Improving Collaboration Between Architects and Engineers

The Canterbury earthquakes and the more recent Wellington earthquake have led to a professional rethink about the way architects and engineers work together. The clear lesson to emerge is that architects and engineers need to collaborate better in the early stages of building projects. An architect designing a building and then saying to an engineer: "Now make it work", isn't good enough, and risks mediocrity or worse. At the extreme, if the collaboration between architect and engineer is poor, the results can be dangerous.

In its report, the Canterbury Earthquakes Royal Commission said: "A structural Chartered Professional Engineer should be engaged at the same time as the architect for the design of a complex building." [1]

The Institution of Professional Engineers New Zealand, the New Zealand Institute of Architects, and the New Zealand Registered Architects Board, supported by the Ministry of Business, Innovation and Employment, have together prepared this publication. In their collective view, the Canterbury Earthquakes Royal Commission's statement, cited above, is correct. A change in professional thinking is required, so that both architects and engineers better understand how, in the design of complex buildings, they need to work together from the beginning to maximise the contribution that both professions bring to the design process.

While arising primarily from the Canterbury Earthquakes and addressed specifically to architects and structural engineers, this topic is just as relevant to other engineers.

This document responds to the following Canterbury Earthquakes Royal Commission recommendations:

163	A structural Chartered Professional Engineer should be engaged at the same time as the architect for the design of a complex building.
185	The Institution of Professional Engineers New Zealand, the New Zealand Institute of Architects, and the New Zealand Registered Architects Board, supported by the Ministry of Business, Innovation and Employment, should work together to ensure greater collaboration and information sharing between architects and structural engineers.[1]

What is collaboration?

Most building projects demand that architects and engineers communicate and work together. This is necessary to:

- meet the clients' requirements
- comply with relevant standards
- achieve design coherence and then a high performance, safe building.

Collaboration involves the design disciplines working together, sharing knowledge, learning from each other, and, by that, designing a building informed by professional inputs and consensus. Collaboration acknowledges the process of design development. It depends on analysis of problems and an iterative feedback of design solutions and options to and from the entire design team, so that collective decisions are made at each stage. This requires a methodology of presentation and discussion where the logic of design decisions is explained and serious discussion takes place. For participants, it means being a party to iterative design and contributing their professional expertise and judgement to keep the project moving forward. Collaboration also means acknowledging that elements may change and design development is not only inevitable, but desirable.

The key to successful interdisciplinary collaboration is in understanding that it is not a technology but rather a psychology. Collaboration is not a process that can be codified into a set system; it is more of an attitude that needs to be inculcated in the culture of a firm. It begins with every participant acknowledging that each of the others brings something valuable to the project and that their combined intelligence is more likely to deliver positive results than working in isolated silos. This can be challenging for architects, since a culture of pride in individual authorship is deeply ingrained in the profession [2].

Is collaboration a problem?

At first glance, the collaboration described above may seem unrealistic. A design team may include members with different professional objectives and different approaches to the design process. Getting differing design perspectives to converge to achieve a satisfactory outcome for all team members, the client and those who experience the building during its lifetime can be difficult.

Architects and engineers have different design foci and methods. For example, architects are responsible for *many* aspects of design. They seek to meet clients' expectations given the necessities of complex sites and client briefs. They must satisfy both functional and aesthetic expectations, and as such may want to avoid the potential blandness of symmetry, regularity and right angles, despite these being sought-after structural characteristics. By contrast, engineers are more narrowly focused and prefer a linear design approach in their quest for safe, economical and code-complying structures. Many architects aspire to create a sense of lightness of building elements, whereas engineers typically focus on 'grounding', providing force paths from superstructure to foundations.

These differences reflect contrasting styles of professional education. Architects adopt an iterative process in attempts to synthesise large numbers of design requirements. This is like trying to complete a jigsaw puzzle with no single right or wrong outcome. Architects design and then rework their efforts again and again, until all aspects are resolved. Engineers also iterate to some extent, such as when an engineering concept is found to be wanting later in the project. However, in general, engineers focus on specific problems and seek the "technically correct" solution that delivers structural integrity efficiently.

A cultural shift is required for both engineers and architects. Engineers need to adapt positively to architects' iterative design approaches, while architects, drawing upon engineers' specialist expertise, must understand structural principles and incorporate core engineering requirements into their design imagination.

Both need to set aside preconceived professional attitudes and replace them with cooperative lateral thinking and interdisciplinary engagement.

How does collaboration work?

To satisfy diverse design objectives, collaboration requires considerable skill and commitment. It is the responsibility of the lead consultant to keep dialogue and design explorations progressing until critical consensus decisions, like agreeing on the final structural configuration, are made. Every team member must be encouraged to contribute, share responsibility, and be satisfied that the chosen solution is best for the project and meets their professional standards.

Collaboration requires the right mix of skills. Before beginning, the lead consultant must review the professional experience and expertise of the design team members. Given the architectural and structural complexity of the project, they must be suitably equipped to provide the required quality of advice and design expertise. Each team member must be an expert in his or her field.

