. They claim that unless the regulator requires it as a condition of consent, or as a requirement towards the issue of a code compliance certificate, the engineer's recommendations to the building owner that they be allowed to observe construction to ensure designs are correctly implemented may be ignored, so the observation may not occur.

Engineers also comment that the post-construction consenting of work done under urgency (designed as built) may not be recognised, and thus not sufficiently well handled under the 2004 Act (note the change from 1991 to 2004 whereby construction now must comply with the consent documents, rather than the *Building Code*). This can occur in the construction of complex commercial buildings – design mistakes may be detected during construction, and decisions made as to how to proceed. Construction activity cannot stop whilst the design is corrected, and approval of the Building Consent Authorities sought, a process that might take a number of days or even weeks.

5. Effective Co-regulation

The way in which the Building Act and the CPEng Act interact creates a form of co-regulatory model. The list of competent engineers supports decision making and risk management under the Building Act. In turn, the CPEng Registration Authority needs information from the Building Act regulator to provide the necessary educational programmes, and make decisions of how to deal with poor performers.

Co-regulatory or self-regulatory systems recognise the legitimacy of standard setting within the profession itself and actively support that activity. The profession may adopt a new practice or standard more quickly than a regulator is able to react.

5.1 USE OF REGISTERED ENGINEER AND/OR MIPENZ BY REGULATORS PRE-2003

Prior to repeal of the 1924 Engineers Registration Act there were a number of activities that were required to be undertaken by a Registered Engineer. Some of these were in regard to machinery, some in pressure vessels, cranes, and passenger ropeways, some in water regulations, but none under the Building Act 1991.

The acceptance of producer statements was more tied to Professional Membership of IPENZ than to registration.

Prior to 1991 each local authority decided its own means for demonstrating that engineering work was of a suitable standard. This may have included production of engineers' certificates.

5.2 USE OF CPENG BY REGULATORS POST 2003

A requirement that specified work may only be carried out by a CPEng is not common. There are four main areas:

- The Department of Labour require CPEng for particular functions in regard to health and safety of people working with machinery'
- The New Zealand Transport Agency require CPEng for sign off of certain types of vehicle safety
- A CPEng whose practice area includes dam safety may become a Recognised Engineer under the Building Act
- Building Consent Authorities may require producer statements presented under the Building Act to be signed by a CPEng.

Candidates define their own practice area. They can be quite specific but the practice area is not declared on the register as it evolves over time. It is an ethical requirement for engineers to work within their competence areas and not undertake work they are not qualified to perform.

The impact on regulatory processes is that engineers self-assess as to whether they are appropriate to do the work, and sign off the work as being undertaken by suitably qualified engineers. The self-assessment is in terms of the level of competence required to do the work, and of the nature of the work.

Some regulators have requested CPEng registrants be assigned to a field (eg structural, civil, geotechnical) indicating they believe such fields would allow the regulator to check the suitability of the engineer more closely. To date this has been rejected by the Registration Authority and CPEng Council because:

- At the time of consideration of the Chartered Professional Engineers Bill, the Select Committee considered the matter, but decided it should not be required in the CPEng Act.

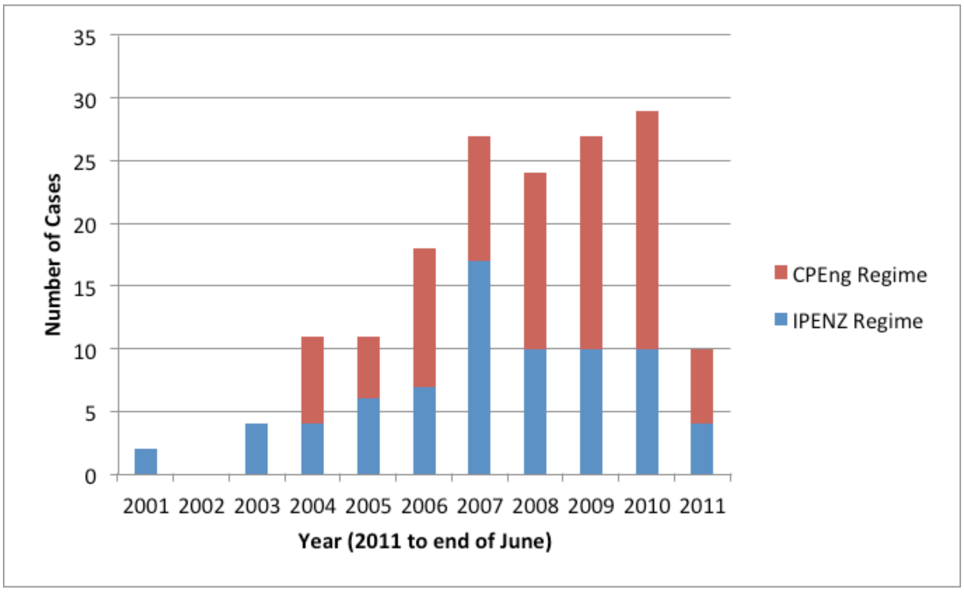
- The experience of one regulator outside the construction industry which specified a "CPEng with a qualification in mechanical engineering" has been that the regulation is not always identifying suitable persons when the device to be certified has structural, electrical and mechanical components.
- The regulatory sign-off is normally done by a single engineer on behalf of a team – the signing engineer may have driven the quality assurance process, but not be the most expert of some elements of the work – seeking exact alignment is then unhelpful.
- Fields overlap and many engineers are multi-disciplinary – an engineer classified as civil as the predominant field can often do certain types of structural work.
- Competence is demonstrated within rather than across a field. A structural engineer might be competent on steel and wooden structures but not competent on certain types of reinforced concrete.
- Competence can change between the regular (five yearly) assessments depending on the projects undertaken.
- Self-certification of the area of competence is commonly used in professional occupational regulation, and is most common when the competence assessment standard is generic across all fields. Where different competence assessments are conducted in different fields, then registration might be within a scope of practice eg medical registration.

5.3 DISCIPLINE

Under the CPEng Act, and also within the context of IPENZ being a self-regulating professional body, there is a disciplinary system for determining complaints. The grounds for discipline include:

- Incompetent or negligent engineering services/activities
- Failure to meet a code of ethical conduct.

In the 1990s IPENZ received occasional complaints against Members, but by 2003 this had risen to four per year and the number has continued to climb. From 2003 complaints could be made against CPEng registrants, and the number of complaints against CPEng registrants is about 15 to 20 per year meaning that approximately 25 to 30 complaints are received in total annually. The chart below provides some insight into the number of complaints received by IPENZ both in its role as registration authority for CPEng and in its role as a self-regulating authority.



Complaints are processed through a three stage process. The first stage determines jurisdiction or a ground for discipline, the second is an investigatory stage, and the third culminates in a Disciplinary Hearing. About two-thirds of complaints made over the last decade have failed at the first stage; the remainder go to an investigating committee. The investigating committee conducts a detailed investigation, and if it considers there are grounds, the matter is referred to a disciplinary committee for determination. A disciplinary committee considers the information in front of it. The investigating committee will provide evidence from its extensive investigations and the complainant and respondent have an opportunity to provide evidence. At each stage, including at the disciplinary hearing, the principals of natural justice are adhered to allowing all parties an opportunity to provide submissions in support of their point of view. The intent of this is to reach the truth of the matter rather than a solution which may unfairly disadvantage either the complainant or the person being complained about.

IPENZ may on its own motion under CPEng rule 55, or IPENZ Disciplinary Regulation 4, deem a matter worthy of enquiry, and if it does so proceeds as if the matter were a complaint. Since 2005 there has been a low tolerance approach to information received about apparent poor performance by professional engineers, and in ten cases, an enquiry commenced. Seven of these were in structural engineering; however only four of those reached the final stage of a Disciplinary Committee. Two of those were fined $500 and $1,500 respectively and censured providing contributions to costs of $5,000 each, although one more recent case was fined $2,000, suspended and asked to pay a contribution of $11,000 to costs.

Since 2003 (including both IPENZ and CPEng cases) there have been 14 disciplinary committee hearings of which nine made orders. Of the cases dealt with over the last ten years, just over one third have dealt with structural engineering issues of which only three were determined against the engineer.

Of these limited number of structural engineering cases more have pointed to poor construction than to poor design, and this is a major reason why no disciplinary action was taken. If any conclusion can be drawn with such limited cases, it points to an issue with the building regulatory system more than to occupational regulation. In the small number of cases where disciplinary committees have ordered disciplinary action to be taken, the view was that poor documentation and quality assurance processes were at fault rather than poor design, in that design mistakes were not adequately picked up in the quality assurance.

5.4 NON-STATUTORY REGISTERS

Through its International Engineering Alliance membership, IPENZ is involved developing benchmark competence standards at three globally recognised levels – professional engineer (already described), engineering technologist and engineering technician. IPENZ provides registers at each of these levels - Engineering Technology Practitioner (ETPract), Certified Engineering Technician (CertETn). Whereas a CPEng demonstrates the ability to resolve complex engineering problems, the ETPract registrant demonstrates the ability to resolve “broadly defined” engineering problems, and the CertETn the ability to resolve “well-defined” engineering problems. That is, the difference is in regard to the level of engineering knowledge held and the complexity of the problem that it allows the engineer to resolve.

These registers opened in 2007, and experience shows the candidates can move up or down the competence levels depending on how their career changes. ETPract and CertETn can perform and sign off simpler activities than a CPEng.

The New Zealand Construction Industry Council in its submission to the Building Amendment Bill No 3 in May 2011 supported recognition of multiple competence registers as a desirable feature of an engineering occupational regulation system. If this were adopted, simple structural work eg in houses, might be signed off by a lower level registrant than a CPEng. It follows that if a multiple tier system was adopted it could be used for competence levels above as well as below CPEng.

6. Codification of New Engineering Knowledge

6.1 RESEARCH STRUCTURE AND TECHNICAL INFORMATION SERVICES

A characteristic of structural engineering research over many decades has been a strong linkage to practice – research ideas might originate from an innovative practice, rather than from the research provider. However, peer review has been the main means of ensuring the quality of research.

Research outputs have tended to be published for the wider public benefit.

6.1.1 Pre 1987

Prior to 1987 research was primarily conducted in the two civil engineering University departments, but also in the Department of Scientific and Industrial Research and the Central Laboratories of the Ministry of Works (which also played a major role in materials testing and modelling to assist design engineers). With the disestablishment of the Ministry of Works in 1988, the Central Laboratories passed to what eventually became Opus International Consultants Ltd in 1997. When the Department of Scientific and Industrial Research was broken up in the early 1990s, the relevant research passed to what are now GNS Science and Industrial Research Ltd two of the Crown Research Institutes.

Each of these organisations had separate budgets from different Government Votes.

The Building Research Association began in the 1950s as the Building Research Bureau, an industry-owned information service. In the late 1960s, the building and construction sector (with leadership from IPENZ and the New Zealand Institute of Architects) and the Government discussed the setting up of Building Research Association, and Parliament passed the Building Research Levy Act in 1969. The Association receives the levy for investment in the development of knowledge for, and dissemination of knowledge to, the sector. Initially, the Government also provided an annual financial contribution, but this ceased in the late 1980s.

The Heavy Engineering Research Association was formed in 1978 after a period of industrial relation disputes had affected the creditability of the structural steel industry as part of the construction industry in New Zealand. The organisation was formed by companies to provide technical support and redevelop the use of steel as a construction material. In undertaking these functions it has improved the way steel structures are designed, fabricated and erected, upgraded welding skills and the welding knowledge of the industry, and improved quality assurance systems.

The Cement and Concrete Association provided technical resources based on local and overseas research. It started in the 1950s as a technical resource service from the concrete making industry to provide technical support for the use of concrete as a building material.

6.1.2 Post 1990

The main providers of structural engineering-related research in New Zealand are now the two civil engineering departments, the Building Research Association, the Heavy Engineering Research Association as well as GNS Science. The Opus Central Laboratories no longer have a major role, and the role of the Industrial Research Ltd is less.

Funding can come from the Building Research levy, from the Earthquake Commission, from the Ministry of Science and Innovation (eg the Natural Hazards Platform), and from private sources. Funding is now obtained in a competitive model, although the Natural Hazards Platform, by being cooperative of the main players, is less so.

The Heavy Engineering Research Association and the Cement and Concrete Association continue to provide technical information services.

