



PRACTICE NOTE 14 **STRUCTURAL ENGINEERING DESIGN OFFICE PRACTICE**

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Introduction

In recent times the quality of structural engineering practice, particularly as it relates to the design of buildings, has come under scrutiny both from inside and outside of the engineering profession. There is little doubt that the practice of structural engineering has changed considerably over the last 30 years. Many factors have required practices to adapt, such as:

- greater reliance on technology for design
- superior modelling ability that allows less conservative results and encourages more complex solutions
- new construction technologies
- speedier communications enabling demands for instant response
- reduced training and a loss of institutional knowledge amongst engineering technicians (draftspersons)
- less time available for design
- more complex codes and standards
- loss of technical knowledge from local authorities (Building Consent Authorities (BCAs))
- pressure on fees and services from clients
- overly competitive behaviour from consulting firms
- a more litigious society (less accepting of failure).

In many ways, the adaption has been remarkable, with great technical skill and innovation being exhibited along with fantastic increases in productivity. However, these quality improvements have not been uniform and perceptions of poor design quality do exist.

With this in mind, the IPENZ and ACENZ Boards have encouraged the production of this practice note, which aims to define the fundamentals of acceptable office practice for structural engineering design, improve the overall quality of structural design services and, ultimately, regain the trust and respect of the public and regulators, which has been lost or at least tarnished.

Background

The leaky homes crisis and to a lesser extent the Scarry open letter triggered significant changes to the licensing and regulation of building practitioners, including structural engineers, through the *Building Act 2004* (BA). Prior to that there were other indications that the quality of building design services, generally, were decreasing. The New Zealand Construction Industry Council's *Design Documentation Guidelines* were the response to a senior contractor exclaiming "Just give me some drawings I can build from!".

Structural engineering firms, in particular, have cheapened the "value" of their work by competing vigorously on price. Consequently they have reduced their services to remain competitive, providing less innovation and documentation, more performance-based and proprietary design, and reduced or no construction monitoring. Previous recessions (notably the 1987 crash, made worse by the privatisation of the 1980s) accelerated the problem with the result that consultants had little profit to invest in staff retention, let alone staff training. As a consequence, many engineers left the industry and considerable experience was lost. The loss of the state sector as a major employer and training ground for engineers and technicians exacerbated the problem.

While engineering consultancies have flourished and shown considerable growth during the period 1995–2008, typically, they have not regained the status, level-of-service or fees that were lost.

Function of a Design Office

In general terms, a structural engineering office will:

- meet the client's stated needs, in relation to structural engineering consultancy services, by satisfying the brief or defined scope of services
- produce (design) solutions that comply with relevant codes and statutes, and meet recognised engineering standards of practice
- perform to standards expected of a competent engineer, as measured by professional peers
- produce clear and complete documentation that may be understood and interpreted without significant elaboration
- produce designs that can be constructed using materials and construction technologies that are reasonably procurable
- produce cost-effective designs within the time and quality constraints imposed by the brief
- take reasonable steps to ensure that the resulting construction matches the design intent
- perform in a timely manner
- provide a safe and rewarding environment for staff
- encourage staff to engage in continuing professional development (CPD), and provide opportunities for staff to gain experience and advance their career
- make sufficient return to attract and retain quality staff and to invest in new technologies
- make a profit!

Communications and Contracts

While this practice note is primarily about technical structural engineering issues it is worth noting that many complaints about engineers from outside the profession, typically from clients, relate to issues of communications, fees and performance (timing). With this in mind, the following simple guidelines should be followed.

