31 January 2012.

Canterbury Earthquakes Royal Commission
PO Box 14053, Christchurch Airport
Christchurch 8544,

For the attention of the commissioners,

Re: The Training of Engineers and Organisation of the Engineering Profession.

I am writing this letter in response to the Royal Commission's request for information relating to the training of engineers. Specifically my comments relate to the training and assessment of Chartered Professional Engineers (CPEng) working in the field of structural engineering. I have had experience of the chartership assessment process both as a candidate and as a CPEng Practice Area Assessor (PAA). I believe that my observations may prove to be useful to you during your review.

I am a structural engineer with more than seventeen years experience both in New Zealand and overseas, and have been a Chartered Professional Engineer for nine years. For the last four years I have been a volunteer Practice Area Assessor for IPENZ, and have been involved in a SESOC/IPENZ working group to develop the core competency guidelines for structural engineering that are currently used during the assessment process. Recently I have co-authored the SESOC Structural Design Review Guide, and take an active interest in professional standards in the field of structural engineering.

It is my observation that the current assessment process is not robust enough with regard to determining the technical ability of candidates. Under the current system technical ability does not get the same degree of scrutiny granted by internationally comparable engineering qualifications (e.g. British and American), or other professional qualifications here in NZ such those required to become a Chartered Accountant.

Below is a brief discussion outlining what I believe to be weaknesses in the current system and suggestions on how the system can be improved. My comments are primarily on aspects of the assessment procedure that relate to technical ability within the structural design practice area, as it is the area in which my experience lies and where I believe the process requires most reform.

Weaknesses in the current CPEng assessment process:

- The assessment process is highly subjective in nature.
- The assessment process lacks thoroughness.
- Excessive reliance on referees appraisals of the candidate.
- The assessment process promotes disparities in knowledge amongst chartered engineers.
- The assessment is not robust enough to determine the technical abilities of engineers with limited or no formal training in seismic engineering.

- Inconsistencies in the abilities and experience of assessors.

These points are examined in more detail below.

1) Subjective Nature of Assessment

The current CPEng assessment system relies upon two assessors (a Staff Assessor - SA, and a Practice Area Assessor - PAA) to review a candidate's suitability based upon submitted documentation, work examples, referee reports and an oral interview. From this the assessors determine whether the candidate's ethics, experience and ability are at chartered professional level. Often, for initial assessments they will set some sort of an examination in order to determine a candidates understanding of an aspect of their practice area, or to probe potential weaknesses in the candidate's experience. This is typically a three hour essay, although other examination types are permitted.

A candidates ability is measured against a prescribed set of core competencies (appended to this letter). However, there is no quantitative measure for assessing the candidates technical ability, nor is there any defined minimum level of technical knowledge (either in regard to specific practice areas, or to fundamental engineering principles). This process is highly subjective as it relies on the opinions of two people, whose work experience may not be comparable with that of the candidate. Personal interpretations of the core requirements, particularly with regard to measuring compliance with 'Complex Engineering Problems' can vary considerably along with the expectations of each reviewer.

Continuing Registration Assessments (CRA's) for those who already have achieved CPEng status are even more subjective as the level of documentation provided for the reviewer is lower, and there is typically less interaction with the candidate.

The subjective nature of the assessment procedure is not conducive to achieving conformity in standards within similar practice areas, or setting and measuring standards across the profession.

2) Thoroughness of Assessment.

Many international professional qualifications for the structural discipline require the candidate to undergo a formal examination as well as a holistic assessment. Examples include the United Kingdom's 'MIStructE' qualification and the United States 'Professional Engineer (PE)' qualification. In both examples above there is a heavy technical bias to the examination which can be up to 8 hours in duration.

In the United States graduate engineers are required to pass a 8 hour 'Fundamentals of Engineering (FE)' exam, before they can sit the PE examination. In many states structural engineers must pass an additional 'Structural Engineer (SE)' examination in order to be able to approve complex or high importance level structures such as schools or hospitals (or in some cases to approve any structural design). This examination is typically 16 hours in duration, although in California, where there is a similar seismic hazard to NZ, an additional 8 hour exam must be passed.

Links to the requirements for these qualifications are provided below should you require additional information. Attached to this letter is a document taken from the from the National Council of

Structural Engineers Associations website explaining structural engineering regulation in the United States. It should be noted that in conjunction with the examinations it is common for the candidate to partake in structured tutorials or workgroups prior to sitting the professional exam in order to attain the required level of knowledge.

Requirements of the MIStructE examination;

http://www.istructe.org/membership/examination

Requirements of the PE qualification examination;

http://www.ncees.org/Exams/FE_exam.php

http://www.ncees.org/Exams/PE_exam.php

http://www.ncees.org/Exams/SE_exam.php

http://www.ncsea.com/downloads/groups/licensing/2010_16-Hour_Strl_Exam_article.pdf

My understanding of these examinations is limited, however from what I can ascertain some of these examinations allow the candidate a certain level of choice, to reflect varied background of the candidates, however all require a minimum level of technical, and practical knowledge to be demonstrated by the candidate. Pass rates for these examinations are typically low, which is a reflection on the level of knowledge and experience required to be attained by the candidate over several years after graduating university. The 2011 SE exam had a pass rate of 35% for first time applicants, and the pass rates for the MIStructE 2010 and 2011 examinations were 33% and 37% respectively. I do not have information on the IPENZ CPEng examination pass rates for the structural discipline, however the collective pass rates for all disciplines was in the order of 90% for the years 2007 to 2009. I suspect that the CPEng pass rate for the structural discipline in NZ is considerably higher than those achieved in these comparable professional qualifications.

In comparison to the American and British examples above, the NZ assessment appears less thorough, and places far less emphasis on technical ability.

It is interesting also to compare the requirements of other professions in New Zealand with regard to attaining the equivalent of our CPEng. For example accountants must undergo (and pass) approximately three years of structured and assessed training prior to undergoing a formal examination to determine competency. Below are links that list the requirements that an accountant must successfully accomplish in order to become Chartered in NZ.

http://www.nzica.com/Join-us/New-Chartered-Accountants-Program/About-the-new-Program.aspx

http://www.nzica.com/CApathway.aspx

When measured against the chartered accountant requirements, the CPEng assessment procedure is less thorough.