Importance of collaboration

Successful collaboration can bring much more to a project than just facilitating its design and completion. The client and the users of a building are the primary beneficiaries of architect-engineer collaboration, but architects and engineers themselves benefit greatly.

Successful collaboration results in the following benefits which are illustrated by brief examples.

Benefits	Examples
Seismic performance	Optimal seismic performance is achieved through structural solutions which maintain architectural objectives but also make sure structural performance is uncompromised by configuration irregularities such as a soft-storeys or large torsional eccentricities.
Cost-effectiveness	A structurally-refined column layout allows for an economic floor system as well as cost-effective beams and foundation design.
Certainty	Minimising re-work gives confidence to maintain the momentum of the design development progress.
Innovation	Improved design and construction systems and approaches challenge professionals to understand and embrace other points of view and push the boundaries of their own fields.
Integration quality	Functional and aesthetic goals are better met when there is a seamless meshing of structural layout and services components with architectural planning requirements.
Satisfaction and professional development	Design team members widen their perspectives and approaches to design, and, as a result acquire new knowledge and develop new skills whilst enjoying working together efficiently and harmoniously. They share ideas and problem-solve together so that the input of each profession overlaps.

Timing of collaboration

Experience shows that for collaboration between architects and engineers, “earlier is better”! This is especially true at the conceptual stage of a project where critical project-shaping decisions can be made easily, compared to being much more difficult, costly, and inefficient later in the project. Comments are made below regarding collaboration at each design stage.

Project stage	Comments
Pre-design	Geotechnical input is required and reports from other engineering disciplines regarding traffic or existing services may be needed. This may affect early design decisions, including the location of a building on a site.
Concept	Especially at this stage of design, architects should share their design aspirations with the design team and obtain advice regarding engineering systems during their design iterations. These include structural systems to resist earthquake forces, sustainable engineering strategies and geotechnical options. Decisions made at this stage provide the conceptual framework for future design development but may need to be revisited later as the design develops. The ramifications of these early decisions profoundly affect the success of a project as measured by many factors. These include cost, day-to-day functioning and disaster performance in a fire or earthquake. Only the most experienced engineers possess the necessary expertise to advise at this stage. A high level of engineering judgement is needed to maintain core engineering requirements yet accept compromise in less critical areas. In some cases, a brief conversation between architect and engineer may be sufficient to ensure the implementation of sound engineering strategies that can be developed in later phases. However, for more complex projects there could be many design iterations. For seismic retrofitting and other projects where the engineer is the lead consultant, architectural advice should be sought.
Preliminary	During this phase, decisions made earlier are reviewed and given more extensive consideration to the extent they can be communicated approximately on drawings; first to indicate how engineering systems can be integrated, and secondly to show how these systems support the primary architectural objectives. This phase and those following require an increasing degree of coordination between architectural and engineering documentation.
Developed	When further refinement of engineering systems occurs, member, spatial and mechanical component dimensions are more accurately sized to correspond with increasing architectural resolution.
Detailed	When the final resolution and detailed coordination and integration of engineering systems and architectural details are being communicated through plans and specifications, special attention needs to be paid to any gaps between areas of professional expertise, such as the seismic performance of non-structural elements.
Construction	Design issues arising during construction can be resolved to the satisfaction of all affected parties by reviewing detailed “shop drawings”, design related to proprietary systems, and any revisions to the detailed design.

Collaboration must occur at the onset of a project: before architectural concepts are developed or very early on in their conception.

Business conditions that restrict early architect/engineering interaction must be alleviated (by the use of a general consulting retainer fee, for example, recovered from those projects that are achieved).

If the architect does not want to interact with his [or her] engineer, or if for some reason is prevented by doing so, then he should work with simple regular forms, close to the optimal seismic design.[3]

The need for collaboration at *all* stages, from conceptual design through to construction, has implications when one professional is preparing an agreement for other consultant services. For example, after obtaining the client's approval, an architect preparing this agreement should make special provision to obtain the conceptual design advice the project deserves. More complex projects require higher degrees of engineering expertise. Establishing a cohesive project team right from the beginning is essential.

Quality of collaboration

Like any other human endeavour, collaboration can be done well or poorly. Some guidelines are suggested below for getting this right.