- Always have a written commission.
- Ensure the scope of your services is well defined.
- If you can't give a lump sum estimate because the scope of work is unclear, at least make sure that the client has an idea of what range of fee to expect. Once the scope is defined, refine the estimate to reduce the risk of misunderstandings.
- Advise the client of other fees they can expect to pay – consents, investigations, disbursements, sub-consultants, or other consultants.
- Insist on reasonable allowances, to cover design and site contingencies.
- If there's a change of scope, advise the client that there will be an effect on the fee.
- List the assumptions and limitations that are implicit in the design and explain them to the client. For example, it can be useful to record floor loadings on drawings.
- Record and explain the risks that are inherent in the design. Whenever possible, educate the client about the nature of risk, return periods, and probabilistic risk assessment.
- Involve the client in critical decisions.
- Give realistic timeframes for your services and for obtaining consents.
- Use standard contracts (for example, ACENZ/IPENZ's *Short Form Agreement For Consultant Engagement* or the joint ACENZ, IPENZ, INGENIUM and Transit document *Conditions of Contract for Consultancy Services*).
- Always limit your liability, except for domestic clients.
- Do not operate without professional indemnity insurance and, whenever possible, ensure that other design firms with whom you work also maintain appropriate cover.

More advice on this subject can be found in ACENZ *Briefing and Engagement* and FIDIC *Definition of Services*.

Design Office Dynamics

The organisational culture of a design office is an important indicator as to its likely long-term success and to the quality of its output. Attributes shown by successful design offices include:

- professional and ethical behaviour at all times and in all relationships
- a spirit of technical collaboration, both internally among office members and externally between firms and professional peers
- effective mentoring of all staff members to develop and transfer skills and experience
- a commitment to CPD and staff development
- a culture of questioning and challenging assumptions, "givens" and set procedures
- building enduring relationships with clients, other designers and industry stakeholders
- self-review and assessment of individuals and the office or practice as a whole
- encouragement of external peer review when appropriate (it encourages collaboration and CPD)
- a desire to keep up with the latest technical developments
- a process of continual design optimisation and value engineering
- conscious risk identification and mitigation (not transfer)
- a commitment to innovation.

Design Process

This is the crux of the matter and the hardest to define. As a guide, competent design offices will typically do the following.

- Clearly understand the needs of the other stakeholders – client, users, architect and other consultants. That is, be looking for an effective overall solution not just the optimal structural solution.
- Ensure the brief/scope is well defined before commencing work. If it's not defined, then that should be the first activity.
- Carry out research, investigations and pre-design studies. A pre-design site visit should normally be essential.
- For alterations to existing structures, carry out structure condition investigations.
- Determine the design criteria including relevant codes, standards and compliance documents. Be particularly aware of alterations to existing buildings as change-of-use provisions may apply. The New Zealand Building Code (BC) establishes minimum design criteria for structural design, with reference to relevant standards. Structural engineers should consider whether the minimum standards are appropriate for the project. The BC's criteria are generally based on life safety and protection of other's property. They may not address other criteria relevant to the project and client, such as aesthetics, cost, damage limitation, sustainability or buildability, which may either be specified, or assumed by stakeholders.
- Follow logical design phases – concept, preliminary, developed, detailed – with review, cost update and preferably client sign-off at the end of each phase.
- Involve senior and experienced engineers in deciding the structural form.
- Fit structural form to function, that is, when considering grid spacing, positions of walls, bracing, etc.
- Consider future reuse of the structure. In general terms, function-specific design is the least sustainable.
- Consider a wide range of factors when selecting a structural form. For example, when selecting and recommending a floor system, the following issues might be considered:
 - span v load capacity
 - ability to carry point loads, diaphragm actions
 - vibration and liveliness
 - durability
 - fire performance
 - acoustic properties
 - soffit appearance (if it is to be exposed)
 - surface finish, wearing properties
 - future flexibility
 - ability to accommodate set-downs and penetrations
 - ability to take fixings, from above and below
 - craneage, offsite prefabrication and buildability
 - insulation, thermal properties
 - issues relating to environmentally sustainable design
 - cost.
- Consider alternatives during the concept and preliminary phases, and obtain relative costing advice when appropriate.
- Clearly identify natural hazards and expected loadings, for example:
 - seismic soil, importance, zone and ductility factors
 - floor loadings
 - wind loadings
 - snow loadings
 - liquefaction, ground instability
 - tsunami, seiche and flooding
 - aggressive or corrosive environments
 - shrinkage, temperature, creep and stressing
 - climate change, such as sea-level rise, changes in wind and snow loadings.
- Clearly define load paths and structural systems, preferably in writing, early in the design process. Creating and updating a Design Features Report during the design phases is recommended, particularly for complex work.
- Adopt analytical models that reflect reality.
- Anticipate the analytical models and rationalise any unexpected results.
- Take care to translate the design into a practical and buildable physical structure.
- Detail connections so that they can cope with the expected forces and deformations.
- Always be mindful of construction tolerances.
- Prepare drawings that are clear, substantially complete, and have logical sequence and referral systems.
- Prepare specifications and method statements that are specific and relevant to the project.



