Coordinating for Success - Enhancing Seismic Restraint Through Early Design Involvement

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ABSTRACT

Tuhiraki is the new agricultural science research facility for AgResearch Limited, situated in Lincoln, Canterbury. The workplace and laboratory structures underwent significant improvements in design efficiency and coordination of seismic restraint to building services and architectural elements. This was achieved through two key changes to typical construction-phase seismic restraint design:

- Compliant seismic restraint design, 3D brace modelling and proactive coordination occurred during the design phases.
- The wider design team, project manager and contractor had an active contribution to seismic restraint strategy, design, and spatial coordination throughout the design and construction phases.

These changes elevated the role of the seismic restraint engineer to be integral to the design and coordination journey. This enabled critical design team decisions to be made earlier in the design process, allowing for collaborative and cost-effective resolution compared to traditional delivery methods. Complex areas were also identified more readily, leading to bespoke secondary steel solutions that were more efficient to construct and reduced potential on-site clashes.

Modelling seismic restraint elements facilitated spatial coordination with structure, architecture, and building services. Active collaboration with the contractor during the in-ceiling coordination process ensured an effective transition from model to build.

This paper examines the practical application and advantages of this approach within the Tuhiraki project, including the resulting ease of seismic restraint installation during the construction phase.

Figure 1: Tuhiraki architectural render (workplace in foreground) - Courtesy Architectus

1 PROJECT BACKGROUND AND SUMMARY

AgResearch Limited is a New Zealand Crown Research Institute with a focus on agriculture and biotechnology. Their new research centre, Tuhiraki, comprises two functionally separate spaces referred to herein as the "laboratory" and "workplace". The buildings are located at the corner of Ellesmere Junction Road and Springs Road and are connected via circulation links with a seismic joint.

Table 1: Summary of Tuhiraki Building Characteristics.

Characteristics	**Laboratory**	**Workplace**
Design drivers	Functional, low vibration, low deflection, cost emphasis	Aesthetics and experience, sustainability emphasis
Structural system	ComFlor composite concrete slab spanning to steel beams and columns. Precast façade panels. RC raft slab with foundation beam grillage.	Potius mass timber box/tees spanning to LVL/Glulam beams and columns. Timber frame façade. RC raft slab with foundation beam grillage.
Lateral system	RC precast and in-situ shear walls	Post-tensioned rocking CLT shear walls.

2 PROJECT ASPIRATIONS

AgResearch desired to adopt a holistic approach incorporating seismic restraint engineering and progressive design development within the design team. This built on lessons learned by AgResearch from previous projects in which seismic restraint design followed typical construction practice and was deferred as performance-based design delegated to the contractor. To complement this design strategy, a 3D BIM seismic restraint documentation model was progressively developed during the design phases. This was a significant step change from previous 2D mark-up documentation traditionally delivered during construction.

The key outcomes expected from AgResearch procuring seismic restraint design and modelling were to:

1. Ensure a holistic seismic strategy was developed and understood by all design consultants early in design development including where deflection planes are best accommodated, the amount of movement to be designed for and any special considerations associated with laboratory containment.
2. Ensure spatial allocation for seismic restraints is provided for and coordinated, particularly in the heavily congested ceiling cavities within the laboratory.
3. Provide an informed measurable quantity take-off to assist cost estimates and competitive tenders after Detailed Design.

3 PROCUREMENT METHODOLOGY

Initially, the design consultant request for proposal (RFP) was structured to procure the seismic restraint design and modelling from the discipline responsible for designing the element that needed to be restrained to mitigate model coordination across more consultants than was necessary. However, following the development of the BIM execution plan, the practicality of delivering these designs separately was flagged as a potential project risk and an alternative strategy was explored by the project manager, Johnstaff, to better realise the key outcomes of AgResearch.

To develop a holistic seismic restraint approach without introducing additional engineers and designers into the mix, Beca was engaged as an extension to their structural engineering commission to develop a seismic restraint strategy and design documentation.

3.1 Summary of scope

Beca's seismic restraint design scope was limited to suspended in-ceiling electrical, mechanical and hydraulic services and equipment, suspended ceilings, non-loadbearing partitions, and significant laboratory equipment. The seismic restraint modelling scope was limited to suspended in-ceiling services and non-loadbearing partitions. Seismic restraint design for all other non-structural elements remained with the contractor, as generally these items are dependent on contractor selection, or have combined actions to be considered (e.g. services within risers). The sprinkler pipework restraint design was deferred to the sprinkler installation contractor due to the specialised compliance pathway for sprinkler systems. Gravity support of all non-structural elements was also excluded to allow the contractor and subcontractors to develop the design based on their preferred construction methodology.