Guidelines	Comments
Quality of completed project	The quality of the completed project, as viewed by the client, will undoubtedly reflect the quality of collaboration. The client will be acutely aware of how the project meets everyday requirements; but will also expect seismic and fire performance requirements, as previously discussed and agreed to by the design team, to be met. Assessments of quality also include less tangible criteria, such as the degree of innovation, the elegance of the technical solutions and their integration with the overall architecture, and more quantitative measures such as cost, cost versus budget, and the meeting of deadlines.[4] Poor, untimely or inadequate collaboration impacts negatively on all of these measures of project quality.
Openness	A successful design team is characterised by an open and trusting culture. Engineers and architects must be open with each other regarding their design aspirations and concepts. They need to communicate with each other what they are hoping to achieve. Engineers should actively contribute to the development of the primary architectural design ideas. Design team members must also trust each other to maintain their individual professional standards whilst working towards the best collaborative outcome.
Leadership	Leadership is required in all highly collaborative team environments. Although decisions by consensus is one of the hallmarks of collaboration, the lead consultant is responsible for ensuring sufficient design iterations have been completed before final decisions are jointly made. The responsibilities of all team members must be clear and all important seismic or non-seismic design aspects must be attended to. At the beginning, responsibilities for design co-ordination and management should be identified. The team approach inherent in collaboration means each team member exercises leadership informally. This may be as simple as taking the initiative on an issue such as a safety concern that falls within the ethical responsibilities of engineers.

Meeting expectations	High quality collaboration should meet the needs and realistic expectations of all design team members. At the least, all necessary information requirements must be met. But also the different professional strengths, weaknesses and design perspectives of each profession in the design team mean there are differing expectations. For example, surveys of architects and engineers reveal that engineers appreciate architects having sufficient structural understanding to contribute to the engineering issues under discussion. Engineers also greatly value having their structural advice being sought early, rather than when it is too late for them to make a significant contribution. Architects welcome engineers engaging with the development of architectural design ideas by suggesting innovative rather than just conventional solutions.[5]
Relationships between collaborators	All parties in a collaborative relationship need to work at maintaining and improving positive relationships. At a formal level, this can be achieved by timely and clear communications. Positive informal interactions can further enhance the quality of these relationships.
Thoroughness	When all aspects essential to required engineering performance have been attended to, this indicates high-quality collaboration. For example, non-structural elements must be correctly designed and specified to ensure satisfactory seismic performance.
Collaboration between engineers	There are a number of overlapping areas between structural and mechanical engineering. The seismic performance of mechanical equipment is an example. Clarification as to who designs equipment fixings and verifies equipment seismic performance is required project-by-project.

Improving Collaboration

A wide range of actions and tools can be used to maintain and improve collaboration between engineers and architects. Some suggestions are listed below.

Actions	Suggestions
Checklists	The U.S. Federal Emergency Agency (FEMA) has provided several comprehensive checklists in FEMA 389 to facilitate collaboration between clients, architects and engineers.[6] Structural engineers should consider using (with adaptation as necessary[7]) the following checklists at appropriate phases during design: • *seismic expectations* • *checklist to facilitate architect/engineer interaction* • *design scope-of-work guidelines* • *non-structural component seismic resistance responsibility matrix.* Also refer to checklists for architects and engineers in the NZ Construction Industry Council *Design Documentation Guidelines.*[8] Checklists that can be considered as agendas for collaboration and coordination are provided for each project design phase.
Building Information Modelling (BIM)	BIM systems are becoming more widespread and facilitate collaboration when a single BIM model is used by all members of the design team[9, 10].

Alliances	Firms of architects could consider forming alliances or less formal relationships with engineering consultants, and vice versa. The aim is to facilitate more informal collaboration at conceptual design stages.
Continuing professional development	Engineers should increase their sensitivity to architectural concepts and qualities. Apart from reading architectural journals and books on architectural theory that their colleagues might recommend, two books are recommended – *Informal* [11] and *Structure as architecture: a source book for architects and structural engineers*[12]. Architects can increase their structural understanding through a text such as *Seismic design for architects: outwitting the quake*[13], or through an on-line course offered by NZ Society for Earthquake Engineering based upon *Architectural design for earthquake: a guide to the design of non-structural elements* [14]. Reference can also be made to *FEMA 454 Designing for earthquakes: a manual for architects*[15] and *Designing architecture: the art of collaboration in architecture*[16]. Architects and engineers are also encouraged to attend CPD events on these topics, such as seminars, workshops and conferences. Architects attending engineering events and vice versa can be beneficial.

Recommendations for improved collaboration

For engineers:

- Appreciate that architectural design involves a synthesis of a very wide range of different criteria, and is iterative and therefore different from engineering design.
- Contribute as constructively as possible to the design team in the expectation that early concept design solutions will need developing, refining and in some cases reworking.
- Look beyond conventional solutions for innovation that could better the project, all the while both maintaining core engineering requirements and acknowledging areas of possible compromise.
- Understand the desired architectural concepts and qualities before suggesting solutions.
- When in the role as lead consultant, such as on a seismic retrofitting project, recommend the client engages an architect at the pre-design/concept design stage.

For architects:

- Initiate collaboration as early as possible by engaging a structural and other engineers at the pre-design/concept design stage for the best project outcome.
- Match an engineer's expertise and experience with the complexity of the project.
- When leading a design team, cultivate an open and trusting culture to facilitate knowledge sharing, and encourage a 'best for the project' consensus approach.
- Facilitate communication with and between design team members so that all contribute fully and are satisfied with and take responsibility for the solutions at each design stage of the project.
- Increase understanding of structural and non-structural seismic design issues.

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