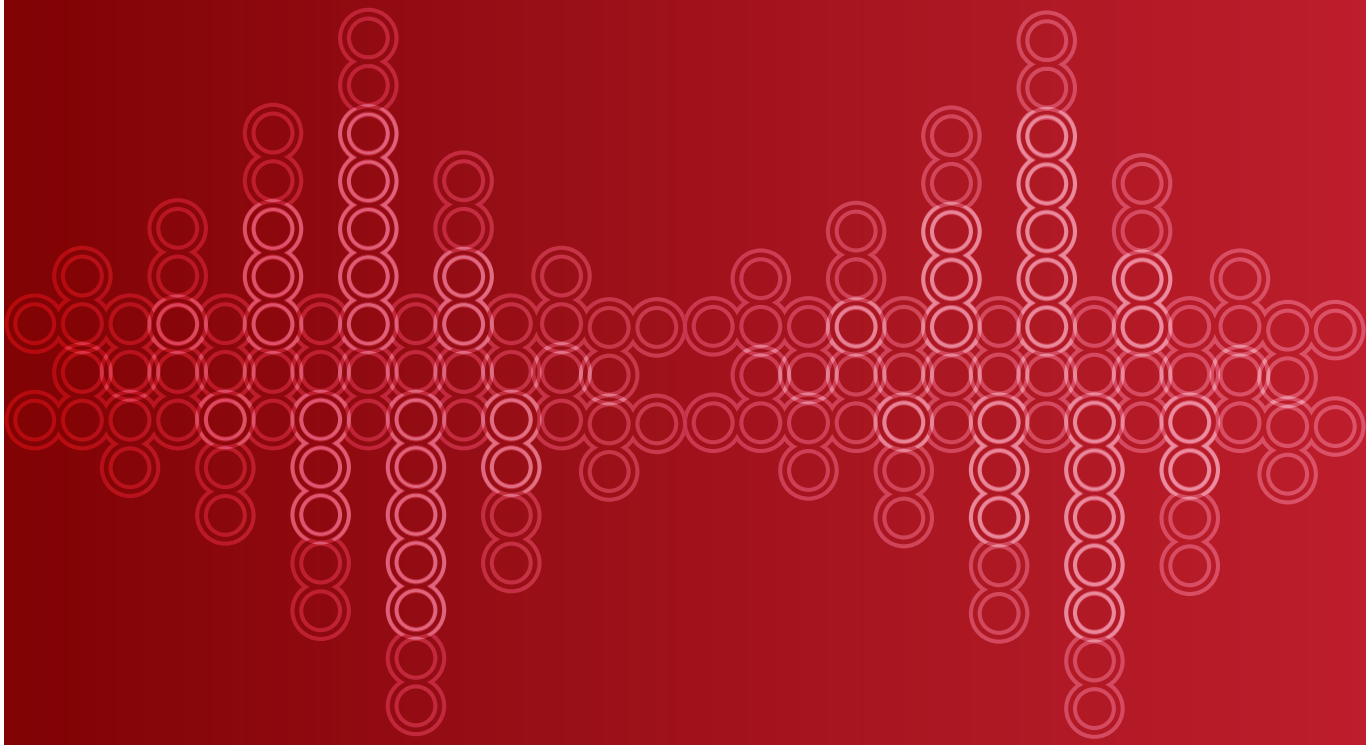
SEISMIC PROCESS GUIDE FOR MECHANICAL SERVICES SUBCONTRACTORS

October 2014



Climate Control Companies Association

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1 INTRODUCTION

The purpose of this guide is to assist the mechanical services industry to achieve compliance with NZS 4219:2009 *Seismic performance of engineering systems in buildings*. It is recognised by the construction industry that compliance with NZS 4219:2009 can be difficult to achieve and that there have been varying levels of compliance in the past.

More than half of the costs incurred in the Canterbury earthquakes were associated with non-structural elements. This represents a significant cost to the New Zealand economy, and considerable focus is being placed on our industry to achieve compliance with NZS 4219:2009.

The industry has struggled with lack of clarity on seismic design criteria and certification/producer statement requirements, as well as the lack of suitably qualified seismic design resources. This has led to inconsistencies in the pricing, application and construction of appropriate seismic restraints.

This document has been developed to provide a basis for mechanical services subcontractors to provide a consistent, risk-managed solution for seismic performance of non-structural building mechanical elements.