6.2 LEARNED SOCIETY ACTIVITIES

Because of the strong research to practice links in New Zealand there are active learned society activities to facilitate the sharing. The learned society activities are conducted primarily through technical societies that started their life under the umbrella of IPENZ but which have gathered sufficient momentum and size for independent incorporated societies to be formed. Those of greatest relevance to structural engineering are:

- The New Zealand Society for Earthquake Engineering. This society was formed in 1968, holds a biennial technical conference and arranges a variety of regional technical meetings. It also publishes a learned society peer reviewed journal. Engineers wanting to engage in learned society activities about strengthening of existing buildings often join the New Zealand Society for Earthquake Engineering.
- The Structural Engineering Society of New Zealand. Founded in 1988, The Structural Engineering Society of New Zealand regional groups hold learned society meetings on a regular basis in five centres. The Society also publishes a learned society peer reviewed journal, and cooperates in conferences, often with the New Zealand Society for Earthquake Engineering. Engineers wishing to find out more about modern methods of reinforced concrete and metal structures design and construction often join Structural Engineering Society of New Zealand.
- The New Zealand Geotechnical Society. This society started in 1958 as IPENZ's first technical interest group. It holds regional technical meetings and runs an annual conference. It also publishes peer reviewed papers. Engineers wishing to find out more about foundation and ground stabilisation systems often join the New Zealand Geotechnical Society.
- The Timber Design Society. A smaller society with a focus on use of timber as a structural material. It runs regional technical seminars, meetings and sometimes conferences. It also publishes a peer-reviewed technical journal each quarter.
- New Zealand Concrete Society. The New Zealand Concrete Society also operates technical meetings and has an annual conference. It is the predominant place for information on concrete precasting.

A distinct characteristic of these societies is that they draw researchers and practitioners together, who may present papers. IPENZ runs joint meetings of its geographically organised but multi-disciplinary branches with the societies from time to time.

The learned society activities (conferences and journals) are an important quality assurance vehicle in which the practising community debates what is good and bad practice. This might be discussion of how to apply new research, or it could be discussion of an innovative design feature in regard to how well it performs in practice, or better means to calculate its performance.

6.3 DEVELOPMENT OF STANDARDS BY GOVERNMENT PRE 1987

The Ministry of Works accepted that one of its functions was to develop standards and codes of practice for all central government construction work. Through the years it established and amended a range of standards by using expertise working in committees to reach consensus on what was appropriate.

The loadings standard's development is described in detail in Appendix 3. Work started after the Hawke's Bay earthquake in 1931, and was informed by visits to important earthquake sites, overseas research, and research in New Zealand.

The Ministry of Works also established its own codes, as discussed in section 4.1.

6.4 DEVELOPMENT OF INDUSTRY GUIDANCE NOTES, CODES OF PRACTICE SINCE 1987

The changes resulting from the Ministry of Works' absence from driving collegial activity gave life to the role of the technical societies. The Structural Engineering Society of New Zealand for instance, was established in 1988.

From collegial debate about advances in engineering knowledge or practice comes consensus on new ways of undertaking engineering activities. Either directly through the societies, or by the societies working with IPENZ staff, a variety of guidance notes and codes of practice have emerged. These tend to be in a hierarchy:

- One-off advice, normally from the committee of a society warning members that they have concerns following exposure to what seem to be anomalous performance results.
- Guidance or practice notes which are normally written by an expert group and peer reviewed. They may or may not be endorsed by IPENZ and the originating society. The onus is on the user to ensure the note is properly interpreted and used.
- Codes of practice which are developed similarly to guidance notes, but the review process is more thorough, and the code attempts to be a comprehensive document setting out good practice. In contrast to the two earlier types of document, codes of practice tend to be seen as more authoritative, and whilst the user needs to check applicability, many engineers place greater reliance on such documents. Again, there might be multiple endorsements if a number of parties are satisfied with the peer review process. The Structural Engineering Society of New Zealand has an interesting code of practice in the form of design software it makes available to its members.

IPENZ recognises that changes in guidance notes, codes of practice and standards are important to the practising community. IPENZ collaborates with the societies to provide short course education to industry on recent changes in practice, but attendance is voluntary. As covered earlier, the onus is on the practising engineer to recognise what professional development he or she should undertake.

6.5 STANDARDS NEW ZEALAND

A further development involves using a Standards' process. Sometimes industry-developed documents are reviewed through a standards' process, sometimes the whole development occurs in the standards' process. Either way, Standards New Zealand needs to ensure a rigorous consensus-seeking protocol is applied. Standards at this level are still voluntary unless formally made a part of the regulations

In many countries including both New Zealand and the United Kingdom, the Standards body grew from the engineering profession. In New Zealand, after the 1931 Hawke's Bay earthquake Standards New Zealand was established. A large proportion of its standards are in engineering fields.

Standards New Zealand is established by statute as a national body able to approve and promulgate Standards. It is affiliated with the International Standards Organisation and works closely with Standards Australia. Its approach is to seek to maximise the use of international or Australasian Standards. However, standards relating to buildings tend to be New Zealand ones.

Although a Crown entity, Standards New Zealand receives no public good funding. It is self-funding through a combination of sales of Standards, and through providing resources by those with interest in a particular Standard being reviewed or developed. Standards New Zealand is restricted in the extent to which it can research greatest need, or ensure the most needed Standards are revised or developed. It must chase the available money and volunteer time. This was less of an issue whilst the Ministry of Works was in existence because Standards' development for engineering was often largely undertaken and funded by the Ministry.

At the present day, the absence of some public good funding for the standards body appears to make New Zealand anomalous amongst similar countries.

There appears to be no systematic overall plan to ensure the right types of industry guidance, codes and Standards, and enough of these, are developed. Rather, the things that are developed are those that have a champion providing either money to pay for development or significant amounts of volunteer time. IPENZ, through its Engineering Practice Advisory Committee, monitors where there is greatest need and tries to facilitate development where there are obvious gaps. In doing so, it works with the relevant societies but can only act to persuade. In general, the whole system relies on the commitment of time from volunteers. This differs from the situation up to about 1987 when preparation of guidance notes and codes was seen as part of the employment role of many government-employed engineers.

Nevertheless, the key structural engineering standards have been updated. Those of the era 1936 – 1984 are listed above in section 4.1, and those of the post 1991 modern era include:

- NZS 4203:1992 *Loadings Standard* (superseded)
- AS/NZS 1170 set, including NZS 1170.5:2004 *Earthquake actions – New Zealand*
- NZS 3101:2006 *Concrete Structures Standard*
- NZS 3404:1997 *Steel Structures Standard*
- NZS 3603:1993 *Timber Structures.*

6.6 RELATIONSHIP OF INNOVATION, PRACTICE AND REGULATION

Through the period to about 1985 the nature of the processes for creating Standards and regulatory requirements was generally conservative. For an innovation to be allowed it would have been scrutinised by both government and private sector engineers.

As indicated earlier, with the progressive breakdown of a highly regulated economy, by the late 1980s this conservative approach was eroding. The then popular free market approach led to de-regulation, and the prospect that innovations could be applied before being sufficiently proven became real.

The 1991 Building Act, by being performance-based, may have had fewer checks and balances on the way alternative solutions could be approved to ensure practice did not outpace knowledge than the standards-based regulatory system it replaced. The likelihood of a relatively poorly-proven innovation being approved by a de-skilled Building Consent Authority could have increased. Whether the regulatory environment was such that the practising community could become too risk-taking in widely applying such innovations and whether the regulator responded adequately during this period is difficult to tell. Some engineers do not believe that all Building Consent Authorities had the skill to properly evaluate engineering innovations such as tilt slabs and precast units which grew in popularity during this period.

Since the 2004 Act, the Department of Building and Housing has been progressively addressing issues where there has been debate about practice outstripping knowledge. The present model of large numbers of relatively poorly skilled Building Consent Authorities is not conducive to rapid improvement in this respect.

7. Building Consent Authority Performance

7.1 ISSUES RAISED BY ENGINEERS

In respect of commercial buildings, issues raised by engineers in regard to the performance of Building Consent Authorities under the 1991 and 2004 Building Acts include:

- The authorship of producer statements has not always been by CPEng. Some Building Consent Authorities have run supplementary "lists" of other engineers who have not been subject to stringent competence assessment such as for CPEng.
- The means and extent of peer review of alternative solutions have been inconsistent. Some Building Consent Authorities contract their own peer reviewers who report directly to the Building Consent Authorities. This is seen as better practice than those that allow the applicant to choose their own peer reviewer. In the latter cases there are suspicions that peer reviewers are chosen for ease of getting a positive report, not because they are the most qualified to undertake the task.
- The fees available for peer review may not be sufficient for the reviewers to follow good practice guidelines. Reviewers who find what they believe to be errors in design may over-run the estimated time if the designer-reviewer correspondence proves to be lengthy.
- The peer review report being received by a building official of too low competence to fully understand the issues and whether the designer's revisions have resolved the concerns.
- Some Building Consent Authorities are too reticent to make the designer's observations a condition of consent; this may mean that critical observation does not occur.

Overall, these comments suggest that there is not a nationally agreed good practice for Building Consent Authorities dealing with consent applications and issue of code compliance certificates for complex commercial buildings. Even within the seven Councils that now form part of Auckland Council there was significant variability.

7.2 MANAGEMENT OF EARTHQUAKE PRONE BUILDING POLICIES

Under section 131 of the Building Act 2004, territorial authorities are required to have a policy on earthquake-prone buildings – including specifying their intended approach, their priorities, and how the policy will apply to heritage buildings. This policy must be reviewed every five years. Earthquake prone buildings are defined as buildings where their ultimate capacity would be exceeded in a moderate earthquake and where they would be likely to collapse causing injury or death, or would cause damage to other property.

A moderate earthquake is defined[1] in regulations as an earthquake that would generate shaking at the site of the building that is one-third as strong as the earthquake shaking that would be used to design a new building at the site.

[1] Building (Specified Systems, Change the Use and Earthquake-prone Buildings) Regulations 2005 (SR 2005/32), Clause 7

Currently many territorial authorities are in the process of undertaking their five-yearly review of policies, and although not up to date, the Department of Building and Housing's website has a summary of policies. For 73 territorial authorities the following is of note:

- Twenty-eight did not have a timetable for strengthening of earthquake prone buildings.
- The average maximum time for strengthening was 21 years.
- Eight territorial authorities did not identify earthquake prone buildings and saw this as a building owner responsibility.
- Twenty-five required the building owner to undertake an initial assessment and 44 territorial authorities undertook this assessment.
- Thirty-four recommended improvements greater than one third of the New Building Standard and 21 recommended strengthening to greater than two thirds of the New Building Standard.

Clearly there is considerable room for improvement by territorial authorities and/or building owners, and of enforcement by government agencies.

7.3 THE BENEFITS AND COSTS OF STRENGTHENING

Retro-strengthening of existing buildings raises the issue of financially viability. A report on the Cost Benefit of Improving the Performance of Buildings in Earthquake (Hopkins and Stuart, March 2002) was prepared for the Department of Internal Affairs and later used as the basis for the currently required one-third level of the New Building Standard. Some benefit/cost ratios from this report are shown in the following table.

Location	Benefit/Cost ratio 33 per cent New Building Standard	Benefit/Cost ratio 66 per cent New Building Standard	Benefit/Cost ratio 100 per cent New Building Standard
Wellington	2.90	3.70	3.80
Christchurch	0.39	0.62	0.82
New Zealand	0.87	1.22	1.47

The benefit/cost ratios tend to increase as the strengthening standard is raised. Although Christchurch's seismicity will be reassessed, it is recognised that in low seismicity areas the benefit/cost ratio will be low. There may therefore be a case for having a lower strengthening standard in low seismicity areas (minimum of 33per cent) and a higher standard in other areas (up to 66per cent).

However the regulator and the building owner may have different perspectives on benefit/cost ratios.

The regulators (the Department of Building and Housing and the territorial authority) are concerned with durability over the specified life of the building[2]. The above benefit analysis included construction costs, injury and fatality costs, and reductions in business interruption and social disruption.

Property owners often have a much shorter time perspective – possibly ten years or fewer. They are interested in a different set of benefits including the potential rental premium, and savings in insurance costs.

Since it is almost ten years since the earlier benefit/cost analysis was undertaken, and that, for example, insurance costs might be significantly different, it may be that the benefit/cost analysis should be updated.

