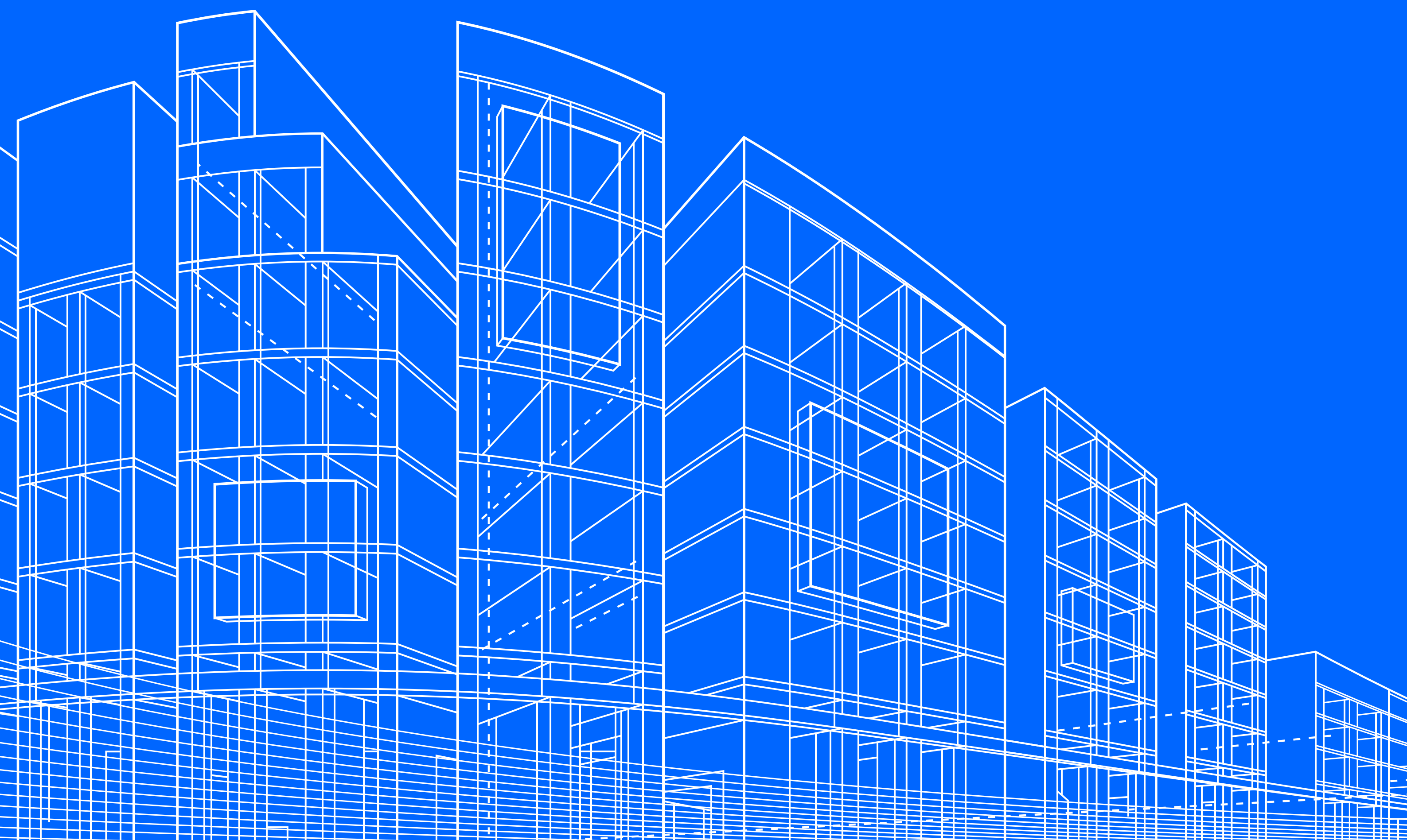
engineering new zealand
te ao rangahau

QUALITY ISSUES IN THE BUILDING SYSTEM

Overcoming inadequate structural engineering design



EXECUTIVE SUMMARY

The building system is not working as well as it could. This report outlines weaknesses in the system that in some cases have led to significant structural engineering design failures. In this report we discuss case studies and provide examples of building designs where costly faults were identified too late in the design-build process. Quality is, at times, being compromised.

To address quality issues, we need to understand the primary causes of shortcomings and the way in which the system impacts outcomes. This report gives a view of roles and responsibilities in the building system, highlighting where challenges exist and speaking to the role of engineers and Engineering New Zealand to drive better outcomes. Although this report focuses on structural examples, the observations and conclusions are applicable to all engineers working in the building system, particularly geotechnical and fire engineers.

To support the profession, this report also highlights what good looks like, providing references for engineers and industry on expectations around good design performance.

In the conclusion of the report, we outline the next steps for Engineering New Zealand, as follows:

1. Support Building Consent Authorities (BCAs) in their role consenting engineering design work, specifically by discussing how Engineering New Zealand as the Registration Authority can help manage risk and support BCAs to ensure quality outcomes
2. Work with the Association of Consulting and Engineering (ACE) New Zealand to support its work on improving the robustness of quality assurance processes in New Zealand's engineering firms
3. Advocate for wider building system reform to provide a greater focus on quality
4. Strengthen the technical and professional support provided to engineers, including:
    - 4.1. design review expectations and ethical obligations
    - 4.2. clearer guidance and greater monitoring of continued professional development requirements
5. Strengthen the way engineers are regulated. This involves:
    - 5.1. Continuing to address current concerns with the Chartered Professional Engineer system so that the registration and re-registration of Chartered Professional Engineers provides clarity to industry that these engineers have been appropriately assessed, within the scope of the current Act and Rules
    - 5.2. Supporting the development of an improved occupational regulation system that provides assurance to the public, industry, government, and profession that those undertaking engineering services are appropriately registered and that engineers involved in high risk work are appropriately assessed as being competent to perform this work.

CONTENTS

Introduction **4**
Why this report and why now? 4
Background 4
Overview of this report 5
Problem **6**
Design issues involve at least one Chartered Professional Engineer 6
Quality assurance processes are not always catching significant design shortcomings 6
Report problem definition 6
Common characteristics of poor design 7
Systemic concerns 7
Quality assurance in the building system **8**
The role of the Chartered Professional Engineer 10
Other parties in the building system 10
What are the causes of quality issues in the building system? **12**
Limitations of the Chartered Professional Engineer system 12
Regulators are relying on Chartered Professional Engineer registration to manage risk 13
Review processes are not always robust 14
"Race to the bottom" 14
Case Studies **15**
Southland Stadium 15
Residential properties in Tauranga 16
230 High Street, Christchurch 17
Masterton buildings 18
Root causes of quality issues **19**
What does good look like? **21**
Individual performance 21
Organisational performance 22
Peer review processes 22
Early design phase 24
Management of the Chartered Professional Engineer system 25
Conclusions **26**
Next steps 26
References **27**

INTRODUCTION

Why this report and why now?