3) Reliance on Referees.

A candidate is required to provide two referees who can vouch for the abilities and character of the candidate. During the assessment procedure some reliance is placed on the referee's appraisal of the candidate's ability with regard to the core competencies. Pressure due to personal relationships with the candidate can cloud the referee's judgement, and in some instances the referee may not have the in-depth knowledge of the candidate required for an accurate assessment. Furthermore, a candidate is unlikely to request a referee report from someone who does not believe they are of the required standard, which further erodes the benefit and objectivity of the process. Consequently the advice of a third party, who may not be suitably familiar with the CPEng competency requirements, may not provide a firm basis for determining a candidates competency.

4) Disparity in knowledge between practice areas.

The CPEng system is reliant on chartered professionals acting within their practice areas through self regulation. By 'practice areas' I refer to the specific sub-discipline or specialty of engineering in which the engineer practices and is assessed as being competent in e.g. light commercial/industrial design, bridge design, or advanced analysis techniques, rather than global disciplines such as structural or civil. This is often a major source of contention, as areas of specialisation in my experience are difficult to define, and a lack of technical understanding can result in engineers straying outside their areas of competence without understanding that they are doing so.

A difficulty with assessing and awarding Chartership along the lines of a practice area is that it can lead to disparities in quality amongst engineers. For example, an engineer working in bridge design requires a higher level of technical knowledge than an engineer specialising in domestic housing/light industrial. However, as the technical demands are greater for bridge design, so is the level of competence required to achieve CPEng status. This could lead to the situation where (all other competencies remaining equal) an engineer of higher technical ability would not become chartered, whereas the engineer with lower ability might. Arguably for the example outlined above the system could be seen to be working, however it is heavily reliant on self regulation which, in my experience often does not work.

As practice areas are not published by IPENZ, it is almost impossible for clients or members of the public to discern between engineers of differing ability/experience. Reliance is placed on the engineer to work within their assessed practice area, and no means of verifying that this is the case is available for those that rely on the engineer's performance.

5) Non-Seismically Trained Engineer Assessments.

Assessments of non-seismically trained structural engineers is particularly difficult. Examples of these include some foreign engineers and NZ engineers working in the structural field who did not take any seismic analysis and design papers during their engineering degree course, or have not undertaken any tertiary level education in seismic engineering.

Non NZ trained structural engineers are able to become Chartered in NZ if they have an appropriate degree from a Washington Accord accredited university, and pass the CPEng assessment procedure (or pass a reduced version of the CPEng assessment procedure if they already hold a professional qualification comparable to CPEng). In many instances foreign engineers hold engineering degrees from universities that do not contain any course content related to seismic engineering, which is an essential requirement for the vast majority of NZ chartered structural engineers.

Whilst it is possible that through self study or structured courses these candidates may develop an understanding of the principles of seismic analysis and design, there is no requirement to sit a formal examination to determine the extent of this knowledge. The candidate may have never undertaken a tertiary course on seismic analysis or design that has a measured assessment component, and the quality of their 'on the job' training would be limited by the quality of their colleagues knowledge, and available training programmes. The effectiveness of the assessment for such a candidate will come down to the SA and PA assessors understanding of the candidate's seismic knowledge. There is significant room for misjudgement under this system.

6) Quality of Assessors.

Assessors are members of the profession who have either been nominated by another, or volunteer and are approved by IPENZ. There is no formal process whereby potential assessors can be gauged against the professional requirements of his/her practice area. Essentially it comes down to the opinion of others whether they are suitable for the role. Errors in judgement could result in unsuitable assessors being approved or being assigned to unsuitable practice areas. In addition, assessors are often busy practitioners who, on occasion may struggle to dedicate the required time to an assessment - particularly for borderline candidates, where the assessment demands are greatest.

Possible amendments/improvements to the CPEng Assessment Process:

- Adopt a formal examination
- Adopt a tiered chartership qualification within the structural discipline
- Detailed assessor training
- Place less emphasis on 'practice areas'

1) Adopt a formal examination;

I believe the structural discipline does require minimum technical standards of its engineers, and these need to be measurable and less subjective in nature than determined by the current assessment process. These standards should be relatively independent of practice area, but would relate to broad structural engineering concepts that would help the practitioner to understand their limitations, and provide assurance to clients as to the ability of the engineer.

A formal examination in conjunction with a holistic assessment would remove, or improve most of the concerns listed above. Benefits would include; minimising subjectivity, being able to set measurable standards within competencies, improving engineer quality, and reducing demand on assessors.

It is still possible to maintain the concept of a 'practice area' within a standardised examination type approach to assessment. As well as the obvious technical content, an examination could also incorporate management, risk, or ethics competencies. Alternatively, an holistic assessment of the candidate (similar to that undertaken in the current process) could be used to investigate the non-technical competency components, in conjunction with a technical examination.

2) Adopt a tiered Chartership Qualification;

A possible way of dealing with the differences in knowledge between practice areas is to adopt a tiered Chartership qualification, similar to the way that ETPract and CertETn differentiate between skills and experience under the current system. Grades of CPEng (possibly 2 or 3 different grades) could be developed based upon broad practice areas, and tailored to different levels of ability or the risk/importance level of practice areas. Possible examples of such could include a grade covering domestic and light industrial/commercial, another encompassing all domestic commercial & industrial, and another for civil infrastructure. Note that under the current Building Act, Dam engineers are already differentiated from other CPEng qualified engineers, so introducing a tiered qualification is not an unfamiliar concept.

Examples of a tiered qualification exist worldwide, for example in California, where an additional qualification (SEIII) is required to be able to undertake or review high occupancy/critical building work such as hospitals, prisons etc...

A tiered system could also help accommodate structural engineers that have a less technical role, such as site engineers and managers. A qualification tier recognising their level of professional ability could be made without necessitating an examination of unnecessary technical requirements.

3) Detailed Assessor Training;

Advanced assessor training covering such things as; technical requirements of roles, dual practice area requirements etc..... along with detailed case studies would go a long way to improving the quality of assessors and promoting conformity in assessment of candidates with similar practice areas.