[2] New Zealand Building Code, Clause B2, Durability

8. 2003 Structural Engineering Taskforce

Following receipt of an "open letter" authored by Mr John Scarry, IPENZ commissioned a structural engineering taskforce in 2002. It reported in 2003, making six major recommendations in the following areas:

- Development of Standards and Codes of Practice. There was an urgent need to develop more comprehensive standards (for practices that could be described in a prescriptive way, eg through Standards New Zealand's processes) and codes of practice (for practices requiring substantial professional judgement eg through activities of the professional body).
- Systematic recognition of competent structural engineers. There was a need to ensure that those competent in simple structure design (normal loads), and those competent in design of complex structures (considering the varying loads that occur in seismic events) were identified, and that structural work be limited to those with the relevant competence for the nature of the design required. The competence assessments had to stringent, and this was noted being a challenge for the profession.
- Ongoing professional involvement. There was a need to ensure ongoing professional involvement so the effective sign-off of structural work post-construction (including all the variations from the agreed design) when required would be undertaken by a competent structural engineer.
- Expanded technical leadership role for Government's central regulator (then the Building Industry Authority) in providing a code of practice for the Territorial Local Authorities who were taking over this role. The central agency had to take on a foresight and leadership role so problems could be anticipated and assertive actions taken. This aimed to help lift the performance of Territorial Local Authorities and certifiers.
- Improved Consent and Audit Processes. The variability in standards between Territorial Local Authorities, and the unacceptably low standards in some cases, had to be eliminated by ensuring that consent approvals and code compliance certification only occurred after high quality evaluation processes, including peer reviews by expert structural engineers where the building had non-standard structural features. Territorial Local Authorities had to establish a culture of complaining about the competence of engineers who present sub-standard work on an on-going basis so these people could be investigated by the registering authority.
- Responsibility of Building Owners. Building owners had to be required to employ or engage suitably qualified people.

Since 2003 IPENZ has implemented a co-ordinated set of activities. Appendix 4 sets out that programme and key achievements.

9. Improvements to Building Regulations for Engineering Work

In section 3.8, IPENZ has set out possible alternatives to the present occupational regulation system for engineering. In this section some building regulation possibilities, IPENZ considers would have wide support in the engineering community, are described.

- Develop Building Consent Authorities' capability to quality assure structural engineering work – this will involve a small number of large Building Consent Authorities with expert engineering staff. The model used by Wellington City Council of contracting services from active structural engineers is often commended.
- Establish formal information flows from Building Consent Authorities to IPENZ about engineer performance to allow IPENZ to take steps to coach, educate, or reassess, and as last resort discipline those regularly producing work of low quality.
- Formally recognise the need for designer involvement during construction through imposition of requirements to provide evidence of the builder implementing correct designs.
- Require designers to document their design philosophy in building consent applications, particularly if there is structural irregularity.
- Recognise that minor architectural changes may require fundamental rethinking of the structural design philosophy and allow opportunity for this to occur, even when there is limited time.
- Establish those requirements so the engineer is able to charge a reasonable fee to fully complete a good quality structural engineering practice.

10. Concluding Remarks

IPENZ acknowledges the assistances of a number of Members and some non-members who have added to our knowledge and made significant contributions to this report. We have endeavoured to ensure the accuracy of the information provided but this cannot be guaranteed.

APPENDIX 1 – Comparison of the New Zealand Chartered Professional Engineer competence standard with the exemplar developed by the International Engineering Alliance

Minimum Standard for Registration as Chartered Professional Engineer	International Engineering Alliance Exemplar Professional Competences
(1) To meet the minimum standard for registration, a person must demonstrate that he or she is able to practise competently in his or her practice area to the standard of a reasonable Professional Engineer.	(1) To meet the minimum standard of competence a person must demonstrate that he/she is able to practice competently in his/her practice area to the standard expected of a reasonable Professional Engineer.
(2) The extent to which the person is able to do each of the following things in his or her practice area must be taken into account in assessing whether or not he or she meets the overall standard in subclause (1):	(2) The extent to which the person is able to perform each of the following elements in his/her practice area must be taken into account in assessing whether or not he/she meets the overall standard.
(a) Comprehend, and apply his or her knowledge of, accepted principles underpinning — (i) widely applied good practice for professional engineering; and (ii) good practice for professional engineering that is specific to New Zealand	(3) Comprehend and apply advanced knowledge of the widely-applied principles underpinning good practice Comprehend and apply advanced knowledge of the widely-applied principles underpinning good practice specific to the jurisdiction in which he/she practices.
(b) Define, investigate, and analyse complex engineering problems in accordance with good practice for professional engineering	(4) Define, investigate and analyse complex engineering problems.
(c) Design or develop solutions to complex engineering problems in accordance with good practice for professional engineering	(5) Design or develop solutions to complex engineering problems.
(d) Exercise sound professional engineering judgement	(6) Recognise complexity and assess alternatives in light of competing requirements and incomplete knowledge. Exercise sound judgement in the course of his or her complex engineering activities.
(e) Be responsible for making decisions on part or all of 1 or more complex engineering activities	(7) Be responsible for making decisions on part or all of one or more complex engineering activities.
(f) Manage part or all of 1 or more complex engineering activities in accordance with good engineering management practice	(8) Manage part or all of one or more complex engineering activities.
(g) Identify, assess, and manage engineering risk	(9) Evaluate the outcomes and impacts of complex engineering activities.
(h) Conduct his or her professional engineering activities to an ethical standard at least equivalent to the code of ethical conduct	(10) Conduct his or her engineering activities ethically.

Minimum Standard for Registration as Chartered Professional Engineer	International Engineering Alliance Exemplar Professional Competences
(i) Recognise the reasonably foreseeable social, cultural, and environmental effects of professional engineering activities generally	(11) Recognise the reasonably foreseeable social, cultural and environmental effects of complex engineering activities generally, and have regard to the need for sustainability; recognise that the protection of society is the highest priority.
	(12) Meet all legal and regulatory requirements and protect public health and safety in the course of his or her activities.
(j) Communicate clearly to other engineers and others that he or she is likely to deal with in the course of his or her professional engineering activities	(13) Communicate clearly with others in the course of his or her engineering activities.
(k) Maintain the currency of his or her professional engineering knowledge and skills.	(14) Undertake continuity professional development activities sufficient to maintain and extend his or her competence.

Complex engineering activities means engineering activities or projects that have some or all of the following characteristics:

New Zealand Chartered Professional Engineer	International Engineering Alliance Exemplar
Involve wide-ranging or conflicting technical, engineering, and other issues.	Involve wide-ranging or conflicting technical, engineering and other issues.
Have no obvious solution and require originality in analysis.	Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models.
Involve infrequently encountered issues.	Involve infrequently encountered issues.
Are outside problems encompassed by standards and codes of practice for professional engineering.	Are outside problems encompassed by standards and codes of practice for professional engineering.
Involve diverse groups of stakeholders with widely varying needs.	Can extend beyond previous experiences by applying principles-based approaches.
Have significant consequences in a range of contexts.	Have significant consequences in a range of contexts.
Cannot be resolved without in-depth engineering knowledge.	Requires research-based knowledge, much of which is at, or informed by, the forefront of the professional discipline and which allows a fundamentals-based, first principles analytical approach.
	Are high level problems including many component parts or sub-problems.

Complex engineering problems means engineering problems that have some or all of the following characteristics:

New Zealand Chartered Professional Engineer	International Engineering Alliance Exemplar
Involve wide-ranging or conflicting technical, engineering, and other issues.	Involve wide-ranging or conflicting technical, engineering and other issues.
Have no obvious solution and require originality in analysis.	Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models.
Involve infrequently encountered issues.	Involve infrequently encountered issues.
Are outside problems encompassed by standards and codes of practice for professional engineering.	Are outside problems encompassed by standards and codes of practice for professional engineering.
Involve diverse groups of stakeholders with widely varying needs.	Can extend beyond previous experiences by applying principles-based approaches.
Have significant consequences in a range of contexts.	Have significant consequences in a range of contexts.
Cannot be resolved without in-depth engineering knowledge.	Requires research-based knowledge, much of which is at, or informed by, the forefront of the professional discipline and which allows a fundamentals-based, first principles analytical approach.
	Are high level problems including many component parts or sub-problems.

APPENDIX 2 – Engineering Education and Accreditation

1. 1950's to 1980's

New Zealand has long had a four-year engineering degree. After World War II it consisted of a one year "intermediate" which was almost entirely science, followed by three years of engineering. The intermediate could be studied at a number of New Zealand Universities, and typically contained subjects such as mathematics, physics and chemistry. The two civil engineering departments at the Universities of Auckland and Canterbury selected students based on intermediate year results into the final three years of study. Within civil engineering, students did a general core covering general civil engineering including structural engineering, and could typically choose to specialise a little in the final year in a sub-discipline such as structural engineering. Graduates achieving higher results might be awarded the degree with honours.

At the University of Canterbury the civil degree consisted of two compulsory "professional" years to give students a broad grounding. The final year included project work, and students were able to choose a cluster of elective subjects. By this choice a student could study more or less structural engineering, but the degree certificate does not differentiate. Employers wanting structural engineers may not have differentiated between potential employees on the basis of choice of elective subjects.

The University of Canterbury programme through this period was characterised by close linkages of research, practice and teaching, so students who chose structural electives were likely exposed to the frontiers of knowledge in the discipline. Indeed some of the electives were also able to be included in Masters programmes.

At the University of Auckland, whilst the degree structure was equivalent (i.e. a general civil degree with elective choices allowing more structural engineering), there was one practical difference. Through the period either side of World War Two architecture students were exposed to structural engineering through the expertise of SI Crookes junior. He drew on the expertise available in Japan and California. It appears that over time the structural expertise in the School of Architecture was shared with the School of Engineering.

It should be remembered that earthquake engineering became much more important following the 1931 Hawke's Bay earthquake, so by after World War Two, both at the University of Canterbury and University of Auckland civil engineering degrees had evolved in response. By the late 1940s civil engineering graduates were exposed to the relevant principles underpinning structural engineering, although the body of knowledge was largely drawn from overseas.

By the 1960s, New Zealand academics were becoming engaged in earthquake engineering research, and certainly by the 1970s (eg through Professors Park and Paulay at the University of Canterbury and Associate Professor Fenwick at the University of Auckland) there were contributions to the international body of knowledge. The researchers had close communication to the New Zealand structural engineering practicing community so by this time, students taking structural engineering electives were likely exposed to both leading edge knowledge and practice.

The three "professional" years of New Zealand engineering degrees were in all probability similarly structured to the three years of a U.K. degree, and Australia had also adopted a similar structure.

2. 1980s and 1990s – Introduction of Accreditation

The intermediate and three professional years model was still in use in 1980 at the time that IPENZ commenced degree accreditation. Accreditation by United Kingdom -based discipline-specific engineering institutions such as the Institution of Civil Engineers had occurred in a number of British Commonwealth countries prior to that time, and therefore the model adopted by IPENZ for accreditation reflected the one i n place in the United Kingdom at the same time.

The nature of accreditation was input-based. That is, panels' examination included, for example, ensuring the time allocations to particular parts of the curriculum were balanced, laboratories were suitable, staff of adequate quality were in place, and there were appropriate management systems. Because of New Zealand's small size, accreditation panels have always included overseas academic staff in relevant disciplines, which has resulted in international benchmarking.

In 1989 IPENZ became a founding signatory of the Washington Accord. The Accord at that time was based on substantial equivalence of accreditation systems. There were not robust quality assurance systems, but generally it was considered that because they had similar educational systems, the other signatories were achieving similar outcomes.

During the 1980s and 1990s IPENZ accreditation panels observed progressive changes in engineering education in New Zealand. One such change was the entry of new providers of Bachelor of Engineering degrees, but none of these has taught structural engineering. Therefore this report focuses on activity at the Universities of Auckland and Canterbury.

In terms of the degree in civil engineering, IPENZ has observed the growing inclusion of environmental engineering into the course of study. In addition, in line with the Washington Accord, our accreditation panels were demanding greater evidence of delivery of contextual knowledge of how engineering interacts with society, and this had to be accommodated. Thirdly, the expanding body of knowledge meant there was an increasingly volume of advanced material in the discipline.

The consequence of these three factors was that study of engineering materials was moved into the first year of the degree. At the University of Auckland, by the end of the 1990s, the first year largely focussed on engineering materials. Students were selected into Year 1, but chose their discipline of study on entry to Year 2. At Canterbury the intermediate structure was retained, but some engineering materials' study moved down into the intermediate. Selection into a discipline at the commencement of Year 2 (still called first professional year) also occurred. The presumption was that the pushdown of engineering materials study created room for more advanced teaching at senior levels.