Engineering New Zealand is the largest professional body for engineers in New Zealand. We are also the regulator of Chartered Professional Engineers. In this report we articulate challenges we observe in the building system and opportunities to support engineers working in this system.

The building system in New Zealand is complex and covers the work of regulators, professionals, tradespersons, developers, associations such as Engineering New Zealand, firms, and researchers. For simplicity, the building system covers work across New Zealand to design, build and maintain residential and commercial buildings.

This report is for engineers. It highlights key challenges we observe in the building system, the impact these challenges have on quality outcomes and the role of engineers to improve quality.

This report is also for central government which is working to strengthen the building regulatory system. Part of the government's work is focused on improving the way those working in the system are regulated (occupational regulation) and part is focused on wider operational changes, such as modernising the building consent system.[1] This document is intended to highlight the challenges and opportunities as we see them.

Finally, this document is for those working within the building system with structural design engineers. Those in BCAs rely on engineers to ensure the structural integrity of consented buildings. For them, this report highlights ongoing constraints of the Chartered Professional Engineer system and recommendations on peer review.

Although this report focuses on structural examples, the observations and conclusions are applicable to all engineers working in the building system, particularly geotechnical and fire engineers, as well as engineers working within other complex systems.

Background

It is our view that quality outcomes in the building system can, and should, be better. Several high-profile structural design shortcomings – including Southland Stadium, 230 High Street in Christchurch, commercial buildings in Masterton, and a series of residential buildings in Tauranga – have occurred, fortunately with no loss of life, but at considerable cost to owners and impacting confidence in the engineering profession. We are concerned the potential for such shortcomings to persist has not gone away.

The Structural Engineering Society of New Zealand (SESOC), the New Zealand Geotechnical Society, the New Zealand Society for Earthquake Engineering, and the Society for Fire Protection Engineers, have been raising concerns about quality of outcomes across the building system for years. Separately and collectively, we have been advocating to the Ministry of Business, Innovation and Employment (MBIE) for improved outcomes. The findings of Engineering New Zealand's own motion inquiry into six Masterton buildings in December 2021[2] led to a renewed discussion on opportunities to highlight our concerns on wider building system quality issues. This report is the outcome of those discussions.

This report focuses on system elements where the engineering profession can have the most influence (ie design, design reviews and construction monitoring). Successful building projects rely on numerous individuals or parties to interact knowledgably, professionally, collaboratively, with integrity, and in a timely manner. There are many things that can go wrong, highlighting the importance of having quality assurance processes in place.

Overview of this report

This report builds on evidence we have gathered in our role as the Registration Authority for Chartered Professional Engineers. Several high-profile cases of inadequate structural engineering designs have been seen in recent years. Engineering New Zealand, as the Registration Authority, has investigated the engineers involved in these issues, as well as complaints relating to lesser-profile engineering design issues. Thankfully, in three of the four cases outlined in this report, no failures of the structure occurred. Checks and balances do exist in the system, although these need to be strengthened. All cases of inadequate design undermine confidence in the engineering profession and building system.

Engineering New Zealand has a duty to support the profession to identify and address systemic problems. Part of our organisation's objective, as defined in our Rules, includes "supporting, promoting and representing the engineering profession".[3] As the regulator, Engineering New Zealand also has a responsibility to ensure Chartered Professional Engineers comply with ethical and competency standards and to hold them to account where they fail to meet those standards.

This report aims to support continuous improvement within the profession and wider industry.

Case studies of structural engineering design issues

The case studies in this report identify key technical issues and shortcomings across both the design and quality assurance stages of projects. They reference disciplinary findings in relation to the engineer, or engineers, involved.

Examples were selected to highlight significant structural design issues across the residential and commercial sectors. Several other high-profile cases featuring similar concerns have been excluded from the examples in this report because either the investigation, civil or disciplinary processes were not resolved at the time of writing.

PROBLEM

Design issues involve at least one Chartered Professional Engineer

The building designs in our case studies were all signed off by Chartered Professional Engineers (or in the case of the Southland Stadium, a member of Engineering New Zealand) at both the design (PS1) and design review (PS2) stages. The building system, in large part, relies on Chartered Professional Engineers to sign off on engineering design work.

Chartered Professional Engineers are registered with Engineering New Zealand under the Chartered Professional Engineers of New Zealand Act 2002. Engineering New Zealand regularly assesses engineers on their competency to undertake complex engineering work.

The need to hold practitioners to account is one reason professions are regulated. As the regulator, Engineering New Zealand must take performance concerns seriously, especially where patterns arise.

Quality assurance processes are not always catching significant design shortcomings

In each case of engineering design issues highlighted, quality assurance processes failed. Errors introduced in the design stage went undetected from early stages (concept design).

No design should be completed in isolation. Engineers and engineering firms should have quality assurance processes in place. Additionally, BCAs should have processes in place to provide assurance that design and construction work complies with the Building Code and is undertaken by appropriately qualified individuals.

Society expects buildings to be safe and to be resilient to natural disasters, such as earthquakes.[4] To deliver quality buildings, all component parts of the system must work to this end.

Report problem definition

The problem definition of this report is as follows:

A series of engineering design and quality assurance shortcomings indicate systemic problems.

Common characteristics of poor design

A review of instances of poor engineering designs highlights concerns with the application of engineering knowledge (technical skills, understanding of the Building Code, Standards, industry best practice, and use of products) by those involved in design, design review and building sign-off. Case studies in this paper highlight issues with:

1. Design

Conceptual flaws with respect to load paths, including the overall layout and configuration of the buildings.

Poor design and detailing of critical members and their connections for seismic actions – a lack of awareness of, or familiarity with, the key design and detailing provisions of concrete and steel standards that give effect to capacity design.

2. Design review

Failure of peer reviewers to identify both conceptual flaws and poor detailing of critical connections within a set of completed drawings. This suggests that some peer reviewers do not have a good understanding of what they should be focusing on.

Reviewers engaged too late in the process, with peer review becoming a basic compliance exercise rather than improving quality. This indicates that the opportunity to identify conceptual issues early in the design process are not being taken.

Systemic concerns

The building system, of which engineers are a part, sometimes fails to prevent and correct poor engineering design work, as above. In this paper, we break down the components of poor engineering design and how these failed to be caught by the system.

Quality assurance is in the hands of the engineering profession. There are no regulatory levers requiring designs to undergo technical review. BCAs often require independent reviews for complex designs (and otherwise depending on the BCA) but such requirements and processes vary across the country.

Engineering professionals must take ownership of the quality of their work. This is critically important for the profession and society.

QUALITY ASSURANCE IN THE BUILDING SYSTEM

Quality assurance systems prevent issues by establishing and maintaining processes that ensure reliable products and services. They also catch errors before they have a chance to materialise. Quality outcomes come through defining and mapping processes, defining objectives, and measuring and improving outputs. These processes support continuous improvement, strengthen public confidence and the credibility of individuals, companies, and the wider profession. An example of a basic quality outcome in the building system is design compliance with the Building Code.