Table 2: Summary of seismic restraint deliverables

Design Phase	**Deliverables**
End of Preliminary	• Holistic seismic restraint strategy report with conceptual mark-ups on the main design team (architecture, building services and structure) documentation.
Developed and Detailed (four weeks out-of-phase)	• Design, documentation, modelling and partial spatial coordination of seismic restraints. • Regular attendance to design team coordination meetings.
Construction	• Review of contractor submissions. • Construction monitoring to level CM3.

The scoped level of spatial coordination does not result in a "clash-free" BIM model. Instead, a pragmatic approach was undertaken that amounted to coordination practices somewhere between developed and detailed design. This aimed to reduce fees and reflected the probability of minor changes occurring during the on-site installation. The design enabled the contractor the flexibility to modify the seismic restraint brace locations and brace installation angle during the construction phase to resolve any clashes.

Seismic restraint design occurred in parallel with the design team, but the documentation was delivered four weeks after the completion of each design phase to allow alignment with other disciplines' finalised documentation.

4 SEISMIC RESTRAINT DESIGN STRATEGY

4.1 Key Design Drivers

The following drivers influenced the seismic restraint strategy within the AgResearch buildings:

- Where practicable, align restraint solutions with structure to reduce demands on the floor slab.
- Where practicable, minimise the number of braces to reduce congestion and on-site coordination.
- Where practicable, accommodate serviceability level inter-storey displacements within the non-structural elements or their restraint to simplify movement detailing.

4.2 Seismic Design Requirements

Generally, seismic design requirements and actions are as per the New Zealand building code Clause B1 (Structure), New Zealand Standard NZS 4219 (Seismic performance of engineering systems in buildings) and the New Zealand Standard NZS 1170.5 (Seismic Design). Accelerations have been determined using “parts” loading. Seismic joint locations and movements are as per the structural and architectural documentation. In addition to determining design demands to drive the capacity and spacing of restraints, maximum restraint spacing limits were applied to each service type based on limits from industry guidance (ASHRAE and SMACNA), and NZS 4219.

4.3 Laboratory Strategy

The laboratory was divided into three broad strategies: the primary reticulation zone, the secondary reticulation zone, and the plant room.

4.3.1 Primary Reticulation Zone

The primary reticulation zone consists of the central lab rooms and the adjacent corridors along the entire building length (Fig. 2). This portion of the building was the most heavily serviced with services reticulating from central risers along the building, down the corridors, and to central labs.

The strategy for this zone was to design secondary steel seismic restraint frames (Fig. 3) that provide restraint to primary building service runs, suspended ceilings, and partial-height partition walls. This was anticipated to reduce potential clashes and congestion within the deep in-ceiling space compared to a traditional approach where each service, partition and ceiling is individually braced at regular spacing. Several design iterations were undertaken to optimise the frame size and spacing with consideration to architectural room layout, services routing, and allowable loads that could be transferred back into the primary structure. The frames also provided gravity support to building services, further reducing congestion. A similar cradle frame approach has been previously undertaken for Wellington Children’s Hospital (Black 2023) and is indicative of the industry trending towards this approach for service-intensive projects.

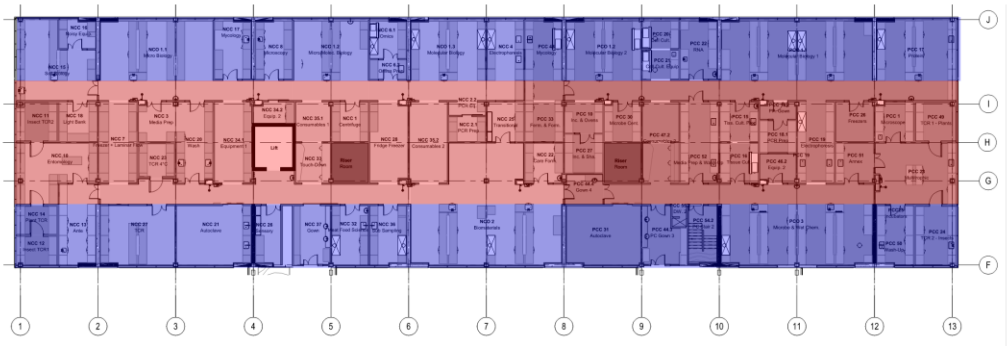

Figure 2: Typical Laboratory Floor Zoning (Red – Primary Reticulation, Blue – Secondary Reticulation)