Whilst from an IPENZ viewpoint, the BE(Hons) degrees conformed to a good international practice, it was argued by Mr John Scarry in an open letter to IPENZ in 2002 that the amount of structural engineering a student in civil engineering needed to do to graduate was reduced. This is borne out by the University of Auckland, who say that the amount of contact hours devoted to structures was reduced by 17per cent in 1995. (There was also a very significant change in the mid-1980s.) The 1995 change it affected all students doing the minimum compulsory structures courses. Obviously, what is no longer covered in the basic curriculum needs to be covered later and displaces more advanced concepts in courses that the "specialised" structures students take.

The structure of the civil degrees remained the same as earlier – a broad grounding, with electives available in the final year, giving students the opportunity to access more or less structural knowledge according to preference. The pattern of close links between professional practice, research and teaching continued. However, the extent to which electives could be made available reduced with pressure to include the wider contextual knowledge demanded by the Washington Accord.

3. 2000 to 2009

Major changes occurred after 2000 in accreditation systems. During the late 1990s and early 2000s IPENZ had commenced developing "outcomes-based" accreditation. The argument was that providers could design their programmes according to need, and the accreditation agency should look at the outcomes achieved. IPENZ began developing a graduate profile which was used as an adjunct to the accreditation system up until 2005. In that year, the Washington Accord developed "exemplar graduate attributes". IPENZ was heavily involved in this work, and used the outcomes directly in its accreditation procedures. Since that time IPENZ accreditation has been primarily based on ensuring the graduate profile of a graduate completing an accredited programme is substantially equivalent to the Washington Accord exemplar and that the provider has the resources and systems to consistently deliver the educational outcomes. This should not be viewed as a change in standard but as a change in process.

During the 2000s one major technical change in the four year degree occurred in New Zealand. It became classified as a Bachelor of Engineering with Honours degree (Level 8) rather than a Level 7 Bachelor of Engineering degree that might be granted with honours. This change meant the qualification needed to conform to the definition of a Level 8 degree, and required a substantive research project. This requirement became compulsory for all University of Auckland Civil Engineering candidates entering in March 2008 and completing their degree in November 2010.

Observing the programmes through accreditation visits and continuing interaction with the engineering deans, IPENZ characterised the Auckland programme at this time as almost four full years of engineering. By retaining an intermediate structure, however Canterbury had an ever-reducing science core in the first of four years.

As a consequence of graduate profile development there was continuing pressure on programmes from IPENZ as the accreditation body to ensure programmes conformed.

At both University of Canterbury and University of Auckland the civil engineering departments started to develop one year taught Masters degrees. The idea was that a BE (Hons) graduate could further develop a technical specialisation, often working part-time as an engineer whilst studying. This model has not generally been widely taken-up, and not at all in structural engineering.

A further influence on engineering education was the introduction of the performance-based research funding in 2003 (with subsequent evaluation rounds in 2006 and upcoming in 2012). Academics were rated on their research quality, according to criteria that placed heavy weight towards peer-reviewed publications, and gave less credit to working with industry and on codes of practice and standards. The major professions (law, accountancy, medicine and engineering) relate anecdotal evidence that the teaching of professional practice has been adversely affected. The "rounded" academic, who designs, researches, teaches and consults may be less common in our engineering schools in 2011 than a decade ago. Certainly, many academic staff have recounted to IPENZ that they are actively encouraged to write peer-reviewed publications as a higher priority than working with industry on practical issues like developing codes of practice.

4. 2009 and Beyond

In 2009, the Washington Accord did make a change in standard. It did this by adopting a new exemplar graduate attributes statement. At the most recent meeting of the Washington Accord in Taipei in June 2011 the signatories agreed that all signatories needed to undertake transitional activities as follows:

- All signatories would undertake a self-study of their respective accreditation requirements against the Graduate Attributes, identify shortfalls and formulate an action plan to address the shortfalls. The action plan must identify changes and actions that are required and time scales for effecting the changes.
- Signatories must submit the self-study in advance of the June 2012 meetings of the Accord.
- The Signatories will consider the submissions and may require a signatory to revise its self-study, shortfalls and action plan. Revisions will be submitted to the 2013 meetings.
- An initial target requiring signatories to demonstrate, in the course of the scheduled six-yearly reviews of their accreditation systems, substantial equivalence to the exemplar Graduate Attributes in 2019. Signatories in a position to do so may demonstrate compliance in scheduled reviews before 2019. The 2019 target will be confirmed not later than June 2013.

From a New Zealand viewpoint, work on the first stage was undertaken during 2009 and 2010. It has been estimated that the shortfall from the pre-2009 IPENZ minimum accreditation standard to the new graduate attributes corresponds to between 45 and 60 credits (up to 0.5 years of study). Extensive discussions and consultation was undertaken with employers of engineers and the New Zealand Council of Engineering Deans. Some are of the view that New Zealand needs to seriously consider programme lengthening from the present norm of 4.0 equivalent full time students to maintain New Zealand's international standing in professional engineer education. Others disagree.

New Zealand could therefore be faced with the prospect that professional engineering education might well lengthen during the next decade. The key areas of difference identified by a working group set up by the IPENZ Standards and Accreditation Board are as follows.

- Fifteen (15) credits of engineering knowledge. The previous accreditation criteria could be met primarily from teaching to up-to-date textbooks. The new Washington Accord international graduate profile requires:
  - students to demonstrate their capability to comprehend and apply engineering knowledge at the forefront of the discipline, accessed through searching the open research literature
  - students to demonstrate their capability to comprehend and apply the codified body of knowledge at the forefront of the practising community.
- Twenty-five to 30 credits of capstone projects (that integrate all the engineering learned in the degree). The new requirements are to:
  - undertake research rather than undertake investigation – a full 30 credit research project would achieve the new requirement whereas 10-15 credits of research as part of a larger project would have previously been sufficient
  - The overall integrated design project experience may need to be 30 credits whereas 15 credits plus some assignment work would have previously sufficed.
- Five to 15 credits in which a range of contextual skills eg working with other disciplines, ethical reasoning, and impacts on communities are developed and assessed, most likely through project-based learning, which could include a component based in industry.

It is particularly interesting to note that for the future it will be explicit that students should receive representative exposure to codified knowledge and tools currently used by practitioners in their area of specialisation. Students should be introduced to the nature of codified knowledge used by the New Zealand practising community in their areas of specialisation, demonstrate an ability to use some examples and undertake critical evaluations of uncertainties. There should also be clear evidence that academic staff research outputs are being used to inform the teaching programme.

From an accrediting body viewpoint, the international change aligns with some of the concerns expressed in the New Zealand practising community as to whether graduates are sufficiently able to work with knowledge at the frontier of the discipline, use codified knowledge and undertake design. The civil programmes at the Universities of Auckland and Canterbury comfortably met the pre-2009 criteria. The extent and the nature of any change to the BE(Hons) degree has not been determined at time of writing. It is too early for any effect to impact on the practice of structural engineering – it will be at least a decade.

APPENDIX 3 – Key Research Advances and their Incorporation into Standards

1. Important 20th Century Earthquakes

1.1 SAN FRANCISCO 1905

Dr Ivan Skinner reports that the earthquake in San Francisco in 1905 showed that some buildings performed much better than expected. There was no good information on the ground motion at that time, so the inertial forces were unknown, but observation showed that non-structural parts of buildings provided bracing and absorbed energy. An attempt to estimate earthquake forces from the deformation and damage to the structural frames led to moderate forces and estimates of ground accelerations of about one g (gravitational acceleration).

These energy-absorbing parts were of architectural rather than structural importance during design. Because their energy-absorbing properties arose as a fortuitous coincidence of their construction, they could not be designed in a quantitative manner.

1.2 HAWKE'S BAY 1931

The method of estimation previously used for San Francisco appeared to confirm similarly low ground accelerations.

The earthquake was followed within minutes by fires, believed by Dr Skinner to have been ignited by Bunsen burners in pharmacies. Broken water mains and an unfortunate change in wind direction made fire fighting very difficult.

The government decided that a building code was necessary, and later that year formed a Building Regulations Committee under the chairmanship of Professor JEL Cull to report and make recommendations on building regulations, with special reference to earthquake resistance. The New Zealand Standards Institution, founded in 1932, became responsible for the work of Professor Cull and the City Engineers of Wellington, Auckland, Christchurch, and Dunedin. The New Zealand Standards Institution appointed a Building Code Committee in 1934 to write regulations in the form of a Model Building By-law. This work was completed in 1935, and was published as a New Zealand Standard in 1936.

A note at the beginning of the1936 Standard states that the functions of the [New Zealand Standards] Institution had by then been taken over by the Department of Scientific and Industrial Research (Department of Scientific and Industrial Research).

1.3 WAIRARAPA 1942

Mr George Butcher reports that three earthquakes in the Wairarapa caused considerable damage in the southern part of the North Island. Dr Skinner recalls collapse of street-frontage parapets and damage to tramway tracks, presumably resulting from street surface deformation. The government introduced emergency regulations for unreinforced masonry buildings which remained in force until 1955. These Regulations gave Local Authorities powers to order the demolition, strengthening, or securing of unreinforced masonry buildings. However because of the shortage of building materials during the war and shortly after it, a large number of buildings remained "at risk". Mr Butcher believes much of the "securing" and "strengthening" work was ill-considered and not well designed. In many cases the work was carried out by people who had little or no real experience in seismic structural design.

1.4 ANCHORAGE 1964

Mr Bob Norman reports that this showed remarkable examples of dynamic response and synchronous effects. Two buildings alongside each other had widely differing natural periods of vibration: one was almost demolished while the other emerged unharmed.

1.5 NIIGATA 1968

This demonstrated the problem of liquefaction as some four storey buildings were almost undamaged except that they were lying on their sides. Ground deformation was also demonstrated by the dropped spans of a nearby river bridge.

1.6 MANILA 1968

Dr Skinner noted similar findings to those of Mr Norman at Anchorage, as in Manila there was also a dramatic selection of damaged and undamaged buildings. A second earthquake 18 months later “selected” a quite different set of Manila buildings for severe damage. Dr Skinner attended both earthquakes.

2. Early Engineering Seismology in New Zealand

2.1 ARCHITECTURE SCHOOL AT UNIVERSITY OF AUCKLAND

Professor Peter Lowe reports that Charles R Ford published *Earthquakes and Building Construction*, Whitcomb & Tombs, 1926. Mr Ford was a partner of W.H. Gummer in an architectural practice in Auckland, and had visited California to study their technical responses to earthquakes. Professor Lowe suggests that Mr Ford’s account is one of the earliest books in English on the subject. Mr Ford later served on the Technical Committee that wrote the 1936 *Model Building By-Law*.

Professor Lowe also reports that Samuel Irwin Crookes Jnr taught the structures content of the architecture course at the University of Auckland and published his book *Structural Design of Earthquake Resistant Buildings*, Leighton, in 1940. The young architects in training were thus exposed to forward-looking teaching on a topic of relevance to New Zealand building and construction technology. The book is based largely on Californian and Japanese knowledge of the time. Professor Lowe suggests that young architects of the period were probably better served in this aspect of their education than were their engineering counterparts.

2.2 WELLINGTON SCHOOL OF ARCHITECTURE

For a number of years Mr Les Meggett taught structural and earthquake engineering at the Wellington School of Architecture.

2.3 WORLD CONFERENCES ON EARTHQUAKE ENGINEERING

Dr Ivan Skinner recalls that during the late 1950s New Zealand researchers and design engineers met informally to present their ideas of how seismic design should be done, and to critique each other’s work. Vern Murphy from the New Zealand Government Railways, who had conducted pull-back and release tests on an elevated water tank, was the only New Zealander to attend the First World Conference on Earthquake Engineering in 1956, but at the Second (Tokyo and Kyoto) in 1960 he was joined by Johnny Johnstone of the Ministry of Works, Ivan Skinner of the Department of Scientific and Industrial Research, and Wilf Edwards of Clendon & Edwards. All wrote papers on their attendance and presented summaries to the Earthquake Symposium organised by the Wellington Branch of the New Zealand Institution of in 1961.

The Third World Conference was held in New Zealand (Auckland and Wellington) early in 1965. Mr Bob Norman, a former Commissioner of Works, reports that he was responsible for developing the programme. At its conclusion he organised a meeting of the three principal participants – the United States, Japan, and New Zealand. Professor George Housner from Caltech, Professor Muto from Japan (then World President) and Lyall Holmes from New Zealand were spokespersons at what turned out to be an accord with huge consequences. It had been evident from the Conference that no one country had the resources to address all the issues. At the same time, the three major players had areas of expertise which, if pooled internationally, would have a big impact on the direction of research. California's installation of strong motion accelerographs gave it the best knowledge of ground motion. Japan had the best knowledge of dynamic response of structures from a great number of half-scale building frameworks and shaking tables. New Zealand's structural group at the University of Canterbury was best suited to analyse the effects of earthquakes on framework connections.