4) Place less emphasis on 'Practice Areas';

It is my opinion that the 'practice area' concept (as defined previously) is difficult to assess, is inconsistent, potentially unfair, does not effectively restrict the work of practitioners as intended, and is almost unenforceable.

Candidates are assessed with regard to their current and past work experience. Chartership is bestowed on the candidate based upon the assumption that the candidate will continue to work within this area of specialisation. These areas are extremely difficult to define and it is not obvious to all as to the distinction between different areas.

Limiting the work area of an engineer by their past work experience is unnecessary. A standardised examination would allow practice areas to evolve post assessment without the burden of additional future assessment requirements. Other mechanisms exist that can pick up engineers working outside their abilities, or unethically. Most obvious of these are Peer or Regulatory review procedures. Auditing of practicing CPEng engineers responsible for signing off designs (similar to the way in which Chartered Accountants audit those with practicing certificates) could be another mechanism that is worthy of consideration.

The natural career progression for the typical structural design engineer involves working as a design engineer for several years, during which they will pick up design office and/or site experience. Then as their experience grows they take on a managerial/supervisory role before either moving entirely into management or maintaining a dual design/managerial role. Although there is a wide range of variance in practice areas within the structural discipline, the majority of design engineers spend the bulk of their time following the above career path and working within a few limited practice areas.

Most specialty work areas require an understanding of many similar engineering principles and design standards. As such, a better focus for the professional qualification would be ensuring that all design based engineers have a strong base level of skills, applicable to a broad range of engineering materials, and design and analysis philosophies. A formal examination of these qualities would be suited to determining this. Levels of differing experience can be accommodated within a formal assessment through choice within examination questions. The professional themselves, can then regulate their areas of expertise.

I hope you find the contents of this letter beneficial, and should you wish to clarify or discuss any points contained within it please feel free to contact me.

Yours sincerely,

Derek Bradley

BE(Hons), CPEng, IntPE, MIPENZ

Attachments:

IPENZ *Practice Field Guidelines - Structural Engineering* (from IPENZ website)

Structural Engineering Regulation in the United States by Jon A. Schmidt, (from NCSEA website)

Practice Field Guidelines - Structural Engineering

Contents

Purpose of guidelines

The purpose of these guidelines is to provide **applicants** with suggestions on the type of evidence that is considered to demonstrate that they meet the competence standard. These suggestions are not exhaustive nor are they definitive – the assessment panel, which is the only entity with access to all of the applicant's evidence, is required to make a judgement on the applicant's competence.

All competence assessments are made in the applicant's practice area (definition below). The applicant is asked to provide a brief description of his or her practice area – which is effectively the professional engineering activities they perform. This description will guide the assessment panel when it assesses the evidence submitted. Assessment panels are instructed to amend the applicant's practice area description if the panel find a mismatch. Hence applicants are asked to consider very carefully their practice area when describing what they do.

Practice area definition

The **practice area** of an engineer is defined (in the CPEng Rules and IPENZ Regulations for competence registers) as:

> **practice area** means an engineer's area of practice, as determined by—
> (a) the area within which he or she has engineering knowledge and skills; and
> (b) the nature of his or her professional engineering activities.

Engineering problems

Complex engineering problems means engineering problems which cannot be resolved without in-depth engineering knowledge and having some or all of the following characteristics:

- Involve wide-ranging or conflicting technical, engineering and other issues
- Have no obvious solution and require originality in analysis
- Involve infrequently encountered issues
- Are outside problems encompassed by standards and codes of practice for professional engineering
- Involve diverse groups of stakeholders with widely varying needs
- Have significant consequences in a range of contexts

Broadly-defined engineering problems means engineering problems having some or all of the following characteristics:

- Can be solved by application of well-proven analysis techniques
- Are parts of, or systems within complex engineering problems
- Involve a variety of factors which may impose conflicting constraints
- Belong to families of familiar problems which are solved in well-accepted ways
- May be partially outside those encompassed by standards or codes of practice
- Involve several groups of stakeholders with differing and occasionally conflicting needs
- Have consequences which are important locally, but may extend more widely

Well-defined engineering problems means engineering problems having some or all of the following characteristics:

- Can be solved in standardised ways
- Are discrete components of engineering systems
- Involve several issues, but with few of these exerting conflicting constraints
- Are frequently encountered and thus familiar to most practitioners in the practice area
- Are encompassed by standards and/or documented codes of practice
- Involve a limited range of stakeholders with differing needs
- Have consequences which are locally important and not far-reaching
- Can be resolved using limited theoretical knowledge but normally requires extensive practical knowledge

Engineering activities

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

- Involve the use of diverse resources (and for this purpose resources includes people, money, equipment, materials and technologies)
- Require resolution of significant problems arising from interactions between wide-ranging or conflicting technical, engineering or other issues,
- Involve the use of new materials, techniques or processes, or the use of existing materials techniques or processes in innovative ways

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

- Involve a variety of resources (and for this purposes resources includes people, money, equipment, materials and technologies)
- Require resolution of occasional interactions between technical, engineering and other issues, of which few are conflicting
- Have consequences are most important locally, but may extend more widely
- Require a knowledge of normal operating procedures and processes

Well-defined engineering activities means engineering activities or projects that have some or all of the following characteristics:

- Involve a limited range of resources (and for this purpose resources includes people, money, equipment, materials and technologies)
- Require resolution of interactions between limited technical and engineering issues with little or no impact of wider issues
- Have consequences that are locally important and not far-reaching
- Require a knowledge of practical procedures and practices for widely-applied operations and processes

Guidelines for Structural Engineering

Professional Engineering - Element 1

ELEMENT DESCRIPTION

1 **Comprehend, and apply knowledge of, accepted principles underpinning widely applied good practice for professional engineering**

PERFORMANCE INDICATORS

- Has a Washington Accord degree or recognised equivalent qualification or has demonstrated equivalent knowledge and is able to:
  - Identify, comprehend and apply appropriate engineering knowledge
  - Work from first principles to make reliable predictions of outcomes
  - Seek advice, where necessary, to supplement own knowledge and experience
  - Read literature, comprehend, evaluate and apply new knowledge