Proper seismic design for mechanical services is interdependent with construction phase[1] design processes, including:

- proprietary equipment selection and details – weight, dimensions, centre of gravity, mounting details/restraint fixing points
- detailed coordination and set-out (dimensioning) – hanger lengths, clearances, coordination of all non-structural component restraint and fixings to structure
- gravity design – seismic bracing generates additional gravity support loads that can impact gravity support design.

Any seismic design undertaken during the detailed design phase (and included in tender documents) is likely to be 'typical' and needing additional construction phase design to achieve compliance with NZS 4219:2009.

Building services seismic design is a specialist design process often outside the engineering capability of mechanical contractors and, in some circumstances, requires structural engineering knowledge, hence the need for contractors to typically engage building services seismic specialists to undertake seismic design, inspection and certification (refer to section 3).

It is anticipated that the process outlined in this document will be adopted by all other building services disciplines, not just mechanical. A review process is currently under way.

US experience

California's Office of Statewide Health Planning and Development (OSHPD) is the most onerous regulatory system for non-structural component seismic performance in the US. Approval options include:

- no details on permit documents – specify seismic design (by contractor) as 'deferred approval'
- generic design submitted with permit documents – design tends to be 'typical' and requires the contractor to employ a seismic specialist to do project/product-specific design
- specify 'OSHPD pre-approved' details by major bracing manufacturers (for example, ISAT, Mason).

California hospital owners are pushing for ways to avoid/minimise 'generic' design that essentially requires repeating (by a different party) to suit construction phase decisions. An OSHPD-type approval system has been considered for New Zealand but discounted as too onerous for a small country.

1. Reference in this guide to developed, detailed and construction phase design shall mean as defined by the New Zealand Construction Industry Council Design Documentation Guidelines (www.nzcic.co.nz/Design.cfm). Note that these guidelines include seismic design of non-structural components within the construction phase design.

2 TENDER METHODOLOGIES

2.1 Option 1: Seismic design carried out during construction design phase

This is the most likely option for New Zealand commercial building projects.

Given seismic details will not be fixed until completion of relevant construction phase design, this methodology will require (at least during a transitional period) the inclusion of provisional sum seismic allowances in tenders. (US experience indicates that accurate tender pricing may be practicable once New Zealand contractors and seismic specialists have established unit cost databases based on a range of project types, seismic design criteria, building complexities and so on.)

Provisional sum allowances may be:

- set by and nominated within the tender documents
- in the absence of such nominated allowances, nominated by the mechanical subcontractor within the tender – it is then expected (via industry-wide education and/or industry-wide endorsement of protocols such as this guide) that tender evaluation will be based on identical seismic provisional sums in all tenders (or be exclusive thereof).

Where tender documents do not nominate seismic allowances, a sample tender note follows:

> *A provisional sum of $xxx,xxx (excl. GST) has been included for the engineering (by a seismic specialist), installation and certification associated with seismic performance of mechanical elements to NZS 4219:2009.*

In the absence of clear definition of processes and information within the tender documents, add the following (but check for and clarify any conflicts or ambiguities between the tender documents and Appendix A of this guide):

> *The provisional sum allowance is based on processes and information in accordance with the CCCA Seismic Guide For Mechanical Services Subcontractors Appendix A as attached.*

Refer to Appendix A for guidance on Option 1 processes and information.

2.2 Option 2: Seismic design completed and detailed within tender documents

For reasons outlined in the introduction, it is unlikely that tender documents will provide sufficient seismic design details (that don't need construction phase reassessment, adjustment and certification), other than perhaps for some relatively small and simple building projects.

Note that seismic design includes more than simply design of bracing systems (refer to section A4.1 for examples), so even if seismic bracing details are provided, the project may still require other seismic-related design activities. The mechanical services tenderer should specifically include or exclude these additional items.

If the tender documents include seismic details but do not specifically identify seismic design responsibilities as above, it is recommended that tenderers either assume Option 1 (preferred) or specifically exclude seismic design from their tender by a statement such as follows (taking cognisance of the potential risk of being considered a non-complying tender):

> *We have allowed for compliance with NZS 4219:2009 on the assumption that the seismic restraint of mechanical systems and equipment has been fully designed and detailed in the tender documents and that the mechanical contractor is only responsible for the installation of those detailed restraints and the associated Construction Producer Statement (PS3).*

3 CONSTRUCTION PHASE DESIGN AND INSTALLATION QUALITY CONTROL

3.1 Building services seismic specialist qualifications

NZS 4219:2009 stipulates seismic designer qualifications where specific design is required as: "An engineer experienced in structural engineering such as a chartered professional engineer with relevant experience and skills in structural engineering".