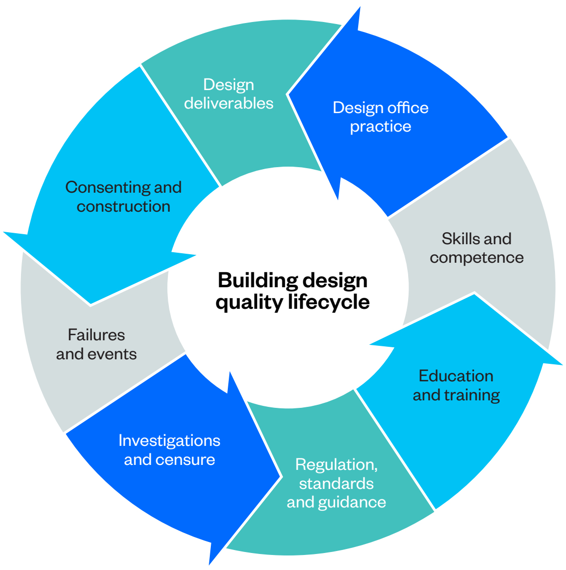
The table below outlines building system participants and their role in quality assurance processes.

Participants	Role
Ministry of Business, Innovation and Employment (MBIE)	Stewardship and regulatory oversight, including performance requirements and monitoring
Councils/Building Consent Authorities (BCAs)	Regulatory enforcement, including day-to-day decision making about whether building plans and work complies with the Building Code
Engineering professionals	Service provision and professional oversight
Engineering consultancies	Oversight of professionals Quality assurance system management
Developers	Develop land through construction, owning the land and development until it is sold to building owners
Building owners	Regulatory system users, defining user requirements.
Public	End users of residential and commercial buildings
Engineering New Zealand	Professional body for engineers Registration Authority for Chartered Professional Engineers As Registration Authority, set rules for minimum standards of competency, keep the register up to date, hear complaints, discipline.
Other associations supporting industry	Other professional bodies and regulators Associations supporting organisations, including ACE New Zealand

New Zealand engineers in the building system typically work for clients, whether this is a developer, building owner or BCA. The end user of engineering services is the public. Organisations like Engineering New Zealand support the profession.

Although the building system has several inbuilt quality assurance measures, these are focused on ensuring process compliance, rather than quality/suitability. There is a strong onus on Chartered Professional Engineers as professionals to act competently, stay within the bounds of their competence, and be responsible for quality assurance, as well as managing risk.

Figure 1 was originally published in SESOC's 2019 submission to MBIE on the occupational regulation of engineers.[5] It highlights the areas that form part of a broader building design quality lifecycle. Attention to, and investment in, all aspects of the lifecycle is necessary in order to improve quality outcomes.



Design office practice
Analysis, design, documentation, design office practice, coordination, collaboration, supervision, review, quality assurance (QA)

Design deliverables
Building consent deliverables, drawings, specifications, design features report, calculations, BIM models

Consenting and construction
Peer review,consenting, technical audits, data collection, construction monitoring, fabrication, construction checking/QA, construction

Failures and events
Disasters, failures, outcomes from adverse events (positive and negative)

Investigations and censure
Forensic investigations, industry reviews, ministerial reviews, Royal Commission hearings, research, disciplinary action, censure

Regulation, standards and guidance
Standards, guidance, practice notes

Education and training
Courses, lectures, seminars, workshops, conferences, mentoring, coaching, academic qualifications

Skills and competence
Knowledge, expertise, experience, judgement, ethics, professionalism, professional qualifications

Figure 1: Building design quality lifecycle. Reproduced with permission from SESOC

The role of the Chartered Professional Engineer

Chartered Professional Engineers provide professional services, either as sole practitioners or within companies of varying size, to ensure buildings meet the needs of the client and the requirements of the Building Code.

In the building system, the role of the Chartered Professional Engineer is predominantly focused on design (including structural, geotechnical and fire aspects of building design), design documentation, design review, and construction monitoring. In practice, the building system relies on Producer Statement documentation signed by Chartered Professional Engineers to assure BCAs that engineering work (design, review or construction monitoring) is compliant with the Building Code. The producer statements used by Chartered Professional Engineers are:

- PS1: Design
- PS2: Design review
- PS4: Construction review

To provide quality professional services, Chartered Professional Engineers must have sound technical knowledge and understanding of the regulatory environment in which they work. They must understand the limits of their own skill, experience, and expertise. Successful engineering projects often cross disciplines, requiring the input of other disciplines to ensure a robust design. They also require the input of non-engineers, including planners, architects, surveyors, and builders.

Regulation

The Building Act 2004 and the Building Code set out rules and performance standards for the building system. The Building Code's Verification Method B1/VM1 defines work that requires an engineer with "relevant experience and skills in structural engineering" and states "a structural engineer who is chartered under the Chartered Professional Engineers of New Zealand Act 2002 would satisfy this requirement". Chartered Professional Engineer registration is therefore used across the building system to provide assurance of an engineer's experience and skills.

Other parties in the building system

Engineering consultancies

As employers of engineers and as parties liable for building design failures, engineering consultancies play an active role in the quality assurance landscape within the building system. Some large consultancies use ISO9001 Quality Management Systems standard or equivalent to demonstrate compliance with international standards for quality management systems. Consultancies that do not use ISO9001 have other quality processes and procedures in place. Members of ACE New Zealand commit to having quality assurance processes in place and are provided with guidance. Although industry works to drive, and support, the wide use of quality assurance processes, compliance to ISO9001, or any other standard is not regulated. By contrast, other industries have mandated quality system requirements or regulations for companies operating in the sector (for example aviation and high voltage electrical).

Design quality assurance can be achieved in many ways. Key components of ISO9001 are engagement, customer focus, leadership, process approach, improvement, evidenced-based decision making, and relationship management. There are many ways for these components to be achieved within firms. As we will highlight in this report, internal checking systems are a critical component of quality.

Building Consent Authorities

BCAs make decisions daily on whether building plans and building work comply with the Building Code. They also manage the regulatory enforcement of the building system. As such, BCAs carry a significant amount of liability for building consents issued.

As part of managing liability, BCAs rely on qualified professionals to ensure design and construction work complies with the Building Code before consent is issued. Although producer statements are not required by the Building Act and have no legal standing, they are used as a proxy by BCAs that designs are compliant when signed by a Chartered Professional Engineer. Producer statements introduce a measure of quality assurance, particularly if the design review (PS2) is carried out appropriately. However, BCAs have no way of knowing the degree of quality assurance that sits behind a PS1 Design producer statement, nor the depth and rigour behind a PS2 Design Review producer statement beyond what is visible in the review log.

Central Government

MBIE provides regulatory oversight of the building system. This includes setting performance expectations of the system through both the Building Code and compliance documents, including standards. These expectations drive behaviour. Absence of suitable performance expectations contributes to poor outcomes.