Mr Norman comments that this shared approach had huge benefits for the international pool of knowledge on engineering seismology. It demonstrated the payoff for setting up "centres of excellence" rather than having a single agency spreading its resources too thinly over a plethora of problems.

There was substantial collaboration between New Zealand and Japanese researchers in the early 1960s. Dr Skinner studied the dynamics of shaking buildings by methods analogous to the electrical resistance – inductance – capacitance circuit, including a physical model with steel wire for the columns and steel sheets for the floors. This model and its associated circuitry was an analogue computer which predated the arrival of digital computers in the Department of Scientific and Industrial Research. Japanese Professor Watabe used the methods of mechanical engineering in the form applied to the severe buffeting experienced by aircraft in some conditions of violent flight.

The Department of Scientific and Industrial Research was also active in the earth sciences. The Engineering Section of its Soil Bureau in Taita provided advice on soil mechanics and geotechnical matters. George Eiby published a useful and readable book called *Earthquakes* in 1957 and a new edition in 1980.

2.4 SEISMIC ZONING

In 1953 the Otago Branch of the New Zealand Institution of Engineers – now the Association of Consulting Engineers – submitted a proposal for the seismic zoning of New Zealand to the New Zealand Institution of Engineers Council, as this process was then under way in the United States and the former Union of Soviet Socialist Republics. The New Zealand Institution of Engineers Council asked the Department of Scientific and Industrial Research committee to consider this proposal, which apparently found it to be premature and did not then recommend it. During the 1970s Mr Bill Stevenson of the Department of Scientific and Industrial Research took it up enthusiastically in the form of "microzoning", and from about 1990 to the present, first the Department of Scientific and Industrial Research and then GNS Science developed the seismic hazard zone maps that have appeared in the later loading standards. This work is presently led by Dr Graeme McVerry.

2.5 NEW ZEALAND INSTITUTION OF ENGINEERS – WELLINGTON CITY COUNCIL COLLABORATION

During 1964 a number of meetings were held by members of the Consulting Engineers Division of New Zealand Institution of Engineers and the Structural Department of the Wellington City Council to discuss high rise buildings in Wellington and their seismic requirements. These lead to agreement to use the draft loading code soon to appear as NZS 1900 Chapter 8, the American Concrete Institute's ACI 318-63 and Blum et al (see below) for reinforced concrete, and the British Standards Institution BS 449 for structural steel. Mr Butcher recalls that in Wellington, reinforced concrete buildings were to be restricted to a height of 102 feet and 10 storeys, apparently following Japanese practice.

2.6 MINISTRY OF WORKS BUILDING CODE

Mr William Darnell reports the existence of a document known as PW 81/10/1 - the Ministry of Works Building Code. The Ministry used it for government buildings, and private-sector designers were required to use it when they won government contracts. The Ministry checked the design work, took new research into account, and advocated its adoption into New Zealand Standards.

During the 1960s the Ministry created a grading system for government buildings which may be regarded as an early form of "earthquake prone buildings" policy.

In the 1970s Otto Glogau, Chief Structural Engineer at the Ministry, played an active role in supporting seismic isolation of appropriate New Zealand buildings.

2.7 PARK AND PAULAY AT UNIVERSITY OF CANTERBURY

Professors Robert Park and Tom Paulay led the work mentioned by Bob Norman. They introduced the seismic design procedure known as capacity design, based on a 1969 paper by JP Hollings published by the New Zealand Society for Earthquake Engineering, and further developed in their 1975 book - *Reinforced Concrete Structures*. In 1995 Professor Park described it as follows:

"In the capacity design procedure for reinforced concrete structures the designer chooses the most appropriate mechanism for the structure to achieve adequate ductility during a major earthquake, normally by ductile flexural yielding occurring at selected plastic hinge positions. The chosen plastic hinge positions are designed for adequate flexural strength and ductility. All other regions of the structure are then made adequately strong in flexure, and the shear strengths of the whole structure made adequately large, to ensure that then post-elastic deformations occur only at the selected plastic hinge regions."

Professor Paulay's particular contribution was to develop by physical testing what have become known as "coupled shear walls". Two walls in tandem, often forming the ends of a rectangular building, were separated by about 1.5 metres and connected by several 1.5 metre beams at different heights. These beams absorbed energy by inelastic bending and shear as the walls they connected deflected in their own planes.

2.8 LITERATURE

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3. Strong Motion Recorders

3.1 SMOKED GLASS SCRATCH PLATES

In 1955 the Department of Scientific and Industrial Research commenced a strong motion accelerometer programme. Six accelerometers were installed from Tuai to Westport, and seven in the Gordon Wilson flats on The Terrace in Wellington. These instruments were based on a tuned mass-spring-damper system with mechanical magnification that left a scratched record on a smoked glass plate.

3.2 MO2 ACCELEROGRAPH

This instrument recorded vibrations in three orthogonal directions by directing beams of light onto a 35 millimetres film which was driven from reel to reel by an electric motor. The sensing elements were cubes of brass, 10 millimetres on side, supported on frictionless flexures, damped by paddles immersed in oil, and carrying a mirror on one face. The instrument was triggered by a separate vertical mass-spring-damper system that actuated a switch when the mass moved far enough. After an earthquake was reported, a technician drove to the (often remote) site, extracted the film cassette, replaced it, and drove back to the laboratory to photographically develop the film and digitise the three traces.

Dr Skinner notes that the initial MO1 accelerograph operated on the same principles but was less convenient to manufacture and operate. The Department of Scientific and Industrial Research's physics and engineering laboratory developed the instrument during the early 1970s, and then licensed the Naenae company of Victoria Engineering Ltd to build them in quantity. The main overseas market was in Los Angeles where a local ordinance required strong motion recorders in some public buildings. Others were sold in Italy and Romania.

3.3 REAL TIME DIGITAL ACCELEROGRAPHS

The MO2 was progressively replaced by superior digital accelerographs from about 1990, but IPENZ has no detailed knowledge of their construction.

4. Loadings Standards

The Loadings Standards (initially incorporated in Model Building By-laws and later known as Structural Design Actions Standards) were originally based on the assumption of elastic behaviour, then progressively incorporated more and more sophisticated methods of recognising the benefits of ductility and energy absorption. Mr Norman describes this as putting a greater emphasis on resilience as distinct from structural integrity, and suggests that resilience in its own right should be a topic alongside base isolation, hysteretic damping, capacity design, and plasticity of building connections.

4.1 N.Z.S. NO. 95 – 1936 NEW ZEALAND STANDARD MODEL BUILDING BY-LAW 1936

The *Building Code* Committee consisted of:

- Messrs J O'Shea and GA Hart, Municipal Association of New Zealand
- Mr FF Gilmore, Fire and Accident Underwriters' Association of New Zealand
- Mr W Mill, New Zealand Federated Builders' and Contractors' Industrial Association of Employers
- Mr HC Morton, New Zealand Institute of Architects
- Mr FW Furkett, New Zealand Society of Civil Engineers (Chair)
- Mr R Burn, New Zealand Manufacturers' Association
- Messrs JT Mair and WL Newnham, Public Works Department
- Dr MAF Barnett (on leave), succeeded by Dr E Marsden, the Department of Scientific and Industrial Research
- Mr JG Lancaster, Electric Supply Authority Engineers' Association of New Zealand
- Prof JEL Cull, Chairman of 1931 Building Regulations Committee.

A separate Technical Committee consisted of:

- Messrs M Dawson and CR Ford, New Zealand Institute of Architects
- Messrs W Mill and RC Jamieson, New Zealand Federated Builders' and Contractors' Industrial Association of Employers
- Messrs RA Campbell and P Holgate, New Zealand Society of Structural Engineers.

The object of the *Building Code* Committee had been to produce a building code applicable to New Zealand's special conditions, but sufficiently flexible to permit the introduction of approved innovations in materials and methods of construction.

Section I related to legal matters and what were then known as Building Permits.

Section II covered general design and construction.

- Clauses 201 to 204 required all parts of the building to be tied together, ornaments to be securely attached, and foundations and footings to be inter-connected.
- Clause 205 required buildings to be designed and constructed to withstand a continuously applied horizontal force of not less than 0.08 of the weight above.
- Clause 207 required the main bracing systems to be located symmetrically about the centre of mass, or else proper provision was to be made for the torsional moment on the building.
- Clause 208 specified that the working stresses under earthquake load should not exceed those tabulated later by more than 50per cent for steel and 25per cent for concrete. The thinking was that a few short duration loads would produce moderate deformation and damage that was acceptable for rare events.
- Clause 209 required steel or reinforced concrete frames for many public buildings, but allowed wooden construction if not otherwise outlawed.
- Clause 215 provided some flexibility for advances by permitting special materials and special forms of construction to be used if the New Zealand Standards Institution agreed.

Section III covered the general basis for design and floor loads.

- In the absence of detailed provisions, Clause 301 required design by rational analysis in accordance with the established principles of mechanics and structural design.
- Clause 309 prescribed unit live loads and unit seismic loads in pounds per square foot of floor area.

Section IV covered masonry buildings of bearing wall construction.

Section V covered walls in framed structures.

Section VI dealt with reinforced concrete, including working stresses and arrangement of the reinforcing bars.

Section VII dealt with steelwork, including working stresses.

Section VIII dealt with plain concrete, including its ultimate compressive strength.

Section IX dealt with chimneys, which had been seen to perform poorly in every earthquake from 1855.

4.2 N.Z.S.S. 95 NEW ZEALAND STANDARD CODE OF BUILDING BY-LAWS 1939

The committees entrusted with the preparation of Parts I to IV of the Standard code were directly representative of the following interests:

- Department of Internal Affairs
- Department of Scientific and Industrial Research
- Law Drafting Office
- Public Works Department
- Municipal Association of New Zealand
- New Zealand Institute of Architects
- New Zealand Institution of Engineers
- School of Architecture, Auckland University College.

Part I gave legal notes and interpretations of terms.

Part II covered Building Permits.

Part III covered general design and construction.

- Clauses 301 to 303 required all parts of a building to be tied together in such a manner that the structure could act as a unit. Wings and main blocks were permitted to be separate structural units. Ornaments had to be securely attached, and more guidance was given on the interconnections of foundations and footings.
- Clause 304 (a) required design to be done by rational analysis in accordance with the principles of mechanics and of structural design.
- Clause 304 (b) required the total horizontal shear imposed by … earthquake to be resisted … in inverse proportion to their individual total deflections from shear and bending effects under unit lateral load. Dr Skinner reports that engineers interpreted this by applying 0.08 g (gravitational acceleration) as a steady acceleration, calculating the deformed shape of the structure, then distributing the loads in proportion to the static deflections.
- Clause 306 required steel or reinforced concrete for many institutional buildings of more than one storey.
- Clause 308 permitted special materials, forms of construction, and methods for design provided the Standards Institution agreed.

Part IV covered basic loads and stresses to be used in design.

- Clause 403 tabulated the unit live loads and unit seismic loads in pounds per square foot of floor area.
- Clause 415 permitted the working stresses for steel to be exceeded by 50per cent and for reinforced concrete by 33 and a third per cent when the excess was due entirely to earthquake forces.

4.3 N.Z.S.S 95 NEW ZEALAND STANDARD MODEL BUILDING BY-LAW 1955

This superseded the 1939 edition, covering design loads, design calculations, and methods of construction.

Part I interpreted terms and gave legal notes.

Part II covered Building Permits.

Part III covered general design and construction.

- Clause 304 (a) required every building and every structural part thereof to be designed in accordance with … methods … which will admit of a rational analysis in accordance with the established principles of mechanics and of structural design.
- Clause 304 (b) required the total horizontal shear imposed by wind or earthquake … to be resisted… in inverse proportion to their individual total deflections from shear and bending effects under unit load. … the main bracing system shall be located symmetrically about the centre of mass … or … provisions shall be made for the resulting torsional moments on the building.

Part IV covered basic loads to be used in design and their methods of application.

- Clause 401 required the building to support the actual or estimated imposed loads including lateral forces without exceeding the working stress specified herein …
- Clause 403 (e) required designers to take into account the most unfavourable condition of loading due to dead load, live load, wind load, or seismic load. Wind and earthquake were not to be assumed to act simultaneously.