GENERAL PRACTICE FIELD GUIDELINES

- This element is intended to show the candidate currently has the level of knowledge of a Washington Accord degree – as evidenced by an accredited Washington Accord degree (or recognised equivalent qualification) supported by on-going CPD, although applicants can demonstrate they have acquired the same level of knowledge through other learning processes.
- Applicants are able to apply that knowledge through work experience. The competence required by the standard is that of a 4-year Washington Accord degree graduate with typically 4 to 5 years post-graduation work experience.
- Qualifications other than Washington Accord equivalent may require knowledge assessment
- Applicants will be expected to show their ability to work from first principles and to comprehend and apply engineering knowledge – and evidence of this skill will be critical for non-Washington Accord qualified applicants in meeting this element of the standard

PROFESSIONAL ENGINEER

A Washington Accord (New Zealand 4-year BE degree) or recognised Washington Accord-equivalent qualification, if gained recently, is good evidence. Otherwise CPD records and work samples will be better evidence to demonstrate how the required level of knowledge was acquired and applied.

Work experience shows career progression in structural design and with exposure to site construction activities.

Evidence includes clear, logical hand written calculations laid out in a manner that another engineer can readily follow (in preference to calculations produced using products such as MathCAD) as good evidence of the applicant's understanding and application of structural engineering models.

Professional Engineering - Element 1

ELEMENT DESCRIPTION

1 Comprehend, and apply knowledge of, accepted principles underpinning widely applied good practice for professional engineering

Evidence shows how engineers have worked within the limits of their knowledge and when they have sought advice from other engineers ("knowing what you don't know"). For example, if their skills do not cover vibrations within structures.

Evidence that demonstrates a good knowledge of the behaviour of structures - in particular a good knowledge of statics that shows the applicant is able to:

- assess structural actions in typical beam and column structures, bridge structures, wall structures or in slabs, and when these are subjected to gravity and lateral loads with and without resorting to the use of a computer – this is an essential skill for structural checking and for analytical modelling;
- assess the structural strengths and deflections of members quickly without resorting to a computer,
- define load paths (both vertical and lateral) through the overall structure and through structural details (such as in the sample calculations)
- draw a free body diagram.
- Draw an engineering sketch with appropriate referencing
- Demonstrates knowledge of common structural materials
- Convey the design philosophy (ie the design features report)
- Define the basic failure hierarchy of a structure, ductility levels.
- Demonstrate understanding of relative stiffness and displacement compatibility.
- Understands basic constructability requirements e.g erection procedures/sequences, splices required for transport,

Professional Engineering - Element 2

ELEMENT DESCRIPTION

2 **Comprehend, and apply knowledge of, accepted principles underpinning good practice for professional engineering that is specific to the jurisdiction in which he/she practices (For CPEng assessment this relates to the jurisdiction of NZ)**

PERFORMANCE INDICATORS

- Demonstrates an awareness of legal requirements and regulatory issues within the jurisdictions in which he/she practices
- Demonstrates an awareness of and applies appropriately the special engineering requirements operating within the jurisdictions in which he/she practices

GENERAL PRACTICE FIELD GUIDELINES

- Evidence that shows the applicant understands and works in compliance with the relevant regulatory framework - for example, compliance regimes covered by statute or local body by-law, mandatory standards or codes of practice.
- Demonstrate an understanding of situations and responsibilities when/where standards/guidelines/specifications need to be modified or amended to suit specific situations and document the resulting implications

PROFESSIONAL ENGINEER

Evidence that the applicant is able to comprehend and apply knowledge of:

- Building Act and New Zealand Building Code
- Loading Standards, for example AS/NZS 1170, or the Transit NZ Bridge Manual
- Relevant structural materials standards, for example NZS 3101 for concrete structures, NZS 3603 for timber structures, and NZS 3404 for structural steel.
- Critical detailing for seismic actions and structural earthquake engineering as practised in New Zealand
- Technical specifications of materials, for example steel, cement, epoxies, etc
- Resource Management Act, occupational safety and health regulations and the Construction Contracts Act where relevant
- NZSEE 'Red Book'
- For reinforced concrete work (as appropriate) evidence of spiral anchoring, handling of steel (300 and 500 grade), diaphragms, connections, hollow core floor subassemblies

Evidence that candidates access recent material from the following sources:

- Department of Building and Housing advisory notices and publications (Codewords etc)
- SESOC, NZ Geotech Society, NZ Concrete Society, HERA, SCNZ, NZSEE and NZTDS publications and journals on matters of relevance
- NZCIC documentation guidelines
- BRANZ publications
- Relevant TA/BCA policy documents.

Evidence that shows the applicant understands the skill base and capability of the local NZ construction industry and its practices.

Professional Engineering - Element 3

ELEMENT DESCRIPTION

3 Define, investigate and analyse *complex engineering problems* in accordance with good practice for professional engineering

PERFORMANCE INDICATORS

- Identifies and defines the scope of the problem
- Investigates and analyses relevant information using quantitative and qualitative techniques
- Tests analysis for correctness of results
- Conducts any necessary research and reaches substantiated conclusions

GENERAL PRACTICE FIELD GUIDELINES

- Evidence demonstrates knowledge of technical fundamentals (including initial specification and brief in terms of client perceptions, use of engineering design standards and specifications) to scope a complex engineering problem
- Examples of methodologies used for analysis, prediction and choice outside those encompassed by standard codes (including preparing functional design requirements, addressing design concepts, and determining possible design constraints)
- Evidence of experiments conducted, prototypes built or simulations performed to test analyses
- Evidence of literature searches, use of network of peers to gather information on approaches to problem solving

PROFESSIONAL ENGINEER

Evidence that shows the applicant is able to investigate and assess options, define and analyse complex structural problems with only limited assistance from more senior engineers includes:

- Work samples and/or reports, including (hand written) engineering calculations, and analysis models if appropriate

Defining and scoping the problem

- Defining constraints that the designer needs to work within – for example, building architecture, available materials, site constraints, operational requirements, budget
- Identification of missing or required information - site related problems – ground conditions, is the structure likely to be affected by settlement? Wind analysis – require wind tunnel tests? Development of briefs for external consultants in order to obtain missing information.
- Define loads
- Defining acceptance criteria for key parameters.