MBIE is also required to monitor outcomes. Responding to poor outcomes is important for ensuring continuous improvement in the building system.

WHAT ARE THE CAUSES OF QUALITY ISSUES IN THE BUILDING SYSTEM?

Each structural engineering design issue highlighted in this report involved at least one Chartered Professional Engineer and quality assurance processes that were unsuccessful at mitigating issues. In this section, we explore how mistakes enter and transfer through the system. To do this we explore the role of the individual engineer and quality assurance processes, as well as compounding system pressures and issues.

Limitations of the Chartered Professional Engineer system

Chartered Professional Engineers typically possess the following:

- a recognised degree in engineering or demonstrated equivalent knowledge
- 4-6 years of professional experience before applying for registration
- an assessment of competency administered by the Registration Authority (Engineering New Zealand).

In part, the construction industry's working assumption is that the three points above are sufficient to ensure quality work. However, as the case studies in this report show, this assumption is not always correct. Some engineers are not meeting expectations because of a mixture of one or more of the following:

- lack of competence – engineers either have poor overall competency, fail to maintain their competence and/or practise outside of their competency;
- negligence – engineers fail to meet duty of care requirements and/or fail to perform their duties with appropriate knowledge, care and skill; or
- human error.

Lack of competence

Competence refers to the knowledge, skills and attributes required for a person to undertake their work successfully. Different activities, roles and projects require different competencies.

There are three components to competency concerns. The first is overall competency. High-quality education and training lift the skills and competency of the professional and mitigate the risk of poor performance. How engineers are trained impacts on individual performance.[6]

The second is maintaining current competency. Chartered Professional Engineers are expected to complete a minimum of 40 hours of continuing professional development (CPD) annually. To practice competently, ongoing learning and development is critical for professionals to remain current and competent. As well as advances in technical knowledge, engineers must also respond to the evolving needs of society, business and changing legislative frameworks. Without ongoing development and maintenance of competency, avoidable errors can arise. This is apparent in one of our case studies in this report: Southland Stadium.

The final component to competency is practicing within the scope of your competency. This requires an engineer to be clear on the scope of their own competency. They must be aware of the limits of their knowledge, skills, and attributes. Information on an engineer's current or past performance sets an expectation of future performance.[7] Knowing (or recognising) the bounds of one's competence is an important component in the successful performance of an activity or task.

Some common technical structural design stage errors seen in the examples of building issues highlighted in this report are:

- poor application of basic engineering principles in design;
- not applying additional verification methodology requirements to designs; and
- not fully understanding the principles of capacity design and the associated detailing requirements.

Negligence

As in every profession, a small minority of engineers do not discharge their duties with appropriate care and skill. This may amount to negligence. Because much of the work of engineers has the potential to be high risk, the consequences of negligent performance can be severe. An engineer's duty of care is to understand their legal and ethical obligations and to discharge their duty in adherence with these obligations.

Human error

Even the most competent professional makes mistakes. Human error is expected in all systems, which is why quality assurance and quality control processes are crucial.

Regulators are relying on Chartered Professional Engineer registration to manage risk

The building system has come to use Chartered Professional Engineer registration as a proxy for determining whether an engineer is competent to carry out independent engineering design, design review, or construction monitoring work. Where this has failed, some BCAs have moved to have their own register of recognised engineers.

Under the Chartered Professional Engineers of New Zealand Act 2002, the Registration Authority (Engineering New Zealand) has managed the registration system. To be registered, an engineer must demonstrate a level of general competence within a self-selected practice area at a particular time. The work of Chartered Professional Engineers is not audited nor is it reviewed by the Registration Authority outside of standard reassessments or in situations where a concern or complaint is raised.

There is a mismatch between industry expectations of Chartered Professional Engineers and the design of the Chartered Professional Engineer registration system. The Act provides for the protection of a title, while industry looks for assurance of competency to carry out specific work. Accordingly, the Chartered Professional Engineer registration system is not providing the building system with a reliable assurance of competency.

The Canterbury Earthquakes Royal Commission highlighted the need for specificity of registration, particularly for structural engineers.[8] Currently a Chartered Professional Engineer self-selects practice area description and practice fields. These are often misinterpreted as scopes of practice, but there is nothing, apart from ethical obligations on engineers to practise within their scope of competency, to stop a Chartered Professional Engineer from signing off work in other fields. To date, neither MBIE or the Registration Authority have fully introduced a recognised structural engineer register nor fully integrated the SESOC Body of Knowledge and Skills[9] into the CPEng assessment process. This said, more recently we have introduced further registration requirements for those within the structural practice area.

The mismatch between the current Chartered Professional Engineer system and industry's expectations highlights that further work is needed by the Registration Authority to work with regulators to manage risk, within the scope of the current regulatory framework, and advance of new legislation regulating engineers. For many years Engineering New Zealand has been advocating for legislative change to the way engineers are regulated, to support improved outcomes for the public.[10]

Review processes are not always robust

The buildings highlighted in this report vary in complexity. However, in each of the cases highlighted, review processes failed. In some cases, there was no review. In others, reviewers failed to pick up technical errors. In one, concerns were raised by peer reviewers but were not fully addressed by the design engineer.

Across both the internal checks carried out by companies and peer reviews of PS2 (Design Reviews), there is evidence of inadequate reviews. We have no indication that effective, independent reviews were carried out at the concept stage, a critical opportunity to check design assumptions. We also observe PS2 peer reviewers signing off work before confirming design changes have been made. That peer reviewers are missing fundamental design issues (such as load paths and capacity design requirements) in the final drawings is a significant concern.

In this report we discuss two types of review – internal checks and PS2 peer reviews. Both forms of review are independent of the designer (ie, they are a fresh perspective). No professional is immune from making mistakes. Independent reviews (both internal and external) are critical to catching errors.

Our observation is that peer reviews are frequently commissioned towards the completion of design work. This is not good practice. Peer reviewers should be engaged early, while the work is in progress, as noted in Engineering New Zealand's Practice Note 2[11]:

When peer reviewers are engaged early in larger and more complex projects, the peer review's value is significantly increased. Peer reviewers can have input at specified points, while the work is in progress. If peer reviewers pick up potential issues early in the project, these can be addressed and potentially save significant re-engineering later on.

"Race to the bottom"

Engineers and engineering consultancies work in competitive environments. Clients, including Government clients, often look to tender for the lowest price, to achieve a perception of value for money. Competition is, very often, at odds with quality outcomes when applied solely on the basis of lowest price tendering.