- Clauses 412 (d) and (e) required the applied horizontal [seismic] force to be the weight of the building multiplied by 0.08 applied uniformly, or a coefficient having a value of zero at the base and rising to 0.12 at the top. Values at floors or other intermediate points were to be determined by linear interpolation.
- Clause 412 (f) recognised the vulnerability of parapet walls and exterior ornamentations by requiring them to be designed with a seismic coefficient of 0.5, ie six times that required for the building as a whole. The factor of six was based on wide experience including the 1942 earthquake which had caused much parapet damage in Wellington.

Part V covered reinforced and plain concrete construction.

- Clause 516 (a) required that when plans were deposited for approval the assumptions made in design and the working unit stresses adopted should be clearly set out and the authority for their use quoted.
- Clause 517 gave an interaction formula for combined bending and axial stresses.
- Clause 518 gave maximum permissible stresses in steel reinforcement.
- Clause 519 gave maximum permissible working stresses in concrete.

Part VI covered panel walls in framed structures.

Design could be by an unspecified calculation or in accordance with tabulated proportions.

Part VII covered fire-resisting construction and means of egress.

Part VIII covered residential buildings.

Part IX covered light timber construction.

This used a prescriptive and tabular style and appears to be the precursor of NZS 3604.

Part X covered masonry buildings of bearing wall construction.

Part XI covered steelwork.

This acknowledges prior work from British Standards, the Welding Code of the Standards Association of Australia, and the Welding Regulations of the London County Council.

- Clause 1108 (a) specified the maximum permissible stresses in “mild steel” and “high tensile steel”. Single values were given for members in tension, but for members in bending formulas were given to allow for what would now be called lateral torsional buckling.
- Clause 1111 allowed increased stresses for members encased in concrete. It was later realised that the concrete could not “contain” severely deformed steel, and it was in fact necessary to provide steel hoops to contain broken concrete.
- Clause 1116 specified maximum permissible stresses in “mild steel” and “high tensile steel” for columns. These were tabulated as a function of the ratio of the column length to its least radius of gyration.
- Clause 1118 gave an interaction formula for stresses in columns under combined bending and direct loads.

Part XII covered chimneys.

This was of prescriptive style, specifying dimensions, proportions, quantities of reinforcing steel.

4.4 NZS 1900.8:1965 MODEL BUILDING BY-LAW

The Loadings committee responsible for the preparation of this revision was drawn from representatives of:

- Department of Scientific and Industrial Research
- Ministry of Works
- Municipal Association of New Zealand
- New Zealand Institute of Architects
- New Zealand Institution of Engineers

- Clause 8.9.1 showed that the working stress method continued to be used.
- Clause 8.10.1 permitted buildings or parts of buildings not amenable to rational design to be designed on the basis of loading tests or model experiments.
- Clause 8.34.3 required earthquake forces to be applied horizontally and simultaneously at each floor and roof level.
- Clause 8.34.3 noted that a more precise form of dynamic analysis may be required for special structures, taking into account only the first three vibrational modes.
- Clause 8.36.1.1.1 required a total lateral seismic force to be calculated from

  $$V = CW_t$$

  where C was to be determined from the seismic zone, the type of occupancy, and the period in the direction under consideration. For a stiff public building in the seismically active zone A, C took the value 0.16, an increase over that required in 1955.
- Clause 8.36.3.1 required the total lateral force V to be distributed over the height of the building in accordance with

  $$f_x = Vw_xh_x/\Sigma w_xh_x$$

  thus maintaining the triangular distribution of the 1955 Standard. Under some circumstances 10per cent of V was to be concentrated at the top storey.
- Clause 8.41.1 required all elements which resisted seismic forces or movements and the building as a whole to be designed with consideration for adequate ductility. This is the first time ductility was mentioned as a desirable feature in the loading standards, but we note that there was no guidance on how to provide it.
- For buildings over 160 feet in height, clause 8.41.2 required ductile frames capable of resisting 25per cent of the total lateral force, and the combined action of these frames and the main resisting structure were to resist 100per cent of the total lateral force.

4.5 NZS 1900.8:1976 MODEL BUILDING BY-LAW

This was a very short document that repeated general performance requirements, and specifically recognised the new document NZS 4203 as a means of complying with those requirements.

4.6 NZS 4203:1976

The various streams of work in New Zealand were codified in 1976 with the first edition of New Zealand Standard 4203 *Code of Practice for General Structural Design and Design Loadings for Buildings*. This constituted a major advance in several respects. The Loadings Committee included representatives from:

- Building Research Association of New Zealand
- Department of Scientific and Industrial Research
- Ministry of Works and Development
- Municipal Association of New Zealand
- New Zealand Institute of Architects
- New Zealand Institution of Engineers
- Association of Consulting Engineers
- New Zealand Meteorological Service
- University of Auckland
- University of Canterbury.

Its Foreword preferred what it called the "strength method" over the "alternative" (working stress) method of design. It required buildings to dissipate significant amounts of energy in-elastically under earthquake attack. This meant that ductility of materials, especially steel, had to be utilised.

- Clause 1.1.3 recognised 3 different methods of analysis:
  - Equivalent static force analysis
  - Spectral modal analysis
  - Numerical integration response analysis.
- Clause 3.3.3.3.1 prohibited the formation of plastic hinges in beam-column junctions, but 3.3.3.5.2 permitted column hinges in single or two-storey structures and in the top storey of a multi-storey building.
- Clause 3.4.2 specified a multi-term approach to calculating the horizontal design force.

  The total horizontal seismic force V was to be calculated by multiplying the seismic weight W_t by a seismic coefficient C_d:

  $$V = C_d W_t$$

  Where:

  $$Cd = CISMR$$

- C took into account the seismicity of the geographical region, the natural period of oscillation of the building, and the type of subsoil.
- I was an importance factor, indicating the requirement for the building to function immediately after a seismic disaster.
- S allowed structural types such as ductile frames an advantage by reducing the required seismic load, but penalised those with diagonal bracing capable of yielding only in tension.
- M was a material factor which rewarded steel and penalised prestressed concrete because of the then known properties in yielding to absorb energy.

- R was a risk factor that required larger forces for buildings accommodating many people, gas and petroleum products, and toxic substances.
- The horizontal seismic forces were to be triangularly distributed with nothing at the ground level and a maximum value at the top.
- Clause 3.4.4 gave an equation based on the Rayleigh method for estimating the fundamental period of oscillation of a building.
- Clause 3.4.6.1 (d) required the distribution of horizontal seismic forces in buildings that had highly irregular shapes, large differences in lateral resistance or stiffness between storeys, or other unusual structural features to be determined in accordance with a dynamic analysis procedure, specified in clause 3.5 as spectral modal analysis or numerical integration response analysis.
- Clause 3.4.7 required horizontal torsional moments to be taken into account.
- Clause 3.8.1 required deformations calculated from the horizontal forces to be multiplied by a factor v (Greek letter nu), a function of Cl/C_d.
- Clause 3.8.2 required separations between buildings and the property boundary. Three criteria were given for the separations, one based on the clause 3.8.1 calculation.
- Commentary C3.4.11.1 mentioned structural irregularities in the context of set-backs, eg office towers over retail podiums.

However, there was still no requirement to consider the vertical components of the earthquake motion.

4.7 NZS 4203:1984

Standards New Zealand published a new edition of NZS 4303 in 1984, using expertise from the same organisations as in 1976, plus representatives from:

- New Zealand Society for Earthquake Engineering
- New Zealand Master Builders Federation.

It continued to recognise (but did not prefer) the “alternative method” of design and for this included equations to cover reversal of load under wind and earthquake where only dead load was available to stabilise the members.

The Foreword introduced the term “capacity design” for buildings designed for flexural ductile yielding or for yielding in diagonal braces. Clause 3.3.2.2 described this as a process by which “… energy-dissipating elements or mechanisms are chosen, suitably designed and detailed, and all other structural elements are then provided with sufficient reserve strength capacity to ensure that the chosen energy-dissipating mechanisms are maintained throughout the deformations that may occur.”

Important provisions in the section dealing with earthquakes included:

- Commentary clause C1.3.2.3 included the note:

  “Although significant vertical acceleration components of ground motions have been recorded during earthquakes (for example 0.2 to 0.3 g in the 1971 San Fernando earthquake) no vertical acceleration load terms have been included in the design loads … except for parts such as horizontal cantilevers and anchorage of machinery because there is at present no certainty about the damage potential of combined dynamic effects.”

- Commentary clause C3.2 included notes explaining adequate ductility:

  "… total horizontal deflection at the top of the main portion of the building … appropriate plastic hinges … is at least four times that at first yield, without the horizontal load carrying capacity … being reduced by more than 20 percent."

  "Primary members of the seismic resisting system … could be required to possess a ductility factor well in excess of 4 to satisfy the overall ductility demand during eight reversals."

- Clause 3.3.3.5.2 continued to permit column hinges in certain circumstances.
- Clause 3.3.9 required buildings to be designed by the equivalent static force method, and in some circumstances required spectral modal analysis as well.
- Clause 3.4.2 slightly reformulated the seismic coefficient Cd as

  $$C_d = CRSM$$

  - C identical to that in the 1976 edition, including the same map of seismic zones
  - R similar to the 1976 edition, but tabulated a little differently
  - S similar to the 1976 edition, favouring ductile frames but penalising elastically responding structures by requiring large design forces
  - M similar to the 1976 edition, retaining the advantage for steel, but giving more credit to reinforced concrete and reducing the penalty for prestressed concrete and reinforced masonry.

- Clause 3.4.2 also gave the equation for the total horizontal seismic force as:

  $$V = C_d W_t$$

- Clause 3.4.6 required the total horizontal seismic force to be distributed over the height of the building in accordance with

  $$Fx = VW_x h_x / \Sigma W_x H_x$$

  with a modification requiring an extra 0.1V at the top and the remaining 0.9V distributed triangularly for slender buildings.

4.8 NZS 4203:1992

Standards New Zealand published the last edition of NZS 4203 in 1992, and the then-new Department of Building and Housing immediately cited it in the *Building Code* that followed the Building Act 1991. The Loadings Code Revision Committee consisted of:

- Mr AB King — Building Research Association, chair
- Mr GC Clifton — Heavy Engineering Research Association
- Dr RC Fenwick — NZ Vice Chancellors' Committee (withdrew)
- Mr IA Fraser — Association of Consulting Engineers NZ
- Mr RD Jury — co-opted
- Dr G McVerry — Department of Scientific and Industrial Research
- Mr TP Newell — NZ Local Government Association
- Mr RN Patton — Co-opted
- Dr SJ Reid — NZ Meteorological Service
- Mr LM Robinson — NZ National Society for Earthquake Engineering
- Dr DD Spurr — Works and Development Services Corporation
- Mr EC Stevenson — Institution of Professional Engineers NZ
- Dr RG Walford — NZ Timber Design Society.

The alternative method of design (working stress) was not mentioned, and thus was taken by structural engineers to be prohibited.

- Clause 4.2.2 introduced the idea of "limit states", requiring adequate strength and stiffness to satisfy the serviceability limit state, and adequate strength, ductility and stiffness to satisfy the ultimate limit state.
- Clause 4.2.3 required designers to choose ductility, limited ductility, elastic response, or a combination of these three at the ultimate limit state.
- Clause 4.2.4.1 introduced the term "structural ductility factor", denoted by the Greek letter μ (mu). This focussed attention on ideas that had previously been incorporated in the S and v factors. Values ranged between one for timber and prestressed concrete structures designed to respond elastically, to six (sometimes more) for ductile steel structures.
- Clause 4.5.2 repeated the Rayleigh equation for estimating the fundamental period, but restricted its use to equivalent static analysis.
- Clause 4.7.3.1 required deflections calculated by the equivalent static method or the modal response spectrum method to be multiplied by μ.
- Clause 4.7.5 often required analysis for what are called "P-delta" effects. When a building sways during an earthquake, the weight is no longer carried straight down the columns, but introduces additional bending effects which in turn cause further deflections.
- Clause 4.6.2.7 changed the name of the seismic coefficient to the lateral force coefficient. For the equivalent static method it was given by

$$C = C_h(T_1,\mu)S_pRZL$$

- $C_h(T_1,\mu)$, a fraction of the gravitational acceleration (g) , was taken from a series of curves that incorporated the fundamental period T_1, the structural ductility μ, and the subsoil type.
- Sp was a structural performance factor that recognised that structures survived better than might be supposed from considerations of structural analysis alone. It usually enabled the design forces to be reduced to two-thirds of what they would otherwise be.
- R was a risk factor based on the number of people in the building and its use. It took values between 0.6 for isolated rural structures to 1.3 for buildings dedicated to the preservation of human life.
- Z represented the seismic hazard zone. A new map gave contours varying between 0.6 for Auckland and places north, to 1.2 for Marlborough, Nelson, Wellington, and north to East Cape.
- L represented the limit state under consideration, with the ultimate limit state requiring forces 6 times as great as the serviceability limit state.