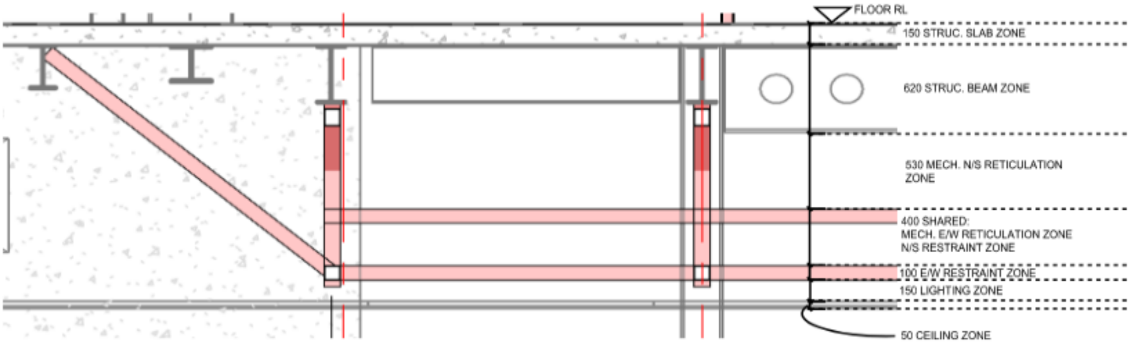

Figure 3: Partial section of restraint frame and vertical zoning set-out

A vertical zoning set-out was agreed upon by the design team (Fig. 3). This zoning was critical to the design of the restraint frames and the building services routing. Locking in the allocation of this space before the start of the developed design phase allowed sufficient space for both the frame and larger mechanical services and created a consistent approach to multi-layered services reticulation.

4.3.2 Secondary Reticulation Zone

The secondary reticulation zone consisted of the outer lab rooms along the entire length of the building (Fig. 2). The proposed strategy for this zone was to brace each non-structural element to the floor above. For building services, this utilised traditional restrained services trapezes. Partial-height partition walls and suspended ceilings were also braced to the underside of the floor above with typical cold-form steel struts. Ceilings were typically not perimeter restrained to maintain displacement compatibility with ceilings in the adjacent primary reticulation zone so that no specific movement joint was required at the zone interface and the ceiling remained continuous with the adjacent corridors.

4.3.3 Plant Room

The plant room is above the roof level of the laboratory and is formed by steel purlins spanning to steel portal frames in the transverse direction and steel cross-bracing in the longitudinal direction. The plant room contains heavy service equipment including large tanks. These were typically fixed down to the ComFlor composite concrete roof with additional supporting secondary steel as required.

The strategy to restrain most suspended services was to use secondary steel frames at regular spacing to form a “highway” that aligned to service routing. Due to higher seismic demands and heavier services within the plant room, the suspended frame solution was altered to form “goalposts”. SHS columns spanned between the roof structure and the floor below to reduce the demands resisted by the lightweight steel roof. Consideration of inter-storey displacement compatibility was critical, and in some cases, pipe bellows were required where this could not be accommodated by inherent flexibility within the service run. Typical trapeze restraints to the roof above were used for services not restrained by the frames.

4.4 Workplace Strategy

The workplace has much fewer non-structural elements, and the spatial constraints in this building are far less critical. The strategy focused on minimising the aesthetic impact of the restraints due to the nature of the mass-timber building having all structure and services exposed. Coordination with both the architect and building services engineer allowed services to be primarily located out of sight lines above meeting rooms adjacent to the reticulation corridor. The meeting rooms were capped with a plywood lid supported by timber joists that were designed to support the lateral and gravity demands from services fixed down to it and act as a diaphragm to partition walls below. Where services were not located above meeting rooms, additional techniques were considered to minimise the number of braced trapezes (Fig. 4).

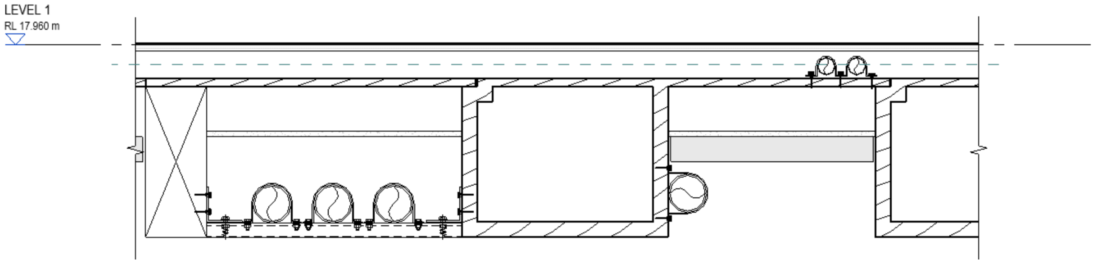

Figure 4: Example detail to minimise the visibility of services and their restraint to Potius flooring.