Investigate and analyse various solutions

- Research material properties, for example reinforced concrete – shrinkage, early age strength etc...
- Selection of appropriate analytical process, eg static vs. dynamic
- Define model including boundary conditions e.g soil structure interaction, staged

Professional Engineering - Element 3

Element description

3 Define, investigate and analyse *complex engineering problems* in accordance with good practice for professional engineering

construction considerations, diaphragm flexibility etc.

- Conduct analysis and can correctly interpret results e.g. chooses an appropriate building period, can correctly determine diaphragm design actions etc.
- Verify the authenticity and conducts sensitivity analysis of results

The calculations submitted for first time applicants could include basic checks, e.g. sum of reactions approximately equals what is expected, or the deflected shapes been checked to see that they 'look' right.

Note that for structural engineering there is likely to be several iterations between elements 3 and 4 – that is, scoping and analysis and developing of solutions

Professional Engineering - Element 4

Element description

4 **Design or develop solutions to *complex engineering problems* in accordance with good practice for professional engineering.**

Performance Indicators

- Identifies needs, requirements, constraints and performance criteria
- Develops concepts and recommendations that were tested against engineering principles
- Consults with stakeholders
- Evaluates options and selects solution that best matched needs, requirements and criteria
- Plans and implements effective, efficient and practical systems or solutions
- Evaluates outcomes

General Practice Field Guidelines

- Evidence of personal responsibility taken in a project or significant task from the end of an investigation phase showing design solutions developed which resulted in all objectives being met. To indicate the level of complexity, describe involvement in detail. This can be over a range of similar projects/tasks, or one overall project/task with multiple components.

Professional Engineer

Design and develop solutions

- Demonstrate how the structural form evolved to meet the constraints (for example constructability considerations, resources, etc)
- How materials are suitable for the solution
- Design of subsystems and opportunity for standardisation
- Size of members, reinforcing bars, length of welds etc; connection design and detailing
- Constructability - Does the structure fit together? Do weld details make sense? Can they be made? For reinforced concrete – does the design indicate that the applicant has thought of how the reinforcing fits together, and the concrete placed and vibrated?
- Documentation and detailing of design solution - Can the applicant prepare and check drawings?
- Prepare observation/monitoring schedule for critical parts of construction process
- Recognise the need for expert assistance, respond positively to reviewers
- Documentation showing load paths (vertical and lateral) have been clearly identified for gravity, seismic and wind loadings

Professional Engineering - Element 5

ELEMENT DESCRIPTION

5 **Be responsible for making decisions on part or all of one or more *complex engineering activities***

PERFORMANCE INDICATORS

- Takes accountability for his/her outputs and for those for whom he/she is responsible
- Accepts responsibility for his/her engineering activities

GENERAL PRACTICE FIELD GUIDELINES

- Demonstrate effective self-management skills (including: undertaking professional development, setting own goals, practising effective time management, and recording professional development activities).
- Undertake and accept responsibility for higher levels of engineering activity, such as preparing and presenting submissions, estimates, project funding requests, annual planning activities and reports to client and senior management. Be responsible for and conduct public and stakeholder consultation and meetings

PROFESSIONAL ENGINEER

The work history forms should record work where the applicant has taken responsibility for complex projects. The applicant can summarise in his/her 'Competence Self-review' where he/she has:

- Been responsible for making decisions and dealing directly with the consequences (as opposed to simply implementing decisions made by others) by documenting specific instances of such experience.
- The attributes that made the work complex – refer to definitions on CA03 (or CA13) form.

Evidence could include how the applicant:

- Handled significant changes to the requirements of a project, either due to a changing brief or unexpected site conditions;
- Handled a situation where there were unforeseen problems or when things 'went wrong', and the actions he/she took in resolving the problem(s);
- Was involved in preparing contracts, evaluating bids, and performing site inspection work;
- Was involved in reviewing contracts, preparing bids, and in managing the work required to get a project built

As CPEng is a quality mark of the applicant's ability and maturity to work as an independent professional structural engineer, evidence must show the applicant has been solely responsible for a wide range of the aspects of a particular project.

Professional Engineering - Element 6

ELEMENT DESCRIPTION

6. Manage part or all of one or more *complex engineering activities* in accordance with good engineering management practice

PERFORMANCE INDICATORS

- Plans, schedules and organises projects to deliver specified outcomes
- Applies appropriate quality assurance techniques
- Manages resources, including personnel, finance and physical resources
- Manages conflicting demands and expectations

GENERAL PRACTICE FIELD GUIDELINES

- Project Management responsibility for a group of smaller projects and engineering activities or a significant part of a larger project
- Undertake site management activities such as the Engineer/Client/ or Contractor's Project Manager.

PROFESSIONAL ENGINEER

Evidence (with examples) of having been responsible for managing a complex structural project includes:

- planning, scheduling, organising (critical path planning, resource allocation, setting and monitoring budgets) and achieving results (this might be a construction site project or it may be organising a design team to complete a design);
- addressing issues such as plant accessing the site, safely building the design (including temporary work etc).
- handling conflict between 'demands and expectations' such as trying to deal with an unreasonable deadline (what compromises had to be made to get enough done in time to keep 'everyone happy' whilst still being able to complete the outstanding items before it is too late?)
- maintenance of a complete and thorough job file for each project – which combined with properly archived computer analyses, calculations, drawings, reports and contract documents, can be used to 'reconstruct' the course of a project at some (unexpected) time in the future;
- organising and co-ordinating other professionals – fire and building services engineers, geotechnical engineers, structural designers, architects and architectural designers;

For practitioners who are responsible for other engineering staff, evidence of their ability to identify poor practices and poor designs being carried out by persons under their control – and how these situations were handled (for example, training, mentoring, coaching etc.).

Professional Engineering - Element 7

ELEMENT DESCRIPTION

7 **Identify, assess and manage engineering risk**

PERFORMANCE INDICATORS

- Identifies risks
- Develops risk management policies, procedures and protocols to manage safety and hazards
- Manages risks through 'elimination, minimisation and avoidance' techniques

GENERAL PRACTICE FIELD GUIDELINES

- Evidence of training in risk management
- Knowledge of (not necessarily the use of) specialist software used for risk management
- Consider risks within alternative designs/timings/solutions/options
- Considers financial risk and/or potential liability to company.