- Clause 4.8.1.2 required the horizontal seismic shear force acting at the base of the structure in the direction being considered to be calculated from

$$V = CW_t$$

- Clause 4.8.1.3 required the equivalent static lateral force at each level i to be calculated from

$$F_i = 0.92VW_ih_i/\Sigma(W_ih_i)$$

with an additional 0.08V added at the top of the structure.

4.9 NZS 1170.5:2004

This was a joint Australia/New Zealand collaboration based on the philosophy and principles set out in ISO 2934:1998 *General principles on reliability for structures*. Part 0 General, Part 1 Weight, Part 2 Wind, and Part 3 Snow were the same apart from the geographical maps. Part 4 was for earthquakes in Australia and Part 5 for earthquakes in New Zealand. The committee for Part 5 included:

- Mr Andrew King (chair)
- Prof Des Bull
- Mr Charles Clifton
- Dr David Dowrick
- Mr Rob Jury
- Dr Graeme McVerry
- Prof Peter Moss
- Dr Arthur O'Leary

Higher modes of vibration, ie those with periods less than the fundamental, were to be considered. Thus the lateral force coefficient was reformulated in two parts, the first being the elastic site hazard spectrum for horizontal loading, given by

$$C(T) = C_h(T)ZRN(T,D)$$

- Ch(T), no longer a function of gravitational acceleration, was taken from a series of curves similar in shape to those in NZS 4203:1992, but incorporating only the period and the subsoil type.
- Z was renamed the hazard factor, and was taken from a new contour map. Greatest values occurred around Arthurs Pass and Otira, and the least in Auckland and places north. Values were much less than previously, but were made up for by higher values of Ch(T).

    - R became a “return period factor” based on the probability of exceedance appropriate to the limit state under consideration. It incorporated the importance level of the building.
    - N(T,D) was a new factor that increased the design loads for sites near various named earthquake faults.
- Clause 3.2 required vertical loading to be considered, with a value 70 per cent of that already calculated for horizontal loading.
- Clause 5.2 gave a new way of incorporating the structural performance factor Sp and the structural ductility factor μ. Sp was determined as before, but μ was combined with the soil class to create a new factor kμ. The horizontal design action coefficient was then determined from

  $$C_d(T_1) = C(T_1)S_p/ k_\mu$$

- Clause 6.2 required the horizontal seismic shear to be calculated from

  $$V = C_d(T_1)W_t$$

  where Wt was the seismic weight, including the dead and a portion of the live weight.

  The equivalent static horizontal force, Fi at each level, i, was to be obtained from

  $$F_i = F_t + 0.92V[W_ih_i/(\Sigma W_ih_i)]$$

  where F_t = 0.08V at the top level and zero elsewhere.

  The second term gives a triangular distribution of force, zero at the bottom and maximum at the top, and the first term adds a little extra at the top.

  The equivalent static horizontal forces were to be applied through points eccentric to the centre of mass at each level to allow for accidental eccentricity.

5. Materials Standards

The principal materials for buildings are concrete, steel, and timber.

5.1 NZSS 95

This combined loadings, design, construction, and materials into the same set of documents. See the notes on Parts V, IX, X, and XI above.

5.2 NZS 1900

This comprised the *Model Building Bylaw* and incorporated loads in its Chapter 8 and Materials in its Chapter 9.

5.3 NZS 3101:1982 CONCRETE STRUCTURES

Mr Carl Ashby reports that this was the turning point for designing reinforcement for columns and beams in concrete frames. It recognised the "capacity design" idea of requiring energy-dissipating elements or mechanisms to be chosen and suitably designed and detailed.

5.4 NZS 3101:2006 CONCRETE STRUCTURES

This revision was written with the objective of being compatible with the AS/NZS 1170 set of the design action Standards.

5.5 NZS 3604 TIMBER FRAMED BUILDINGS

This is a prescriptive Standard, based on NZS 3603 (see below), organised to avoid the need for specific engineering design for buildings of the size of single houses.

- Section 3 on site requirements does not include the potential for liquefaction as a disqualification for what is known as "good ground". Even in the 2011 revision tests for the possibility of liquefaction are not required.
- Section 7.5 gives the requirements for concrete floor slabs under timber buildings. For single storey buildings, the floor slabs were not required to include any steel reinforcing.

5.6 NZS 3404:1989 STEEL STRUCTURES

This incorporated AS 1250:1981 which was written in working stress format.

5.7 NZS 3404:1997 STEEL STRUCTURES

This is written in limit state format for use with a limit state Loadings Standard. It was generally anticipated that this would be NZS 4203, presumably the 1992 edition then in common use.

Although the main body was written in limit state format, it included Appendix P on the alternative (working stress) approach. Because NZS 4203:1992 did not recognise the alternative method for earthquake-resistant structures, Appendix P was mainly of use to mechanical engineers who were not concerned with earthquakes.

It provided explicit guidance on three methods of structural analysis: elastic, elastic with redistribution, and plastic.

In May 1999 the Structural Engineering Society published its Simplified Design of Steel Members. This design guide described the simplest design requirements NZS 3404 required for common non-complex structures, and remains an extremely useful document.

Professor Charles Clifton has drawn attention to the performance of several steel-framed buildings in Christchurch, including some with the energy-absorbing ”eccentrically braced frames” and with several colleagues written a paper which IPENZ expects to be provided to the Royal Commission.

5.8 NZS 3404:PART 1:2009 STEEL STRUCTURES

This comprises the first of a proposed seven part revision. It is useful for construction end users and detailers rather than designers, but includes new sections on corrosion and protective coatings.

5.9 NZS 3603:1981 TIMBER STRUCTURES

Mr David Reid of the Timber Design Society advises that NZS 3603:1981 Timber Structures introduced the concept of “duration of load”. The loads a component can carry are higher for loads applied only briefly, such as wind and earthquake, and lower for long term loads such as gravity. Timber grade stresses (basic working stresses) based on in-grade testing were published.

5.10 NZS 3603:1993 TIMBER STRUCTURES

This was a “soft conversion” of the 1990 edition into limit state design format to tie in with NZS 4203:1992. A section on designing for earthquakes was included with clauses covering the ductility of structures.

6. Can Practice Precede Standards?

By their very nature Standards codify good elements of existing practice, and when cited in legal regulations or codes force practitioners to come into line with what may previously have been confined to academia and other organisations at the leading edge. Professor Lowe points out that the status of a code in regulatory terms essentially means that new thinking and new technology faces many hurdles to even being trialled. Liability in the various senses provides a formidable barrier to innovation.

We note that the object of the Building Code Committee of 1934 was to produce a building code applicable to the special conditions of New Zealand, but sufficiently flexible to permit the future introduction of approved innovations in materials and methods of construction. If full advantage was to be taken of scientific and technical progress, the code had to be subject to periodical review and revision.

The NZS 95–1936 explicitly permitted special materials and special forms of construction provided the designer could convince the Standards Institution, as it then was, that the innovation provided the strength and durability required by the Standard. Tests could be required at the applicant's cost.

Professor Lowe's idea in relation to the development of what is known as the "base isolation" method of defence against earthquakes could be explored.

During the late 1960s Department of Scientific and Industrial Research's Ivan Skinner realised that it was possible to concentrate the ductile parts in the space between the foundations and the bottom of the building, and design the habitable areas of the building to remain elastic. Hence most of the building could be correctly designed in the office by traditional elastic methods (working stress design), but the ductile parts would have to be the subject of experimental development. At the time the legal requirements were encapsulated in NZSS 1900 which recognised for the first time the value of ductility, but gave no guidance on how to design this desirable feature into new buildings.

Mr Skinner presented a paper to the Fifth World Conference on Earthquake Engineering in Rome in 1972. For the first time an international audience heard of his concept of "seismic isolation", and the eminent American researcher Newmark complimented him with the remark that it was nice to see something fresh being presented.

In 1973 the New Zealand Government Railways were planning an upgrade to the North Island Main Trunk line near Taihape and several long and high viaducts were required. The steel lattice construction used 70 years earlier was no longer economic, and reinforced concrete was the material of choice. Mr Skinner proposed a system in which each pier would be in the form of a capital H but with two crossbars. The feet of the H would rest on rubber pads to spread their weight over a concrete foundation, but would be free to lift off, or step, if attacked by an earthquake in the cross-bridge direction. If there were a severe vertical acceleration, both feet would lift off together. In both cases the span carrying the tracks high above would bend elastically. In the event of an attack in the along-bridge direction, the seismic forces would be resisted by reactions at the compression abutment, and there would be no stepping.

In this system gravity provided the spring force as the H piers stepped, forming an inverted pendulum. A system of energy absorbing dampers was required between the feet of the H and the foundation below. These dampers were developed experimentally, initially with models, then at full scale, in the Department of Scientific and Industrial Research laboratories during 1974 and 1975, and the South Rangitikei Viaduct itself was built between 1979 and 81.

In 1976 the new loading standard NZS 4203 appeared.NZS 4203:1976 required buildings to dissipate significant amounts of energy in-elastically under earthquake attack.

Clause 1.2.2.1 allowed parts of buildings not fully amenable to analysis and design to be test loaded to demonstrate that the construction was adequate for its intended purpose. Hence the Department of Scientific and Industrial Research method of development was acknowledged, but the Standard gave no guidance on how to do the tests.

Work proceeded apace, with a different form of steel damper being developed in 1989 for a new bridge planned to cross the Clutha River at Cromwell.

Dr Bill Robinson took an interest in this work, and from his metallurgical knowledge realised that steel dampers were bound to have finite fatigue lives, but the ability of lead to recrystalise at room temperature meant that a lead damper could have no limit to its fatigue life. By placing a lead plug in the centre of the rubber and steel laminated bearings commonly used for bridges he could add damping – a system used for the first time in the William Clayton building for the Ministry of Works District Office in Wellington. Dr Skinner reports that he and Otto Glogau had agreed to support this building on the laminated rubber-steel blocks commonly used for bridges, and to damp the motion with separate energy-absorbing steel cantilevers. It was Dr Robinson who suggested replacing the separate steel absorber with a lead plug in the centre of the bearing.

In the late 1980s, Dr Robinson devised a variation on the theme the lead extrusion damper in which a streamlined piston forced solid lead to extrude past itself from one end of a cylinder to the other. This device provided damping properties only, and the spring elements had to be provided by other means. The first use of the lead extrusion dampers was in the Bolton Street and Aurora Terrace bridges over the Wellington Urban Motorway, and the second in the base isolation system for the Wellington Central Police Station. Springs for the police station were provided by means of very long piles that were free to sway horizontally over most of their length, necessitating the use of hypohemispherical bearings with solid lubrication at their upper ends.

By the time of the police station job, NZS 4203: 1984 had appeared.

Clause 1.2.2.1 continued to allow the “test load” method of the 1976 edition to demonstrate adequacy of construction.

In the context of capacity design, clause 3.3.7.2.2 permitted one quarter of the foundations to lift in some ductile buildings, but did not explicitly recognise the stepping action of the South Rangitikei Viaduct.

Clause 3.3.8 permitted structures of ductile or limited ductility types to be designed by “special study” if they were not covered elsewhere in the standard.

The final edition of NZS 4203 appeared in 1992. Apart from clause 1.1.2 which required a special study to be made for unusual buildings, test loads ceased to be mentioned or implied. It was timely for the design for Te Papa Tongarewa Museum of New Zealand which was under construction in the mid 1990s, very publically featuring lead-rubber base isolators.

The first edition of NZS 1170.5 appeared in 2004. Clause 1.4 required a special study to justify any departure from or extension of the Standard, but its minimum provisions and performance objectives were to be maintained. Commentary clause C1.4 noted that “rocking structures” including the flexibility of their fixing points and the actual mass distribution were examples of structures requiring special study.

We conclude that the loading standards during the period 1965 – 2004 did not prohibit advances being made, but nor in the case of base isolation did they give any guidance.

7. ACKNOWLEDGEMENTS

Dr R Ivan Skinner, formerly of the Department of Scientific and Industrial Research and Earthquake Commission

Mr William Darnell, formerly of the Ministry of Works and Opus International Consultants Limited

Mr Win Clark, formerly of the Sinclair Knight Merz and now the New Zealand Society for Earthquake Engineering

Mr Stuart Ng, Standards New Zealand

Prof Charles Clifton, formerly of the Heavy Engineering Research Association, now University of Auckland

Prof Peter Lowe, formerly of the University of Auckland

Mr George Butcher, formerly of the Morrison Cooper

Mr Bob Norman, formerly of the Ministry of Works

Mr Carl Ashby, Spencer Holmes.