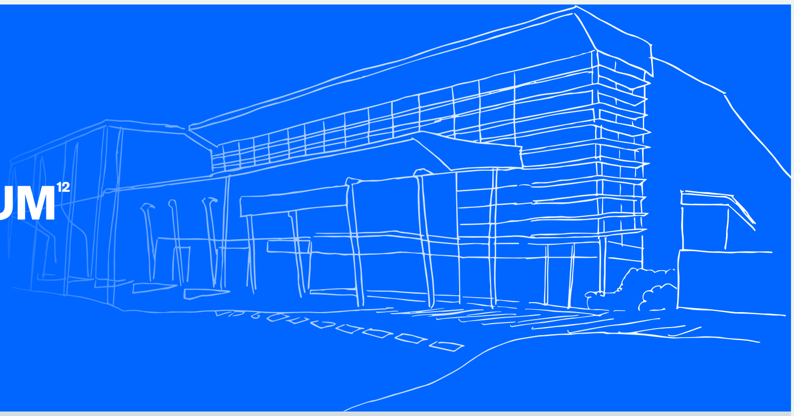
This is described by the industry as a "race to the bottom". At its worst, this race undercuts costs and impacts on quality because it leaves engineers without the resources to do work correctly. At best, this race may lead to lower initial costs to clients, but with lingering risk that appropriate quality outcomes may not always be achieved.

In this environment, the value of pricing projects accurately to allow for appropriate quality assurance steps is critical. Transparency with clients, including documentation of costing decisions made, is essential. The profession must actively educate clients on the impact of driving costs down, as this has potential impact on the quality of work.

Likewise, clients have an obligation to recognise risks associated with low-cost tendering approaches, to understand reasonable cost to undertake work with an appropriate level of quality assurance and to avoid "race to the bottom" behaviours. Competition, improved efficiency and innovation should be encouraged, while recognising that such outcomes often require investment in research, development and training to be realised.

CASE STUDIES

CASE STUDY 1
SOUTHLAND STADIUM[12]



Engineer working beyond competence and a lack of peer review

Invercargill's Southland Stadium had two large interlinked spaces comprising of community, event and court areas. These had roof trusses with clear spans over the two spaces. Construction took place between 1999 and 2000, during which time excessive deflections occurred in the roof trusses above the community courts area. To address these deflections, modifications had to be made late into construction.

Ten years later, on 18 September 2010, the roof structures over the main area of the stadium collapsed after heavy snow. Fortunately no one was killed or injured.

Key technical failings

Design modifications to reduce the steel quantities in some of the community courts' trusses were made to the structure during construction. However, an error in the calculation of the loadings used meant late-stage design changes were required to address problems that included:

- excessive deflections of the roof trusses
- the low design capacity of the community courts trusses
- inadequate column head connections.

The modified design was compliant in terms of design for strength but susceptible to progressive collapse due to:

- site splices in the community courts trusses at the most highly loaded mid-span location
- design modifications resulting in simply supported trusses over the community courts, reducing redundancy
- fragility of the connections of the community courts trusses to the south wall concrete columns.[13]

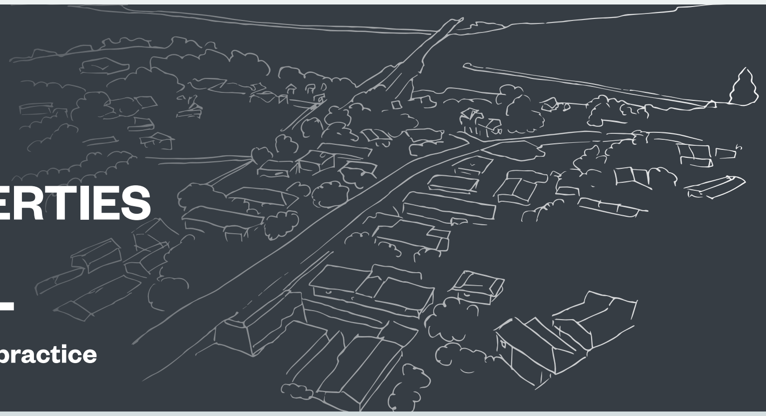
Quality assurance issues

There was no external peer review of engineering design work completed. Instead, the design engineer checked his own drawings and undertook all construction monitoring activities.

Construction defects were found to be critical in weakening the structure that would have otherwise been able to support the snow loads of 18 September 2010. Many, but not all, of these defects were associated with execution of design changes during construction.

The deficiencies identified above should have been picked up in the construction monitoring stage of the project. Deficiencies were not identified and corrected.

CASE STUDY 2
RESIDENTIAL PROPERTIES IN TAURANGA[14]



Lack of rigour and attention to quality practice

Between 2015 and 2016, a Chartered Professional Engineer sole practitioner was involved in the engineering design and construction monitoring work for numerous residential properties in a residential subdivision. Most design work involved either retaining walls or foundation designs. The Tauranga City Council raised concern with Engineering New Zealand, for both the design and construction monitoring work completed.

An Engineering New Zealand Disciplinary Committee found the engineer "exhibited a concerning pattern of poor and unacceptable practice over a long period of time. He did not provide sufficient information with his PS1s and PS4s... [and] did not respond to the Council in a meaningful way, nor change his record keeping practices when advised by the Council that his site inspection records were insufficient to achieve CCC [Code Compliance Certificate]."

Key technical failings

A technical reviewer found the engineer:

- signed and submitted Producer Statements – Design (PS1) without supplying sufficient supporting information
- signed and submitted Producer Statements – Construction (PS4) for building work that did not comply with the relevant requirements of the issued building consent and/or without supplying sufficient information
- provided engineering services that did not meet a reasonable standard, including applying incorrect design assumptions, failing to apply relevant standards, and submitting standard drawings that were inappropriate for the specific site.

Quality assurance issues

The technical reviewer observed "frequent and common errors, many of which in turn demonstrate a lack of checking and over reliance on personal judgement rather than specific investigation. Particularly there seems to be a willingness to sign off on construction standards that clearly are inadequate."

Further, the engineer frequently behaved unprofessionally to those involved in the wider quality assurance process, such as Council staff.

CASE STUDY 3

230 HIGH STREET, CHRISTCHURCH[15]

Inadequate designer competence and neglected peer review feedback.

230 High Street is an eight-storey steel framed building in Christchurch facing onto a busy shopping and pedestrian precinct. It was intended to house retail on the ground floor, offices on the next five floors, and residential premises on the top two floors. Its design and construction was consented in three stages:

1. Stage 1: Foundation, concrete slab and services under the slab
2. Stage 2: Steel superstructure only, excluding foundations
3. Stage 3: Building envelope and building services.

The engineer involved was engaged to complete the superstructure's design in 2015–16. A building consent for this stage was granted in August 2016, with amendments in February 2017 and March 2018.

In November 2017, during construction, an engineer from a different consulting firm observed several issues visible from the street. Those concerns were subsequently referred to the Christchurch City Council ("the Council"). In May 2018, the building owner applied to the Council for a code compliance certificate for stage two, but the application was rejected. A review found the structure did not appear to conform with the Building Code in several areas and the Council applied for a determination by MBIE, which found the design to be non-compliant.