Quality Processes

Some form of quality assurance or internal review process is essential to ensure consistent and defect-minimized design output. While larger practices tend to have more formal processes, all systems rely on thorough and insightful application to be effective. The depth of review should be tailored to suit the:

- complexity of the design and analysis
- size of the project
- experience and ability of the design engineer or technician
- experience of the reviewer
- whether it is a repeat or first-time design
- consequences of failure
- multiple re-use of design.

Review can be undertaken at any phase of the project. Review at an early stage may effectively avoid or limit errors but give less certainty on the quality of the final design. Review at later stages or at completion of the design may result in significant rework, but can give greater certainty of the adequacy of the design. For larger projects, frequent design review, and designated hold-points are essential.

The nature of review will include some or all of the following:

- review of assumptions and loadings
- appropriate and realistic modelling
- review for effective and complete load paths
- review for robustness and adequate redundancy
- arithmetical accuracy
- comparison of computer and computational outputs with anticipated results
- parallel calculations on critical elements
- detailed review of selected or random elements
- effectiveness of detailing to deliver design intent
- review for buildability – see IPENZ Practice Note 13 – Constructability
- review for durability
- translation of design intent into detailed documentation
- review for completeness of design and documentation.

While arithmetical accuracy can usually be checked by competent junior staff, other aspects of review invariably require input by experienced professionals.

Small practices and sole practitioners need to be particularly mindful of how to achieve effective review, particularly when undertaking complex work. Some form of external review, possibly on a reciprocal arrangement, may be an appropriate solution.

Effective, detailed and thorough review of drawings is a tedious yet essential task usually requiring input by senior staff.

Working Within Competency

Competence is the quality of having the necessary ability or knowledge to do something successfully. The test for professional competence includes asking if the person can:

- comprehend and apply appropriate knowledge
- exercise sound professional judgement
- use relevant codes of practice recognised
- recognise the limitations of codes and then use first principles derived from natural laws to formulate an appropriate course of action
- recognise the limits of their competency.

Working within the limits of technical competency is a core ethic and a central plank of the *Chartered Professional Engineers Act 2002*. Just how engineers judge themselves to be competent to carry out a particular task is a difficult issue. It certainly is not just a question of whether an engineer has experience with a particular design task or structural form.

What can differentiate competency relates to complexity in materials, technology systems, analytical and modelling effort, and numerical intricacy. Not all structural engineers are equal in this regard and each individual must recognise this issue.

For a design office, competency can be aggregated across the whole office (or team) as specialists can carry out the particularly complex parts. The important principle is that the design team leader must identify when specialist input is required.

Self-regulation is an attribute that sets professions apart. Self-regulation at an individual level means understanding one's competency limits and working within them. At a group level it means setting minimum standards and limiting entry to those who meet the standards. Demonstrating true self-regulation is essential to gaining and retaining the trust of the regulatory agencies and others who judge engineer's performance. Until it is achieved, others will seek to set up their own competence registers.

To judge relative competency, consider this legal judgement:

"The question of whether the architect or engineer has used a reasonable and proper amount of care and skill is one of fact, and appears to rest on the consideration whether other persons exercising the same profession, and being men of experience and skill therein, would or would not have acted in the same way as the architect in question. It is evidence of ignorance and unskilfulness in any particular to act contrary to the established principles of art or science which are universally recognised by members of the profession."

McLaren Maycroft and Co v Fletcher Development Co Ltd

Demonstrating Compliance

With the advent of the BA the onus of demonstrating compliance with relevant clauses falls more heavily on building designers. This is because, in an effort to improve building quality, most common building performance requirements have now been codified and because technical expertise has been lost within local authorities (BCAs).