Note that NZS 4219:2009 stipulates specific design for:

- components connected to the building structure at more than one level without flexible joints or connections (clause 3.5.2)
- components outside the scope of clauses 3.6 –3.8, for example, wall-mounted components, floor-mounted components without single definable centre of gravity (clauses 3.9 and 3.7.1.1)
- brittle components (clause 5.3)
- pipes > 200 mm diameter (clause 5.8.1)
- steam and gas piping requiring restraint under clause 5.8.1 (clause 5.8.5 and 5.8.6)
- in-ceiling and above-ceiling components > 25 kg (clause 5.13).

Mechanical subcontractors should select building services seismic specialists with relevant qualifications as above.

In some cases, the mechanical subcontractor may wish to use in-house professional engineering resources to prepare designs and details for review by an external seismic specialist. Given it is unlikely for mechanical subcontractors to have in-house resources that are qualified to undertake specific design, this methodology is only likely to be suitable for non-specific design elements.

3.2 Quality control processes

3.2.1 Design

Seismic design is to be undertaken by the building services seismic specialist, who then provides seismic design submissions and a Design Producer Statement (PS1).

Where the mechanical subcontractor prepares designs and details for review and certification by an external building services seismic specialist, the mechanical subcontractor should provide a PS1 and the building services seismic specialist a corresponding Design Review Producer Statement (PS2). (Where the subcontractor prepares pre-engineered (non-project-specific) and pre-reviewed details, the building services seismic specialist should provide PS2(s) that are specific to the project.)

Design details and producer statements should be submitted to the relevant project manager/contract administrator, as well as the building consent authority where such submission is a condition of the building consent.

3.2.2 Installation

NZS 4219:2009 is a performance-based standard and therefore it is not possible to inspect an installation for compliance with NZS 4219:2009 itself. It is only possible to inspect an installation for compliance with a design undertaken in accordance with NZS 4219:2009. Hence, it is important for construction monitoring/inspections to be undertaken by the person responsible for or with detailed knowledge of the design.

The mechanical subcontractor should provide a Construction Producer Statement (PS3) certifying that the installation has been completed in accordance with the seismic specialist's design.

The building services seismic specialist should provide an agreed level of construction monitoring as appropriate to the complexity and criticality of the works and a Construction Review Producer Statement (PS4) certifying that the works have been completed in accordance with the relevant requirements of the building consent. (The defined level of construction monitoring provides the "reasonable grounds" for the seismic specialist's Construction Review Producer Statement (PS4).)

APPENDIX

A PROCESSES AND INFORMATION GUIDE – OPTION 1: SEISMIC DESIGN CARRIED OUT DURING CONSTRUCTION DESIGN PHASE

A1 What is expected from developed/detailed design

Assessment and general coordination of the typical services, structure and architecture to allow adequate space in ceiling voids, risers, plantrooms and the like for coordinated seismic restraint of all building services and other relevant non-structural components (for example, suspended ceilings), including seismic clearances in accordance with NZS 4219:2009.

A2 Information required at tender

A2.1 Tender documents

Tender documents should identify:

- building importance level (IL)
- building location (or zone factor)
- the design 'g' loadings imposed on major proprietary plant and equipment
- identification of all systems that are life safety
- for an IL4 building, identification of all systems that are to remain operational during and after an SLS design strength earthquake
- structure-specific seismic deformation criteria (otherwise NZS 4219:2009 defaults to be used)
- whether fixings in concrete are to be designed for cracked or uncracked concrete
- identification of any concrete or steel structure plastic hinge zones within which non-structural component fixings should not be made
- pre-manufacture seismic submission requirements
- the level of construction monitoring to be provided by the building services seismic specialist(s) in order to provide "reasonable grounds" for the specialist's Construction Review Producer Statement (PS4)
- any requirement for the main contractor to engage a single building services seismic specialist to undertake seismic engineering, inspection and certification for all building services trades (with the expectation of improved efficiency and higher confidence of fully coordinated and compliant non-structural component seismic solutions, for example, for an IL4 building).

A2.2 Main contractor

The main contractor should provide:

- architectural drawings
- structural drawings.