PROFESSIONAL ENGINEER

Demonstrate that engineers use good QA procedures and have take steps to identify and address risk in relation to:

- Health and safety
- On-site practice, errors or inappropriate use of design, correction processes
- Handling uncertain data – doing 'what if' analyses
- Adequacy of resources to do a good job
- Candidate's ability to recognise what he/she does not know
- Confusion over documentation, misuse of documentation
- Need to observe construction
- Document/drawing approvals process.
- Overview and integration of overall design process – for example are there processes to ensure that computer analyses accurately represent the structure as finally designed and documented
- Change control process.
- Financial risk versus liability
- setting project costs taking account of risks
- Identifying who share shares risks and how this is costed and incorporated into project documentation - cost estimation and contingency
- Engineering of new materials
- Retrofit constructions - Historic nature of buildings and constraints on design
- Safe practical construction
- Estimates, project components (such as geotech, structural), safety, work-sites, checklist engineering, toolbox engineering,
- risk management training
- qualitative and quantitative modelling; rank risk;

Professional Engineering - Element 7

ELEMENT DESCRIPTION

7 **Identify, assess and manage engineering risk**

- Safety audits – team member/leader
- Alternative design/timing/solution
- Stakeholder/consultation planning and risks to project from adverse consultation outcomes

It is essential that engineers appreciate the effect on their client and other affected parties of their failure to perform. This often necessitates the engineer 'speaking up', especially in the early stages of work, when others want things that may not be achievable with regard to programme, fees, cost and budget.

Candidates should show their understanding of risk by giving examples of situations where they have identified and managed a risky situation.

Also coming under Ethics, it is imperative that engineers do not think that failure to perform professionally is OK as long as it does not come back as a PI claim, and the resulting problems become someone else's to deal with.

Professional Engineering - Element 8

ELEMENT DESCRIPTION

8 Conduct engineering activities to an ethical standard at least equivalent to the relevant code of ethical conduct

PERFORMANCE INDICATORS

- Demonstrates understanding of IPENZ and/or CPEng codes of ethics
- Behaves in accordance with the relevant code of ethics even in difficult circumstances (includes demonstrating an awareness of limits of capability; acting with integrity and honesty and demonstrating self management)

GENERAL PRACTICE FIELD GUIDELINES

- Evidence of exercising judgement on own competence – outline actions taken when confronted with work outside own area of competence
- Evidence of managing conflicts of interest – description of actions taken to resolve
- Evidence of quality assurance procedures and risk management methodologies used in professional engineering practise

PROFESSIONAL ENGINEER

The 'Competence Self-review' examples should show how the applicant has:

- Demonstrated a clear understanding of his/her competency limits and how he/she has worked within these limits;
- Had to stand up for professional standards (refer to the code of ethical conduct, and outcomes from Environment Court) in the presence of pressure to 'take short cuts';
- Shown an understanding of corporate behaviour – client/contractor/ consultant relationship and how he/she acted when exposed to compromise (to avoid being trapped by inappropriate 'corporate behaviour')
- Identified and taken action to resolve conflicts of interest; What resistance/conflict has the applicant experienced in such situations? How did he/she react when someone else tried to 'deflect' the candidate from potentially unethical behaviour?
- Had open and honest communication with stakeholders
- Applied his/her understanding of the code of ethics describing situations where he/she had faced and resolved an ethical dilemma satisfactorily.
- Engaged with the profession as a whole, and helped foster an environment where day-to-day practice encourages and maintains professional attitudes.
- Demonstrated behaviours expected of a competent structural engineer, such as honesty, openness to criticism, thoroughness, good site practices, being prepared to challenge and critically review, have an enquiring mind and an ability to question, debate and justify matters on a scientific basis.
- Accepted *constructive* criticism, *learnt* from own mistakes, and sought to improve practice. Useful work samples may include peer review correspondence.
- Recognised his or her obligations beyond the immediate client responsibilities – current and

Professional Engineering - Element 8

Element description

8 Conduct engineering activities to an ethical standard at least equivalent to the relevant code of ethical conduct

future building owners, users etc.
Shown an awareness of the limitations of graduate engineers, and must actively support, educate and encourage graduate engineers (and engineers in general) to 'learn their trade.'
What happens on a project they work on 'when the budget is blown?' Do they complete the project to the best of their ability?

Professional Engineering - Element 9

ELEMENT DESCRIPTION

9 **Recognise the reasonably foreseeable social, cultural and environmental effects of professional engineering activities generally**

PERFORMANCE INDICATORS

- Considers and, where needed, takes into account health and safety compliance issues and impact(s) on those affected by engineering activities
- Considers and takes into account possible social, cultural and environmental impacts and consults where appropriate
- Considers Treaty of Waitangi implications and consults accordingly
- Recognises impact and long-term effects of engineering activities on the environment
- Recognises foreseeable effects and where practicable seeks to reduce adverse effects

GENERAL PRACTICE FIELD GUIDELINES

- Evidence of addressing needs of key stakeholders (Iwi, historic places, archaeology, etc - consultation, and possibility for alternative design to reflect needs and aspiration of those affected)
- Evidence of life-cycle considerations in engineering designs – wastage, buildability, materials used, energy consumption and maintenance requirements during operational life, end-of-life issues (disposal and demolition)
- Identify the need for sustainable solutions to engineering and construction activities
- Evidence of actions taken to address health and safety and environmental implications of projects during and after construction/implementation

PROFESSIONAL ENGINEER

Evidence demonstrating competence in this element may include:

- Reports illustrating how the applicant had personal input to decisions on design options or manufacturing processes were made based on minimising the impact on the environment – wastage, water contamination, run-off, energy savings, etc
- Work samples - where applicants have recognised and considered the wider social cultural and environmental aspects of an engineering project for which they were responsible.
- A design brief prepared for client approval, where the applicant considered the broader impact of
- Preliminary design options, or correspondence;
- Structural engineering reports which include discussions/concerns of affected parties, and recommendations with options and the 'pros and cons' of each option.
- Discussion and examples on Sustainability in Design & Construction and Lifetime costs