5 DOCUMENTATION METHODOLOGY

Seismic restraints were modelled to level of development (LOD) 200 with the understanding the seismic restraints would be partially coordinated. At this LOD, each seismic restraint model was formed from generic box sections with a 45-degree brace angle. This does not represent the final installation location as the design allowed a typical construction tolerance of ± 250 mm, with ± 15º brace angle tolerance. These tolerance rules should be communicated to the contractor, along with an open discussion about what level of coordination is required for the project to allow for a straightforward build.

Revit was used for the documentation and modelling software, which enabled model sharing between the design team. Throughout the design process and early construction phase, BIM coordination software, Revizto, was used as an issue resolution tool to resolve spatial clashes as the models were developed. Clash detection tools within Revizto allowed some consideration of the design tolerances.

Documentation was delivered to the contractor in the form of both traditional plan drawings and the 3D model (Fig. 5). Restraints on the drawings were symbolic and spatial representations of the 3D-modelled elements. The drawings were also used for building consent documentation.

6 NOTABLE DESIGN PHASE OUTCOMES

6.1 Primary Reticulation Frame

Initially, the design team sought to use proprietary seismic restraint systems made from cold-formed steel box sections, with bracing in both seismic loading directions. This approach was anticipated to be more cost-effective than structural steel and would allow procurement and installation to be undertaken by the building services subcontractors. However, as the design progressed it was found that the proprietary frames would need to be heavily braced and positioned at close centres due to low connection design capacities for these systems. These connection capacities often governed over member capacities and there were significant challenges in obtaining design values from proprietary suppliers, which slowed design development. We encourage suppliers to quantify and publish this design information.

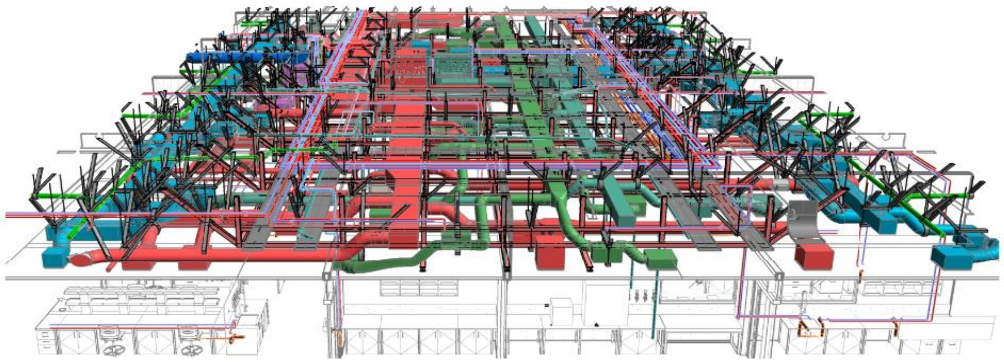

Figure 5: 3D view of restraint Revit model (building services and architectural models also shown)

The design progressed to small SHS structural steel box sections. Early contractor involvement with Naylor Love led to the selection of 100UC sections instead of similar weight 89SHS sections to improve constructability. While this choice had an impact on minor axis strength and stiffness, it simplified frame connections and reduced construction time and complexity associated with connecting services to the frames.

The choice of a structural steel restraint solution enabled procurement and delivery by the primary steel supplier. Shop drawings model coordination and review were also simplified. Finally, this streamlined the construction sequence, with the frames installed before the mobilisation of the services subcontractors.

6.2 Quantities for Tender and Cost Estimation

During typical construction-led seismic restraint design, the quantum of seismic restraints is not fully understood at the time of tender. Allowances on a gross floor area or lineal metre of services approach provide some basis for estimation but do not account for the building's seismic demands per floor or the complexity of services routing (more corners typically lead to more braces).

Modelling to LOD 200 during the design phases and extracting model metadata for cost and quantity estimation is not sufficient to accurately determine the exact number of seismic restraints that will be installed, but it is suitable to reduce uncertainty and contingency. For this approach to be successful, it should be made clear to those tendering what aspects of the design are not modelled or drawn. A costing notes memorandum was found to be suitable for this.

6.3 Ceiling Grid Seismic Performance

Bracing the laboratory ceiling to the floor above relies on the ceiling grid to sufficiently transfer seismic demands to each brace location. Initially, the project used a laboratory-grade aluminium grid system, which provided benefits to constructing pressure-controlled lab spaces. Limited seismic design information was available at the time for this grid. As the seismic restraint design progressed, it became clear that the tension capacity of clips that join ceiling grid tees together would not be sufficient to meet the expected seismic demands. The design team then changed to a typical steel grid ceiling system suitable for seismic regions. We recommend the construction industry and engineers work together to improve the availability of ceiling seismic design data and consider product range availability suitable for seismic regions.