A3 Tender preparation

A3.1 Proprietary equipment

Ensure proprietary plant and equipment suppliers receive and price for the design 'g' loadings that should be included in the tender documents as above.

Note: Proprietary equipment manufacturers for New Zealand and/or international markets should be designing their equipment for specific seismic loads and, where commercially appropriate, offer standard and high 'g' options. For example, Evapco offers standard 1g and optional 5g cooling towers, with the latter incurring approximately 5% weight and 7% cost premium. (NZS 4219:2009 seismic loadings cannot exceed 3.6g.) However, some manufacturers may not have yet responded to local and international demand for proprietary equipment seismic ratings. If they are unable to confirm ratings, manufacturers should, as a minimum, be requested to include in their price for compliance verification in accordance with NZS 4219:2009 C2.4 (i.e. by calculation or testing in accordance with NZS 4219:2009 section 4.5). However if such verification proves the need for seismic strengthening, this would be deemed included in the tender price. Hence, this approach should be applied with caution or such manufacturers rejected and compliant offers sought.

A3.2 Provisional sum

a. Where tender documents do not nominate a seismic provisional sum, either:
   - estimate as (c) below (preferred on large and/or critical projects), or
   - estimate based on a percentage of the services cost, and describe that basis in the tender. (Based on US experience, the rough order of cost of seismic performance is expected to be 5–15% of services cost depending on seismic design criteria and building size/complexity.)

b. Where tender documents nominate a seismic provisional sum, tenderers may wish to check the reasonableness of that sum, particularly on large and/or critical projects, where subsequent identification of an inadequate sum is likely to be problematic to all – refer to (c) below.
c. Estimate with input from the building services seismic specialist/proprietary seismic product supplier:
    - Select a building services seismic specialist/proprietary seismic product supplier, provide all relevant tender documents and request their estimate for:
        - seismic engineering, product supply and inspection/certification
        - labour to install proprietary seismic restraints.
    - Refer to section A4.1 and include allowance for engineering and inspection/certification for items not covered by the selected building services seismic specialist.
    - Refer to section A5.1 and include allowance for consequences of detailed construction phase coordination between services and other non-structural components, for example, ceilings.
    - Estimate total price generally as section A5.6.

A4 Post-tender acceptance

A4.1 Building services seismic specialist

It is recommended that the successful mechanical subcontractor select their seismic specialist(s) as early as practicable.

Note that seismic design includes (but is not necessarily limited to) the following:

- Design of seismic bracing and fixings for linear components (ducts, pipes, rigid cable support), suspended equipment (for example, fan coil units) and tall floor-mounted equipment where applicable (for example, floor-mounted switchboards) and includes design for associated impact on gravity supports and impact of load eccentricity and prying actions on fixing selection.
- Design of floor/roof-mounted equipment fixing for seismic loads, including overturning.
- Details of plinth size/location/thickness including equipment weights, plus horizontal and vertical seismic loads at each anchor point. These are to be submitted to the main contractor/builder who then is responsible for submission to the structural engineer and agreement of appropriate details:
    - NZS 4219:2009 prescriptive solution.
    - Specific plinth anchoring/reinforcement design by structural engineer.
- Design of wall-mounted equipment support and fixing for seismic loads.
- Selection of vibration isolators and their fixings for seismic loads or design of separate seismic limit stops/snubbers.
- Design of vertical pipe flexibility for structural deformation during a seismic event.
- Design/coordination of pipe expansion/contraction and seismic restraint/movement provisions.
- Selection of seismically qualified post-installed concrete anchors based on cracked or uncracked concrete as specified. Note the following:
    - NZBC B1/VM1 cites NZS 3101.1:2006 *Concrete structures standard – The design of concrete structures*, which in turn refers to American Concrete Institute ACI 318-11: *Building Code Requirements for Structural Concrete: Appendix D – Anchoring to Concrete*. Some suppliers of post-installed concrete anchors provide anchor selection software, indicative of the relative complexity of the selection process.
    - Above applies to both seismic and gravity support anchors.
    - Ensuring that proprietary equipment and components are capable of withstanding seismic loads at seismic restraint fixing points.
    - Design of air diffuser/grille fixings to ceiling suspension system (main or cross runners).
    - Coordination of seismic clearances with all other building components.