To assist the BCA, design needs to be identified as one of the following:

1. as matching an acceptable solution
2. as having been derived by a verification method
3. as an alternative solution (more appropriately referred to as a Performance Based Solution).

Note that the second two options are considered as specific engineering design.

This is a change for engineers; in the past, design was deemed to be compliant if it met accepted practice. Typically, this was assessed by peers who understood what accepted practice meant. Today, structural engineering building design will be measured against Clause B1 of the *BC*, and its relevant compliance documents. For most specific design this means compliance with verification method 1.

Designing outside generally accepted codes may lead to trouble. One judge stated the position in these terms:

"I am of the view that bearing in mind the function of codes, a design which departs substantially from them is prima facie a faulty design, unless it can be demonstrated that it conforms to accepted engineering practice by rational analysis."

Bevan v Blackhall and Struthers

Most structural engineers will demonstrate compliance through their calculations and drawings. It is important that consent documentation clearly states how compliance is met (in the introduction to the calculations, or in the design features report) and whether it is by accepted solution, verification method or alternative solution. This is because BCAs, which must be satisfied on reasonable grounds that the design is compliant, will apply different levels of review and audit depending on the solution method.

A BCA may choose to rely on a producer statement as part of what it needs to satisfy itself that compliance is demonstrated. The issuing of producer statements needs to be undertaken with care. Refer to IPENZ and ACENZ practice notes relating to producer statements.

A BCA may also choose to rely on peer review as part of what it needs to satisfy itself that compliance is demonstrated. Peer review for building consent has particular requirements and associated risks, refer to IPENZ and ACENZ practice notes relating to peer review.

Proprietary Design

Proprietary design forms a significant and increasing proportion of structural work, from precast flooring to steel purlins to manufacturers' design tables for all sorts of products and systems. With the introduction of restricted work categories, BCAs will require clear definition of design responsibility for all primary structure. Engineers in design offices will need to be clear as to where their responsibilities start and finish. They will also need to seek clear design verification from suppliers or designers of proprietary elements and then supply this information to the BCA. Typically, connections between proprietary elements and the primary structure remain the responsibility of the design engineer.



Design for Safety

Engineers and employers of engineers need to be aware of their obligations and responsibilities in relation to health and safety, particularly on construction sites. Structural engineers need to be aware that following a construction accident, or even a near miss, their role and the role of design generally can come under scrutiny. ACENZ and IPENZ have the view that the differences between permanent works design and temporary works design should be clearly defined. At times, permanent works and temporary works design do merge. Structures that require a specific construction sequence in order to ensure temporary or permanent stability require clear sequencing instructions from the designer. Refer to IPENZ and ACENZ practice notes on design for safety for further information.

Construction Monitoring

The reduction in levels of construction monitoring during the 1990s, particularly in the upper North Island, was symptomatic of reducing levels of service. The involvement of the design engineer during the construction phase is regarded as good practice and as part of "full service" from consulting engineers. IPENZ and ACENZ recommend that construction monitoring be carried out by the designer, or their representative.

Although it is not a mandatory requirement of the BA, BCAs, clients and constructors understand the important tasks that the designers perform during the construction phase, including:

- answering queries and providing interpretation of the construction documentation
- addressing contingent design issues that arise during construction
- monitoring construction quality and correct implementation of design intent
- reviewing proprietary design and construction phase documentation (shop drawings).

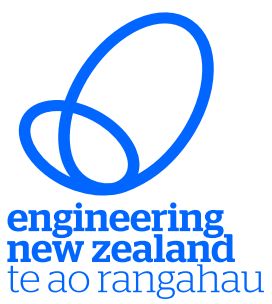
The scope and intensity of construction monitoring should be determined by a review of the following factors:

- the size and complexity of the work
- the experience of the contractor
- the consequences of non-compliance.

The complexity and importance of the construction work should also have a bearing on the experience of the engineer who is selected to carry out the construction monitoring.

It is useful for the designer to advise the BCA on the extent of the proposed construction monitoring, particularly when providing a producer statement.

Further guidance on construction monitoring levels can be found in ACENZ's *Briefing and Engagement* document and on the IPENZ web site under "Construction Monitoring Services".



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