Key technical failings

The expert reviewer engaged in the MBIE determination found 13 concerns ranging from issues with pile capacity to issues with the calculations of seismic loads (torsional stability). Of the 13 items identified, 10 were not in accordance with B1/VM1.[16]

Quality assurance issues

The design engineer commissioned two peer reviewers to review his building design work. These reviewers noted several issues that needed to be addressed for the superstructure to be adequate. Although the reviewing engineers signed PS2s, the design engineer did not resolve all the issues raised in the amended design. However, the designs were accepted by the Council in reliance on the signed PS2s.

Issues identified by the peer reviewers were not resolved by the engineer. Furthermore, fundamental design changes were made during construction without review.

In June 2018, the peer reviewers contacted the Council to advise that they had concerns their Producer Statement documents did not cover the building as it was constructed and that outstanding issues in their original documents had not been addressed by the engineer.

CASE STUDY 4
MASTERTON BUILDINGS[17]

Chartered Professional Engineer negligence and poor internal checking processes

In 2015, concern was raised with Engineering New Zealand about the structural integrity of six commercial buildings owned by the Masterton Trust Lands Trust.

Five of these were signed off by a Chartered Professional Engineer (both owner and principal of a firm) before building consents were obtained through the Masterton District Council. The engineer had not undertaken the design work himself but had reviewed the work and signed off on the buildings in question. The Council engaged a third party to undertake a screening review of the designs before building consent was granted for four of the five buildings. Consents were granted following the review.

Post-construction reviews found the buildings failed to comply with relevant structural standards at the time of design.

Key technical failings

Design structural vulnerabilities included issues with transom supports and methods of connection, portal frame design, poor design calculations that did not consider eccentricities required by the loading standard, roof bracing issues and unclear load paths, no fly braces and little restraint for the rafters and beams, among others.

Construction issues were also observed.

Quality assurance issues

In each case, producer statements were signed for designs which, upon review by third parties, were found to be structurally inadequate.

The principal's reviews of the designs were high-level, and he generally relied on the work of senior engineers. He did not know the extent of the checks that had been carried out on the designs for which he signed the PS1s. There is no evidence that the checking process was documented. Due to the reasonably non-complex nature of the projects, and reassurance gained through the Council's external screening review process, the designs were not subjected to a formal peer review which may have identified the flaws.

ROOT CAUSES OF QUALITY ISSUES

As observed in the cases outlined, root causes of design quality issues are complex. In addition to individual competence, both regulatory and industry settings play a role in quality issues. Examples outlined in this report feature a lack of individual competence or negligence through the introduction of structural design errors, many of these due to a lack of thoroughness. These issues were then not picked up by the design reviewer, industry or by regulatory processes in place. In one case, appropriate changes were not implemented.

Figure 2 highlights potential causes of failure. This diagram moves above the performance of the individual to the complex environment in which that individual works, outlining the current industry settings and regulatory settings that lead to quality issues.

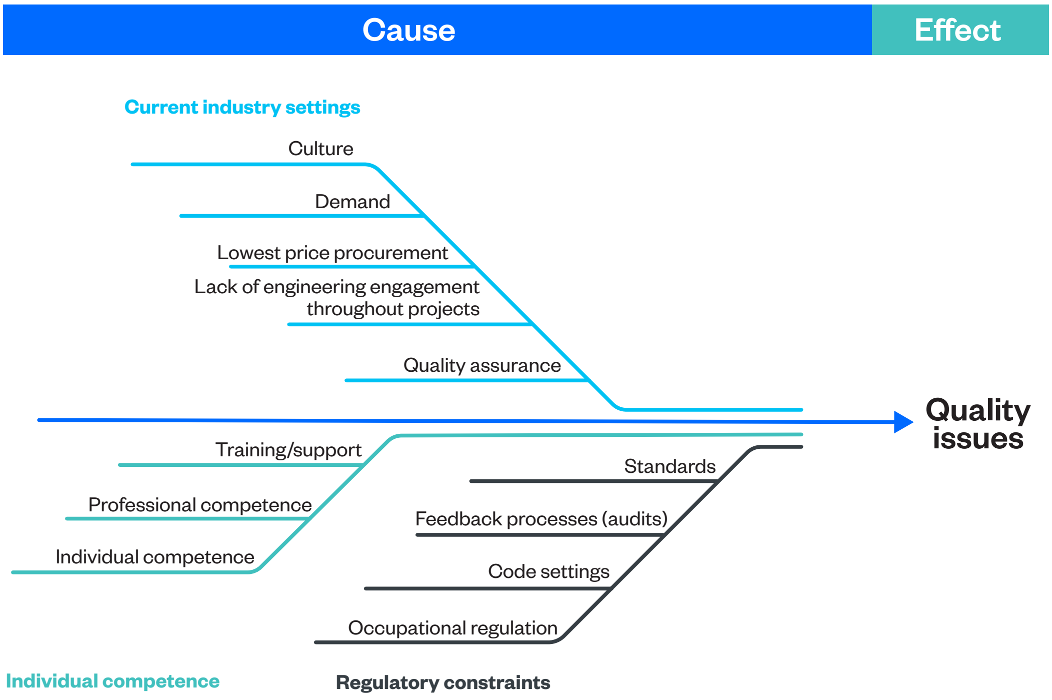


Figure 2: Risks leading to deficient buildings within the New Zealand building system

For brevity, we will not go into descriptions of each cause and the reasons for its inclusion in Figure 2. Instead, we highlight our concern that wider system quality assurance processes are not always preventing significant quality issues. Wherever possible, we must address concerns with individual performance, but equally important is addressing wider system issues that mitigate the risk of poor performance.

To summarise, four component parts of the building system address quality assurance issues:

1. **Professional regulation** – Regulatory bodies are responsible for addressing the risk of poor individual performance by setting and maintaining standards for registration and holding registrants to account for poor performance.
2. **Engineering companies** – Internal checking systems within engineering companies are responsible for catching errors in the early stages of design. The examples in this report are from small- to medium-sized firms, but quality control processes in bigger firms can sometimes also fail.
3. **BCAs** – Each engineering design issue highlighted in this report was consented by a BCA. BCAs carry significant liability in the building system and each BCA manages this risk differently. Some BCAs require the majority of designs consented to have a PS2 review. Others do not require these for 'low risk' residential or commercial designs. Few BCAs have engineering staff involved in consent processing. This means that some buildings are consented without any form of technical review.

   At the time of writing, New Zealand had 69 BCAs. Like firms, there is no standardisation of quality assurance. Although BCAs work together to address risk, many have variable processes.

4. **Central Government** – MBIE has a role in monitoring and managing the performance of the building system. Where there are known issues, MBIE has a duty to address these issues in its capacity as regulator.

The system is not always addressing potential causes of inadequate design

Quality issues happen when the system does not address potential causes of inadequate design. In the case of the building system, this is when quality assurance processes, education and training, procurement terms and conditions, occupational regulation systems, BCA processes, and system feedback mechanisms (reviews and audits) are not catching and addressing issues. When compounded, weaknesses across the system may lead to failures.