Some building services seismic specialists will not necessarily offer all the above seismic engineering and certification:

- **Proprietary seismic restraint system suppliers**: Some will offer proprietary systems along with associated project-specific engineering/certification, but they may not offer seismic selection and fixing of vibration isolation products, engineering and selection of floor/roof/wall-mounted fixings, and so on. (Some may offer product only, without the associated project-specific engineering/certification.)
- **Specialist seismic engineers**: Seismic engineering/certification based on either generic or proprietary seismic restraint systems. Where the mechanical subcontractor

intends to use proprietary restraint systems, the specific brand should be agreed prior to commencement of design.

Also note seismic designer qualification requirements (refer to section 3.1).

Hence, the mechanical subcontractor may need to select multiple specialists as needed to cover all seismic engineering/certification requirements.

A4.2 Review of provisional sum

Where tender preparation did not include estimating input from a building services seismic specialist/proprietary seismic product supplier, consider obtaining such input as early as possible post tender to check the reasonableness of the provisional sum (particularly on large and/or critical projects where subsequent identification of an inadequate sum is likely to be problematic to all). Refer to section A3.2(c) for estimating procedure.

A5 Construction design phase

A5.1 Coordination

Coordination meetings/discussions between all relevant trades (for example, services, ceilings and partitions) and their respective seismic specialists should be undertaken as early as practicable to identify and agree methodologies for key coordination issues, such as:

- coordination of ceiling and above ceiling services restraints and seismic clearances (some services that may not otherwise need to be restrained may need such restraint to reduce seismic clearance requirements)
- coordination of ceiling-mounted services > 10 kg where it is aesthetically unacceptable to maintain 25 mm clearance between ceiling and services component and hence the ceiling must be designed for the gravity and seismic loads associated with the services components.

A5.2 Mechanical subcontractor

The mechanical subcontractor should provide the seismic specialist(s) with:

- construction issue versions of tender documents (refer to section 2)
- coordinated shop drawings of architecture, structure, piping, ducting, mechanical services equipment and associated electrical switchboards, control panels and rigid cable support systems
- details of items of proprietary equipment requiring seismic restraint and/or seismic design of fixings (for example, dimensions, weights, centre of gravity, fixing points and so on)
- for pipe risers and/or other long straight pipe runs with specific thermal expansion provisions (i.e. expansion loops, compensators and so on) – pipe anchor and guide layouts and corresponding gravity and thermal expansion loads (such anchors and guides should be designed for combined gravity, thermal expansion and seismic loads)
- for all pipes and ducts crossing structural seismic joints – proposed methodology and details, for example, bends, offsets, loops and so on or proprietary flexible connections.

A5.3 Seismic specialist(s)

The seismic specialist(s) should provide:

- seismic restraint layout drawings and design details as required by the mechanical subcontractor to enable construction therefrom
- calculations and other inputs to enable the mechanical subcontractor to submit drawings and details (refer to section A5.4)
- Design Producer Statement(s) (PS1) confirming that the design meets the performance requirements of NZS 4219:2009 (as modified by NZBC B1/VM1 section 13.1 for projects within the Canterbury Earthquake region) or Design Review Producer Statement(s) (PS2) where the mechanical subcontractor prepares designs and details for review and certification by the seismic specialist. (Where the mechanical subcontractor's design and details are pre-engineered (non-project-specific) and pre-reviewed, the seismic specialist should provide PS2(s) that are specific to the project.)

A5.4 Seismic submissions

- The mechanical subcontractor should submit seismic calculations and details as specified in the tender/contract documents. In the absence of such specification, refer to Appendix B for a suggested checklist.
- Design Producer Statement(s) (PS1) and Design Review Producer Statement(s) (PS2) where applicable (refer to section A5.3).

A5.5 Main contractor responsibilities

- Manage the coordination of seismic solutions and details by relevant subtrade contractors (including but not necessarily limited to services, ceiling and partition subcontractors).
- Communicate any changes that may affect the seismic design.

- Coordinate and review all non-structural component point loads on the structure prior to submission to the (structural) engineer for review.

Note: Where structural point loads exceed the capacity of the structure, additional mechanical services supports, restraints or load distribution substructure will typically be required to reduce/distribute point loads. (In some circumstances, it may be appropriate for the structural engineer and contractor to review the alternative of upgrading structural elements.)