7 CONSTRUCTION PHASE OUTCOMES

7.1 Coordination

At the start of the construction phase, the 3D model was used to aid the development of mechanical services shop drawings, which finalised the setout of ducts, heating and cooling pipework, and seismic restraint bracing. Shop drawings were also used to finalise the setout of partition wall and ceiling restraints by the contractor. Other changes from the design phase were first tested in the BIM model for potential coordination issues and then confirmed through the typical RFI/CAN process before the installation of the non-structural elements.

Due to the low number of changes between design and construction, the seismic restraint drawings remained a valuable resource for the quick identification of braces and served as the basis for the contractor's quality assurance review of their subcontractors.

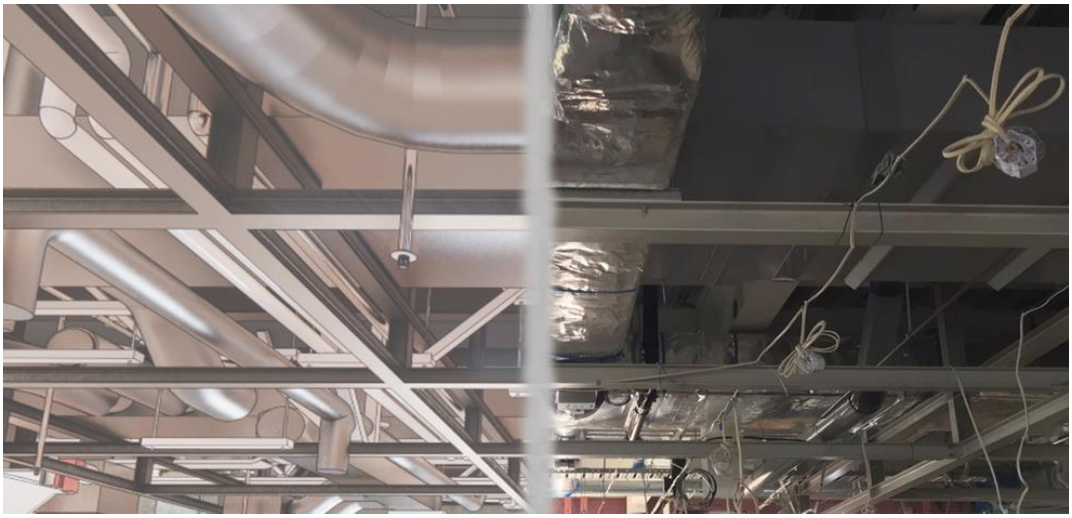

Figure 6: Rendered BIM model (left) and as-built construction (right) of secondary steel frames.

After construction, it was suggested by Naylor Love that the secondary steel frames within the primary reticulation zone (Fig. 6) could have also been utilised in the secondary reticulation zones to improve construction times and reduce congestion within this ceiling space. We recommend that the industry undertake a study to determine under what conditions (such as density of services) secondary steel frames are more cost-effective than individual proprietary trapeze restraints. This study would be valuable to future highly serviced projects such as laboratories or hospitals.

7.2 Construction Monitoring

The seismic restraint design drawings were well suited to aid the review of restraint installation during construction monitoring site visits by Beca. Where issues from installation were identified, markups on these drawings and images of the 3D model were used to convey the location and the expected remedial to the contractor.

The review of services restraint to the secondary steel frames in the primary reticulation zones was straightforward as the connection to these frames was evident from the provided gravity support. It would have been challenging to review that services were restrained per the design documentation if a traditional individual braced trapeze solution had been used, due to the density of services in this location.

8 CONCLUSION

Providing seismic restraint to non-structural elements is a necessary undertaking for buildings in New Zealand. However, there are project risks arising from coordination, cost uncertainty and achieving design compliance. These risks are heightened in buildings of high complexity, such as heavily serviced laboratories, or those with strong aesthetic drivers. It has been shown that undertaking the design and coordination of seismic restraints during the project design phases was an effective strategy to mitigate these risks for AgResearch and its new research centre, Tuhiraki.

REFERENCES

Black I (2023). “Wellington Children’s Hospital – a different approach to a seismic restraint project”. *New Zealand Society for Earthquake Engineering Annual Technical Conference,* 19 – 23 April, Auckland, New Zealand, Paper No 146. https://repo.nzsee.org.nz/handle/nzsee/2553