APPENDIX 4 – Activities undertaken by IPENZ in response to 2003 Structural Engineering Taskforce

The Structural Engineering Taskforce made seven recommendations, of which the six most important are described above. This work programme, and progress on it was reported to the IPENZ governing Board in October 2007 as follows:

1. IPENZ Work Programme

The IPENZ work programme resulting from the task force report has three overarching elements:

- Ensuring structural engineering work is only undertaken by those over whom IPENZ has jurisdiction to assess and discipline. This would be achieved by IPENZ:
  - working with the Department of Building and Housing to ensure the Department recommends to Building Consent Authorities that for professional engineering work Building Consent Authorities should consider requiring that such work be performed by registrants on the CPEng register
  - working directly with Building Consent Authorities to show them how working with IPENZ to use the CPEng register as the basis for deciding the engineers they accept work from allows them to manage their risk
  - developing notification systems for information exchange between IPENZ as Registration Authority and the Building Consent Authorities
  - developing linkages between the Licensed Building Practitioners scheme and CPEng (for example ensuring the design and site licences represent rigorous standards)
  - updating and improving producer statements for supply of professional services.
- Ensuring competence assessment and disciplinary processes are robust and to international best practice. This would be achieved by IPENZ:
  - developing guidelines for CPEng assessors working in the structural area and improved training of assessors
  - benchmarking of our professional engineering competence assessments via the Engineers Mobility Forum review in 2006
  - investigating complaints using best practice processes
  - continually improving our disciplinary processes.
- Developing and introducing a voluntary code of practice by the engineering profession. This would be achieved by IPENZ:
  - working with the Association of Consulting Engineers New Zealand to develop and promulgate a voluntary code of practice in respect of design detailing, improved peer review, and the use of supplementary guidance documents
  - explaining this code to Building Consent Authorities so they will give preference to those who have adopted it
  - working to ensure that regulatory documents eg the Building Code correspond to good engineering practice
  - working with its collaborating technical societies and technical interest groups to develop technical advice including supplemental material to relevant standards and codes of practice eg handling newly arrived types of steel, pre-fabricated concrete

- redeveloping graduate development schemes, enhancing the partnership between IPENZ and endorsed employers, making mentoring more structured, and eventually moving towards qualification-assisted graduate development
- as required, facilitating the development and promulgation of relevant training modules throughout the profession.

1.1 PROGRESS TO OCTOBER 2007

1. Ensuring structural engineering work is only undertaken by those over whom IPENZ has jurisdiction to assess and discipline, IPENZ has:

- Worked with the Department of Building and Housing to ensure they recommends that for professional engineering work Building Consent Authorities should give preference to registrants on the CPEng register. The Department of Building and Housing has appointed International Accreditation New Zealand as the accreditation agency for Building Consent Authorities. IPENZ has discussed the issues with the International Accreditation New Zealand and it has been agreed that requiring structural engineering work to be undertaken by a CPEng is a process by which Building Consent Authorities will meet the accreditation requirement.
- Worked directly with Building Consent Authorities to show them how working with IPENZ to use the CPEng register as the basis for deciding the engineers they accept work from allows them to manage their risk. IPENZ has visited meetings involving almost all Building Consent Authorities to explain CPEng to them. In addition it has circulated information on CPEng to them. A significant number of Building Consent Authorities have now made CPEng mandatory for engineering work.
- Developed notification systems for information exchange between IPENZ as Registration Authority and the Building Consent Authorities. This is perhaps the most important issue. The Building Consent Authorities have informed us that making complaints about CPEng is not an action they would necessarily take. However if a notice to the engineer concerned about poor work is issued, copying this notice to IPENZ could be contemplated. Receiving of more than one notice about an individual would give IPENZ sufficient reason to call in the engineer concerned for immediate competence re-assessment. To date no such notifications of poor work have been received by IPENZ. As a result, the number of engineers called in for earlier than scheduled re-assessment is low.
- Developed linkages between the Licensed Building Practitioners scheme and CPEng eg for example ensuring the design and site licences represent rigorous standards. The Design 3 standard and Site 3 standard are the relevant standards. IPENZ has assisted the Department of Building and Housing in development of these standards. However, the Design 3 standard is more an architectural standard, and in the view of IPENZ is a lower level standard than CPEng. IPENZ has advocated strongly that CPEng is therefore the clear benchmark for structural engineering design competence. However, there remains a risk that engineers will apply for Design 3 licences, and then present to Building Consent Authorities as having equivalent competence to CPEng.
- Updated and improved producer statements for supplying of professional services. The Association of Consulting Engineers New Zealand, IPENZ and the New Zealand Institute of Architects have collaborated to update the producer statements (effectively a form of certificate issued by a professional). A requirement that there is sufficient professional indemnity insurance cover in place provides consumer protection. These certificates are intended for use by either registered architects or CPEng, reinforcing the recommendation to Building Consent Authorities.

2. Ensuring competence assessment and disciplinary processes are robust and to international best practice. IPENZ has:

- Developed guidelines for CPEng assessors working in the structural area and improved training of assessors. In 2006 a small working group was asked to prepare guidelines to assist assessors interpret the CPEng competence standard in the context of structural engineering. These guidelines have been made available to assessors. One of IPENZ's collaborating technical societies, the Structural Engineering Society of New Zealand has agreed to form a second working group with the goal of improving these still further. The Structural Engineering Society of New Zealand has also agreed to help identify experienced structural engineers prepared to undergo training as assessors.
- Benchmarked our professional engineering competence assessments via the Engineers Mobility Forum review in 2006. IPENZ passed this review conducted by three other countries on behalf of the 15 members of the Forum agreement. We submitted 12 cases, including two borderline cases so that the reviewers could see where we set the standard. They confirmed the standard was appropriately set. In addition, the CPEng competence standard was used as the basis for the international exemplar competence standard approved by the Forum in 2005. There has been one appeal on a registration matter to the Chartered Professional Engineers Council where a structural engineer tried to overturn IPENZ's decision not to register him. This appeal was unsuccessful. As part of our continuous improvement process, revised application forms intended to improve the consistency of competence assessments have just been launched and six assessor training sessions held around the country. In its auditing role, the Chartered Professional Engineers Council annually reviews the operation of IPENZ's Competence Assessment Board.
- Investigated complaints using best practice processes. At time of their creation, the investigating and disciplinary processes in the CPEng Rules were reviewed widely, and received positive comments from the Ministry of Justice's peer reviewers. IPENZ has developed a procedures manual to guide those involved as the investigating and disciplinary committees include members chosen for their technical expertise, which means they need assistance on process. Approximately 15 complaints are received each year relating to a wide range of engineering fields. To date there have been four complaints received on structural engineering issues. All four were determined to relate to the grounds for discipline (competence, negligence or ethics) and were sent to investigating committee. One was dismissed by the Investigating Committee, one complaint has progressed to a disciplinary committee and two are still at investigating committees. In addition the Chief Executive has deemed two matters to be complaints as a result of information received. These two matters were investigated, but the Investigating Committee determined that there was no case to answer in either.
- Undertaken continual improvement in its disciplinary processes. The Chartered Professional Engineers Council reviews closed disciplinary cases quarterly as part of its audit. Their comments and IPENZ's own self-learning are applied to improve the processes. Disciplinary Committees involve two lay members. Their feedback on process improvement is welcomed. The recently retired Chief Executive of the Consumers Institute sat on two disciplinary committees (in the IPENZ rather than the CPEng context) and commented positively on the process.

3. Ensuring that there is development and uptake of a voluntary code of practice by the engineering profession. IPENZ has:

- Worked with the Association of Consulting Engineers New Zealand to develop and promulgate a voluntary code of practice in respect of design detailing, improved peer review, use of supplementary guidance document. The Association of Consulting Engineers New Zealand has also formed a working group, but it has yet to report.
- Explained this code to Building Consent Authorities so they will give preference to those who have adopted it. On hold awaiting the code of practice.
- Worked to ensure that regulatory documents eg the *Building Code* correspond to good engineering practice. IPENZ actively submits and works behind the scenes. A recent success was the introduction of the requirement that the new loadings code (S1170) must be applied by a CPEng. This will assist in limiting structural work to CPEng. IPENZ also nominates experts to a wide range of Standards New Zealand committees.
- Worked with collaborating technical societies and technical interest groups to develop technical advice including supplemental material to relevant standards and codes of practice eg methods of handling newly arrived types of steel, pre-fabricated concrete. The Structural Engineering Society of New Zealand has undertaken to develop a set of technical guidance notes – IPENZ will assist this process.
- Redeveloped of graduate development schemes, enhancing the partnership between IPENZ and endorsed employers, making mentoring more structured, and eventually moving towards qualification-assisted graduate development. The revised scheme has been under development for 12 months and will be launched in October 2007.
- As required, facilitated the development and promulgation of relevant training modules throughout the profession. IPENZ has facilitated a number of technical refresher courses in the structural engineering field. The way in which continuing professional development is evaluated at time of re-assessment for CPEng has recently been improved, and puts the onus on the candidate for identifying the new knowledge in their area of practice in the last five years, and then showing how they have taken steps to learn and apply it in their practice. If they are not aware of key new knowledge then this would be seen as sufficient reason to fail the assessment.

1.2 OTHER ACTIONS

IPENZ is taking a number of other actions. The Institution has chosen to take a proactive approach to the confidential reporting by Members of issues they have encountered, so these are available as a learning tool for others. IPENZ will also be using its main Member publications to educate Members more on ethical issues. The Institution particularly wants to create a culture in which poor work is reported as a notification, or if bad enough a complaint.

IPENZ has also advised Members that if they know of a building they consider is at risk they should notify the building owner of the need to have it assessed, and if the building owner is uninterested, to approach the relevant Building Consent Authorities.

IPENZ also wants the complexity of structural issues to be better understood by building owners. Design is an iterative process, and the engineer makes judgements at many stages. For complex buildings small oversights are usually detected, and corrected, sometimes as late as when the building is being constructed. Buildings that are complex architecturally often place the engineer in the role of designing a structure unlike any that he or she has previously tackled. In such circumstances the engineer often works at the frontiers of knowledge for the profession as a whole, and there is potential for genuine mistakes. This is why good processes, involving quality assurance in the design office, peer review, careful detailing etc. is important. However, even with these processes, engineering cannot be made absolutely risk-free. Building owners therefore need to be educated that it is not in their own interests to try to pare back the costs of properly engineering a building. Building owners/developers need to understand clearly that sufficient time needs to be allocated, and funded, as a normal part of a prudent design process.

2. Progress Update (June 2011)

2.1 TECHNICAL INFORMATION

The Structural Engineering Society has published several design guides in its Journal:

- Precast floor support (Professor Fenwick discussed failure of "pigtails" in 2008, and Structural Engineering Society published non-refereed papers in 2009 and 2011)
- Shell beams (Precasters perspective published on the Structural Engineering Society website 2008)
- Precast double tee support systems (Hare et al, 2009)
- Anchor bolts for steel structures (Scarry et al, 2009)
- Tentative seismic design guidelines for rocking structures (Kelly, 2011)
- Design of floors containing precast units (Fenwick et al, 2011).

2.2 DESIGN OFFICE PRACTICE

Joint Association of Consulting Engineers New Zealand /IPENZ Practice Note 14 *Structural Engineering Design Office Practice* published after many rounds of review in 2009. See www.ipenz.org.nz/IPENZ/Forms/pdfs/PN14_DesignOfficePractice.pdf

2.3 CONSENTS PROCESSES

The joint Association of Consulting Engineers New Zealand /IPENZ/NZIA Producer Statements were revised in 2007. See www.ipenz.org.nz/ipenz/practicesupport/endorsedinfo/

Attempts to revise IPENZ Practice Note 01 *Producer Statements* have not yet been successful.

Independent review of structural designs for building consent published in Structural Engineering Society New Zealand Journal 2010. This greatly expanded the guidance on regulatory review given in IPENZ Practice Note 02 Peer Review.

See www.ipenz.org.nz/ipenz/forms/pdfs/PN02_Peer_Review.pdf

2.4 CPENG PROCESSES

Guidelines for assessing the competency of structural engineers have been further developed to assist applicants and assessors.

See www.ipenz.org.nz/ipenz/forms/pdfs/Practice_Field_Guidelines–Structural_Final_version.pdf

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