Professional Engineering - Element 10

ELEMENT DESCRIPTION

10 Communicate clearly with other engineers and others that he or she is likely to deal with in the course of his or her professional engineering activities

PERFORMANCE INDICATORS

- Uses oral and written communication to meet the needs and expectations of his/her audience
- Communicates using a range of media suitable to the audience and context
- Treats people with respect
- Develops empathy and uses active listening skills when communicating with others
- Operates effectively as a team member

GENERAL PRACTICE FIELD GUIDELINES

- Effective communication in English and other language (sign, Maori etc as appropriate) - orally and in writing
- Preparing, interpreting and presenting information, issuing clear and accurate instructions, interpreting instructions, and selecting appropriate methods of communication – for variety of audiences (one-to-one and one-to-many communications; technical and non-technical personnel etc)
- Evidence of acceptance by peers by attendance and active participation in meetings, work place activities, training courses etc where candidate presents points-of-view and debates the topic or issue
- Evidence of leadership - of self and others

PROFESSIONAL ENGINEER

Evidence includes:

- Project reports that demonstrate clear thought process and conveyance of appropriate unambiguous information – either of a technical nature or as a communication to non-technical persons;
- Own application is an example of applicant's communications ability, and will be part of the evidence assessors consider;
- Examples of various forms that have been used to communicate information – has the applicant found these to be effective, and has he/she suggested improvements to improve communications?
- Leadership roles at meetings – leading technical discussion, presenting documents to influence decision makers (management, regulators, clients or other stakeholders);
- Correspondence – especially where the content of the correspondence had (potentially) significant consequences, such as contract related matters, issues involving regulators and related requirements, etc.
- Reference relevant evidence submitted for other elements (such as in competence self-review form – such as management of complex engineering activities, where applicant may have had to negotiate resources, timeframes and costs).
- Design feature reports that document structural concepts, load paths and loading assumptions.

Professional Engineering - Element 11

ELEMENT DESCRIPTION

11 Maintain the currency of his or her professional engineering knowledge and skills

PERFORMANCE INDICATORS

- Demonstrates a commitment to extending and developing knowledge and skills
- Participates in education, training, mentoring or other programmes contributing to his/her professional development
- Adapts and updates knowledge base in the course of professional practice
- Demonstrates collaborative involvement with professional engineers (NZ engineers for CPEng assessments)

GENERAL PRACTICE FIELD GUIDELINES

- Maintains Continued Professional Development (CPD) records
- Identifies future needs and plans competence development accordingly
- Actively participates with professional bodies
- Participates in diverse engineering activities leading to learning and betterment of engineering skills by a combination of training internal to organisation and external CPD, and self directed learning
- Maintains a network of professional engineers – peer reviews, collaborative activities
- Evidence of reflecting and learning from mistakes with the benefit of hindsight

PROFESSIONAL ENGINEER

'Good evidence' is evidence that shows the applicant has taken made a commitment to gaining new knowledge and apply it in his/her practice area, and includes:

- IPENZ CPD records
- Documentation of applicant actively taking responsibility for his/her own professional development, with appropriate balance between technical and "softer" learning ;
- Evidence of efforts made to actively seek out information on engineering failures, 'near misses,' contractual issues and the like – learning from own and others' mistakes, and avoid repeating them.
- networking with other professional engineers – especially important for sole traders and those in small practices or where few professional engineers are employed by company;
- mentoring, coaching or taking a leadership role in sharing new knowledge with peers;
- learning from peer reviews of own work – cite specific examples to illustrate learning.

Professional Engineering - Element 12

Element description

12 **Exercise sound professional engineering judgement**

Performance Indicators

- Demonstrates the ability to identify alternative options
- Demonstrates the ability to choose between options and justify decisions
- Peers recognise his/her ability to exercise sound professional engineering judgement

General Practice Field Guidelines

- Undertake complex and multi-criteria analysis as a part of exercising engineering judgement
- Takes a holistic approach in the development and implementation of engineering solutions, respecting other professional and individual inputs and demonstrating a balanced process to achieve desired outcomes.
- Undertakes decision making - uses technical, economic, social, environmental etc criteria when where there is a choice of options (e.g., what factors were taken into account in making the decision? What impact did those factors have? What were the benefits/compromises in making the decision?)
- Feedback and learning from one's peers (e.g. positive peer review of work)

Professional Engineer

Candidates can demonstrate how they have evaluated options and exercised engineering judgement in:

- Competence self-review form – cite examples and highlight instances where personal input to decision making process. Reference other elements where evidence may also demonstrate engineering judgement – such as ethical behaviour, analysis and investigation of complex engineering problems, taking responsibility for decisions in complex engineering activities etc.
- Work history summary – reference calculations and/or reports (with further expansion as required – or include as work samples);
- A design brief prepared for client approval;
- Preliminary design options, and related correspondence;
- Structural engineering reports which include discussions/concerns of affected parties, and recommendations with options and the 'pros and cons' of each option.
- Discussion and examples on Sustainability in Design & Construction and Lifetime costs
- Demonstrates that technical judgements are in accordance with the intent of the relevant standard or code where not specifically covered within said documents.

Structural Engineering Regulation in the United States
By Jon A. Schmidt, PE, SECB

Professional engineering (P.E.) licensure laws exist in all fifty states for the purpose of protecting the safety, health, and welfare of the public. The practice of structural engineering has a uniquely significant role relative to other design disciplines. Architectural, mechanical, and electrical system failures usually result in unattractiveness, poor functionality, discomfort, and/or inconvenience. A structural system failure almost always has more serious consequences; even in the best cases, there are often substantial costs associated with correcting what is or could become a life-threatening situation.

In addition, as stated in the joint CASE-NCSEA-SEI report on the National Summit on Separate Licensing of Structural Engineers that took place on November 3, 2000:

> The field of structural engineering is changing rapidly. Buildings and other structures are becoming larger and more complex and are being constructed with new materials and methods. Along with these advances in the state-of-the-practice, owners and the public alike have increased expectations about performance. Some structures are now expected to remain serviceable even after experiencing a traumatic force such as a seismic tremor or winds. As a result, it is more important than ever for all engineers with responsibility for structural projects to have appropriate credentials, stay current in the field, and demonstrate sound judgment that comes only with experience.