Engineers often refer to the Swiss cheese model of accident causation. The model outlines how risks can lead to failures. When situations go wrong (for example an engineer makes a technical error), this error will become a failure if there are no preventative barriers in place (for example, robust and effective quality assurance measures).

Many of the root causes outlined above are within the control of individuals, their firms, Engineering New Zealand, industry, and the central regulator to change. As the professional body for engineers and the regulator, Engineering New Zealand has a role to play in strengthening the system to prevent failure.

WHAT DOES GOOD LOOK LIKE?

For the engineering profession, within the current system, we must focus on continual improvement within those parts of the system we control – individual performance, quality assurance processes and the Chartered Professional Engineer system.

Individual performance

As discussed above, individual engineers must both maintain their competency and practise within the scope of their competency. Maintaining competency and practising within the appropriate scope of competency provides greater confidence that unintended errors will not enter designs.

Initial training

An engineer applying to become a Chartered Professional Engineer must have a four-year engineering degree or equivalency. Structural engineers in New Zealand qualify as civil engineers. These engineers then go on to develop their structural engineering expertise throughout their professional careers, gaining on-the-job-training. Applicants for registration as a Chartered Professional Engineer are encouraged to have at least four to six years of experience before applying for registration.

Maintaining competency

Chartered Professional Engineers are expected to do at least 40 hours of CPD per year. Good CPD is a mix of technical training (practice area specific technical training, conferences and/or involvement in technical groups, forums, etc), professionalism training (ethics, cultural competency, etc), business/leadership training, and health and safety training. As the Registration Authority for Chartered Professional Engineers, Engineering New Zealand has guidance for registrants that includes information on CPD expectations.[18]

Practising within the scope of competency

The Chartered Professional Engineer mark relies heavily on engineers understanding and staying within the bounds of their competency. Engineering New Zealand's Code of Ethical Conduct requires engineers to only undertake engineering activities that are within the bounds of their competency.[19] If engineers act outside the bounds of their competency, they are in breach of their obligations under the Code of Ethical Conduct and may be disciplined.

The Dunning-Kruger effect occurs when a person's lack of knowledge and skills in a certain area cause them to overestimate their own competence. Our own self-assessments of competence are subjective. We need the input of others to review our work and provide assurance that it reaches expected standards[20]

Engineering New Zealand has published guidance for engineers entitled *Understanding the bounds of your competence*.[21] All practising engineers should be familiar with the concepts outlined in this guidance and apply these concepts to their practice. Furthermore, engineers should take note of success factors identified in Figure 3 of this report (page 23).

Organisational performance

Engineering firms have a responsibility to ensure quality assurance systems are in place to provide appropriate review of engineering designs. Quality assurance systems and review detail will vary depending on the scale of the business and the size and complexity of the project being undertaken. However, appropriate design review is critical to catch errors where they occur. Design reviews provide checks of ongoing competence and currency with best practice, as well as ensuring systemic errors do not perpetuate. For smaller business entities or sole traders, collaboration with similar businesses may be necessary to ensure ongoing independent review is achieved. In certain circumstances, third party peer review (and provision of PS2 documentation) may be warranted, and forms an additional level of review and independence, over and above that undertaken internally and to satisfy reasonable organisational performance expectations.

Peer review processes

The cases outlined in this report highlight the critical importance of peer reviews being done well, where they are necessary. Peer reviews need to be robust, thorough, and undertaken by sufficiently experienced engineers. To work well, peer review needs to be an open and collaborative process between the designer and the reviewer. We are aware of many engineers who no longer undertake peer reviews after experiencing negative and combative responses from design engineers when they raised concerns or asked for further clarification.

Liability is another reason some engineers are reluctant to accept engagement as a peer reviewer. If a court upholds a claim against a design engineer, a peer reviewer of the design may also be liable for damages. Reviewing engineers should be aware both of their ethical obligations and their contractual obligations, as well as their potential liability, when reviewing design work.

Engineering New Zealand has a practice note for peer review.[22] SESOC also has a guidance note for structural engineering reviews that clearly details the responsibilities and expectations of the designer and reviewer.[23] All structural engineers should be conversant with both documents and follow them when conducting a peer review.

In addition to advice outlined in Engineering New Zealand's practice note and SESOC's guidance note, we recommend reviewing engineers utilise the key quality success factors for the stages of building design shown in Figure 3. It is our view that reviewing engineers should be engaged in review processes early, when required, and that greater focus should be given to validating structural systems at the end of the preliminary design phase. Figure 3 is simple and formulaic, intended to drive the designer and reviewer to consider their role at each stage.