Recognizing this, ten states currently have specific provisions in place that distinguish structural engineers from professional engineers in other disciplines: California, Hawaii, Idaho, Illinois, Nebraska, Nevada, New Mexico, Oregon, Utah, and Washington. However, there is considerable variation among these jurisdictions in the qualifications that are required for structural engineering (S.E.) licensure:

- Idaho, New Mexico, and Washington require at least two years of structural engineering experience for S.E. licensure, over and above the experience required for P.E. licensure. California requires three additional years.
- California, Oregon (beginning in October 2005), and Washington each require the National Council of Examiners in Engineering and Surveying (NCEES) Structural II examination and a state-specific Structural III examination for S.E. licensure, in addition to any examination passed for P.E. licensure.
- Idaho and Nevada require the NCEES Structural I and Structural II examinations for S.E. licensure, in addition to the NCEES Civil examination that is required for P.E. licensure.
- All others require only the NCEES Structural I and Structural II examinations for S.E. licensure, except that New Mexico does not require any examinations for those who have four years of structural engineering experience after P.E. licensure in that state.

There are also important differences in the significance of S.E. licensure within each jurisdiction. Typically they are classified as "practice act" or "title act" states, but this terminology is often carelessly applied where S.E. licensure exists in the form of rules adopted by the licensing board, rather than statutes passed by the legislature. A more accurate scheme refers to practice and title statutes and rules:

- Hawaii and Illinois have full practice statutes.
- California, Oregon, Utah, and Washington have partial practice statutes.
- Nevada has partial practice rules.
- Idaho, Nebraska, and New Mexico have title rules.

The specific provisions in these states are as follows:

- Illinois and Utah statutes formally recognize structural engineers separately from professional engineers. Illinois even has a separate S.E. licensing board.
- Hawaii statutes require the seal of a licensed S.E. on construction documents in order to obtain a building permit.
- Illinois statutes require the S.E. license for anyone who practices structural engineering.
- California statutes require the S.E. license for schools and hospitals.
- Oregon statutes require the S.E. license for hazardous facilities, special occupancy structures, essential facilities over 4,000 square feet in ground area or 20 feet in height, structures with irregular features, and buildings over four stories or 45 feet in height.
- Utah statutes require the S.E. license for complex structures.
- Washington statutes require the S.E. license for hazardous facilities, essential facilities over 5,000 square feet in ground area and 20 feet in height, structures exceeding 100 feet in height, buildings of five or more stories, bridges with a total span of more than 200 feet, piers with a surface area greater than 10,000 square feet, and structures where more than 300 people congregate in one area.
- Nevada rules require the S.E. license for structures requiring special expertise, such as radio towers and signs over 100 feet, and buildings more than three stories or 45 feet in height.
- Idaho, Nebraska, and New Mexico rules provide special qualifications for the S.E. license, but do not explicitly require it for the practice of structural engineering.

This wide variety of S.E. licensing requirements across the country inhibits the mobility of those who already have the S.E. license in one state and seek to obtain it in another. Recognizing this, NCEES added the following definition to its Model Law in 2003:

> The term "Model Law Engineer–Structural Engineering" refers to a licensed engineer who:
>
> a. Is a graduate of an engineering program accredited by the Engineering Accreditation Commission of ABET, Inc. (EAC/ABET)
>
> b. Has passed a minimum of 18 semester (27 quarter) hours of structural analysis and design courses. At least 9 of the semester (14 quarter) hours must be structural design courses.
>
> c. Passes the 8-hour NCEES Fundamentals of Engineering (FE) exam.
>
> d. Passes 16 hours of structural examinations consisting of one of the following:
>
> (1) NCEES structural examinations, 8 hours of which are SE II
>
> (2) 16-hour state-written structural examinations taken prior to 2004

(3) NCEES SE II plus 8-hour state-written examinations

e. Completes four years of acceptable structural engineering experience after confirmation of a bachelor's degree. A maximum of one year of credit may be given for graduate engineering degrees that include at least 6 semester (9 quarter) hours of structural engineering (in addition to the 18 hours noted above).

f. Has a record clear of disciplinary action.

In 2004, NCEES relocated this definition to its Model Rules and added the corresponding designation, Model Law Structural Engineer (MLSE), to its Council Records Program.

Separately, NCSEA's Member Organizations voted in 2003 to establish an independent body, the Structural Engineering Certification Board (SECB), to administer a national board certification program for structural engineers. Specific education, experience, and examination requirements are still being developed. Initially, it is possible to qualify for certification by virtue of holding, as of June 19, 2005, a valid license to practice structural engineering in any United States jurisdiction--which is simply the P.E. license in states where there is no S.E. license--and having been actively engaged in such practice for at least three years prior to the date of application.

The MLSE and SECB criteria are intended eventually to serve as the basis for national uniformity in the qualifications required for S.E. licensure. Structural engineers who wish to lobby for it in states that do not yet have it must first address several key questions:

- Legislative statutes or board rules?
- Practice restrictions or only title recognition?
- Additional education requirements?
- Additional experience requirements?
- Additional examination requirements?

State boards generally establish by rule the specific education, experience, and examination requirements for licensure within general parameters that are set forth in the statutes. State boards also typically have the statutory authority to adopt rules of professional conduct that apply to all licensees, which could serve as the justification for restricting practice. Even so, some state boards may be reluctant to pass new S.E. practice or title rules without explicit legislative warrant, especially if resistance is encountered from organizations such as the National Society of Professional Engineers (NSPE), which has an official policy of opposing any form of discipline-specific licensure.

Seeking uniform separate S.E. licensure nationwide is a daunting task, but one that is worth pursuing--one state at a time. NCSEA plans to invest its resources in at least one or two such efforts in the near future. Structural engineers who believe that their states are ripe for action should contact the author or Susan Jorgensen, PE, the current chair of the NCSEA Licensing Committee, at sajorgensen@leoadaly.com.

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