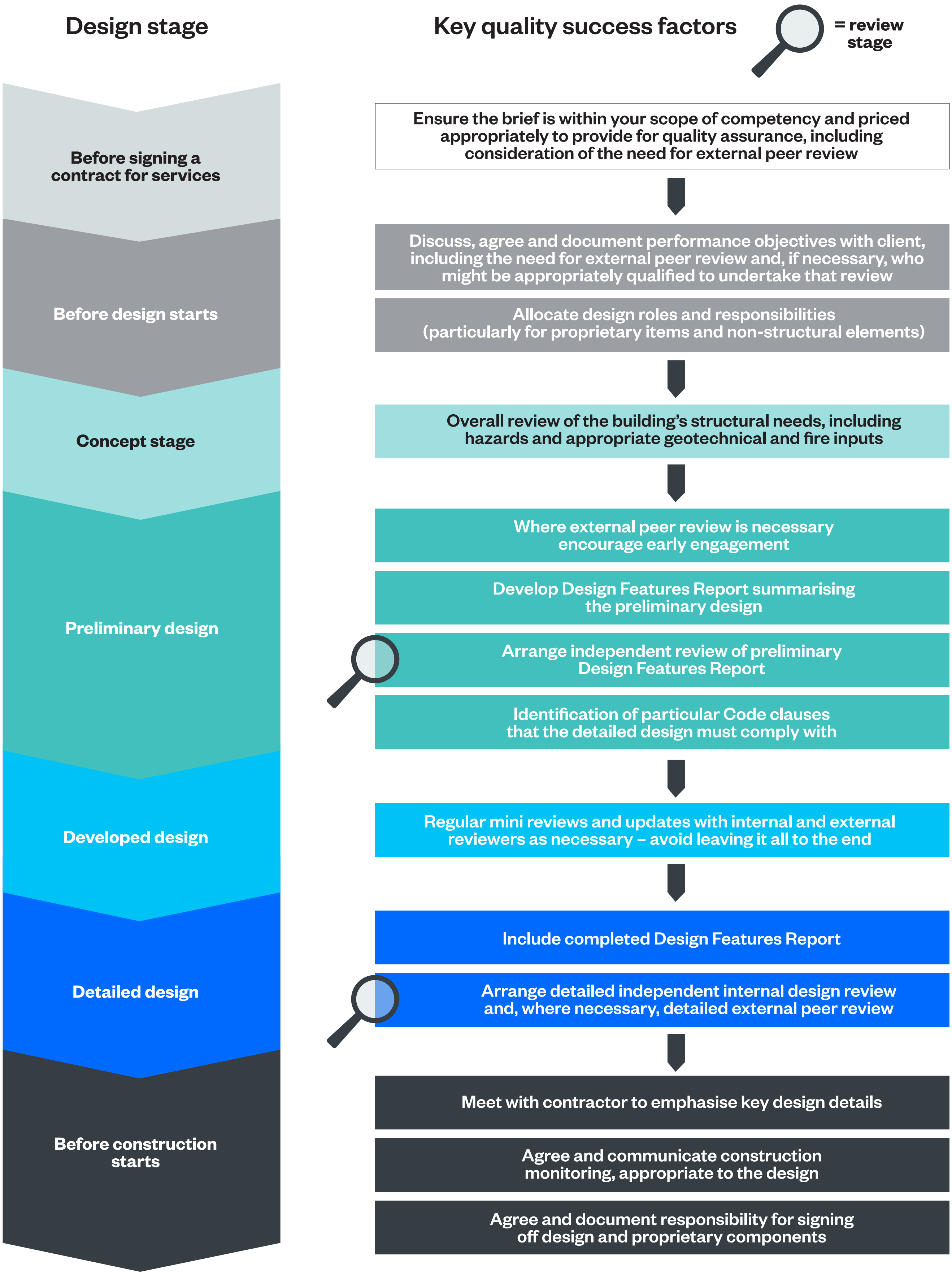


Figure 3: Key quality success factors for the stages of building design

Early design phase

During the project establishment and early design phase, engineers need to consider how the critical structural design aspects may work in conjunction with the client's brief, documenting and confirming performance outcomes required. Projects also need to be priced to provide for quality assurance steps.

For complex buildings or buildings where BCAs require a PS2, engineers are strongly encouraged to engage an independent reviewer during the preliminary design stage. PS2 reviewers should be involved early, rather than at the end of detailed design phase. Involving an independent reviewer in the preliminary design phase is of benefit to all parties.

For less complex buildings, engineers should engage with another engineer within their company or outside to undertake reviews. This is particularly important for sole practitioners working without the benefit of collegial reviews. Design engineers should not assume their designs will be technically reviewed by the BCA in the consenting process.

At the preliminary design stage, reviewing engineers should question key aspects of the structural system, including:

1. Design philosophy, including capacity design approach – is this documented?
2. Load paths – are they clear and appropriate?
3. Seismic lateral load – is the basis clear?
4. Regularity – is the regularity of the structure clearly understood?
5. Separations – are separations in the primary structure with adjacent buildings provided where they need to be and are they of adequate size?

Completion of the preliminary design phase should include a sign-off of the structural system. This sign-off should include validation of key aspects such as those listed above (#1-3). After reviewing the preliminary design, reviewing engineers should also ensure that key aspects of the detailed design pathway are updated, including:

- Detailing objectives – are detailing objectives understood? (eg capacity design principles)
- Detailing requirements – are detailing requirements understood? (eg specific overstrength provisions)
- Rationale – is the rationale for deriving the overstrength loads for columns and foundations understood?

Engineers are encouraged to produce a brief initial version of the design features report. Engineering New Zealand has an example of the design features report available for engineers to download.[24]

Management of the Chartered Professional Engineer system

Industry relies on the Chartered Professional Engineer mark to provide confidence of an engineer's competency. As the Registration Authority for Chartered Professional Engineers, Engineering New Zealand must ensure its processes are rigorous and provide assurance that registrants are appropriately qualified and competent to be registered and maintain registration.

The Chartered Professional Engineer system was established as a voluntary, competency-assessed quality mark for professional engineers. However, in the absence of mandatory professional regulation, the Chartered Professional Engineer system is being forced to play a role in the building system it was not designed for.

Although Government has signalled changes to the occupational regulation of engineers, any changes will be some years away.[25] In the interim, we must continue to strengthen our regulatory processes and procedures. The profession, industry and public need a registration system that is credible and fit-for-purpose, and that appropriately assesses the technical competency and professionalism of Chartered Professional Engineers. We must also hold engineers to account, when necessary.

Since 2020, Engineering New Zealand has focused on strengthening its role as regulator. We have separated governance of the Registration Authority from the Engineering New Zealand Governing Board, we have undertaken an end-to-end review of the system and implemented changes across all our assessment processes. We will soon implement a further set of changes across our complaints and disciplinary system. Our goal is to address public risk across all parts of the system we administer, within the scope of the current Act and Rules.

We are now inviting more feedback from industry on the performance of engineers through disclosure processes,[26] we are working with BCAs to clarify their expectations of the system, and we are strengthening our system to match these expectations wherever we can. Finally, we are working with technical groups on the use of technical Bodies of Knowledge and Skills in the system.

CONCLUSIONS

This report outlines how the building system has come to rely heavily on Chartered Professional Engineer registration to manage risk. The signature of Chartered Professional Engineers on Producer Statements is one of the most significant quality assurance processes used across the system. However, this signature does not necessarily speak to the level of technical rigour or review that has been applied to the design.

This also points to a broader concern because an individual engineer is only one part of the system. Although the individual's role is critically important and we need to regulate the individual appropriately, we also need the building system to address wider risks of poor-quality outcomes. Our system is not always catching mistakes and we must do better.

No professional, regardless of skill, should operate without appropriate quality assurance processes. Humans are fallible and often blind to their own errors and limits. Without appropriate quality checks and balances, outcomes will always be varied. Even if Chartered Professional Engineer registration were to provide assurance of an individual engineer's competence to the standard demanded of industry, that person may still make mistakes, which the system must be able to recognise and address.

Next steps

Engineering New Zealand will work with the profession to support better individual performance and quality assurance processes (particularly peer review processes). We are also committed to improving the Chartered Professional Engineer system and to supporting engineers within the building system. To do this we will:

1. Support BCAs in their role consenting engineering design work, specifically by discussing how Engineering New Zealand as the Registration Authority can help manage risk and support BCAs to ensure quality outcomes
2. Work with ACE New Zealand to support its work on improving the robustness of quality assurance processes in New Zealand's engineering firms
3. Advocate for wider building system reform to provide a greater focus on quality
4. Strengthen the technical and professional support provided to engineers, including:
   - 4.1. design review expectations and ethical obligations
   - 4.2. clearer guidance and greater monitoring of continued professional development requirements
5. Strengthen the way engineers are regulated. This involves:
   - 5.1. Continuing to address current concerns with the Chartered Professional Engineer system so that the registration and re-registration of Chartered Professional Engineers provides clarity to industry that these engineers have been appropriately assessed, within the scope of the current Act and Rules
   - 5.2. Supporting the development of an improved occupational regulation system that provides assurance to the public, industry, government, and profession that those undertaking engineering services are appropriately registered and that engineers involved in high risk work are appropriately assessed as being competent to perform this work.

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