A5.6 Converting provisional sum to fixed price

Once all seismic design and coordination is complete, the mechanical subcontractor should price the seismic systems including:

- seismic design, construction monitoring and certification by seismic specialist(s) (refer to section A6 for guidelines on seismic specialist construction monitoring and certification)
- proprietary seismic restraints
- any custom-engineered seismic restraints
- materials (fixings, cable, Unistrut and so on) and consumables that are not supplied by the seismic specialist(s)
- labour for installation.

A6 Construction phase

A6.1 Installation

- Mechanical subcontractor to install seismic restraints as per design drawings and provide appropriate quality assurance/inspection of work by site personnel.
- Where on-site or client-driven changes are required, these are to be communicated to the seismic specialist, and an amendment to the design is to be provided by the seismic specialist.
- Mechanical subcontractor to manage and coordinate inspections by building services seismic specialist(s) commensurate with the required level of seismic specialist construction monitoring as below.

A6.2 Construction monitoring by building services seismic specialist(s)

- The building services seismic specialist(s) should provide the level of construction monitoring specified in the tender/contract documents. In the absence of such specification, refer to Appendix C for guidelines.
- A defined level of construction monitoring provides the “reasonable grounds” for the seismic specialist’s Construction Review Producer Statement (PS4).

A6.3 Seismic certification

- Construction Producer Statement (PS3) by the mechanical subcontractor certifying that the works have been completed in accordance with their building services seismic specialist’s design.
- Construction Review Producer Statement (PS4) by the building services seismic specialist(s), certifying that, based on the level of construction monitoring provided by them and information provided by the subcontractor, they “believe on reasonable grounds” that the works have been completed in accordance with the relevant requirements of the building consent.

APPENDIX

B CHECKLIST FOR CONSTRUCTION DESIGN PHASE SEISMIC SUBMISSIONS

In the absence of seismic calculation and detail submissions being specified in the tender/contract documents, the mechanical subcontractor should use the following as a checklist:

a. Layout drawings of all pipe, duct and rigid cable support systems identifying seismic restraint and gravity support location and orientation, maximum allowable transverse and longitudinal brace spacing and (by notation) services that do not require specific restraint and the reasons therefore.

b. Seismic calculations and details for the following:
   - All P1, P2 and P3 (hazardous) equipment and linear systems.
   - All P4 (life safety) equipment and linear systems.
   - All P5 equipment and linear systems (required for operational continuity) in IL4 buildings.
   - Floor, roof and stand-mounted equipment > 200kg.
   - Ceiling-mounted equipment > 10kg (i.e. equipment mounted at or directly below ceiling level and either supported and restrained by the ceiling (requiring specific design of ceiling to suit) or independently supported and restrained with 25 mm clearance all round.)
   - Above-ceiling equipment > 25kg.
   - All isolated equipment suspended from the structure via wire, chain and so on.
   - Other suspended equipment > 100kg.
   - Wall-mounted equipment > 50kg. (For multiple wall-mounted and directly adjacent switchboards, distribution boards, controls cabinets and the like, this applies where the total weight of all directly adjacent cabinets > 50kg.)
   - All horizontal pipework requiring seismic restraint, including vertical offsets, drops to equipment and so on
   - All multi-floor pipe risers.
   - All pipes crossing seismic structural separations.
   - All ducts requiring seismic restraint.
   - Flues and stacks.

c. Seismic calculations and details as required above should include the following:
   - Means of compliance, for example, ASHRAE or SMACNA seismic guides, specific design and so on.
   - Seismic and gravity load calculations in each support and brace at seismic restraint locations, including for each of components/supports/braces and anchors/fixings where NZS 4219:2009 Appendix C Performance Factors < 0.85 are used for the former.
   - Maximum allowable transverse and longitudinal brace spacing (linear components).
   - Brace type, material, size, load rating and permissible installation angles.
   - Combination vibration isolation and restraint details where applicable.
   - Gravity support selection at restraint locations, including means for reinforcing where required.
   - Fixings and anchors (to both service and structure) – methods, loads, ratings, sizes, embedment, weld lengths, torque requirements (where applicable) and so on.
   - Anchor bracket details, commensurate with prying factors used in fixing/anchor selection.
   - Evidence of post-installed concrete and masonry anchor certification as ACI 355.2.
   - Schedule of major gravity and seismic point loads on the structure and corresponding fixing details. (see note in section A5.5.)

APPENDIX

C

LEVEL OF CONSTRUCTION MONITORING BY BUILDING SERVICES SEISMIC SPECIALIST(S)

In the absence of tender/contract documents specifying the level of construction monitoring[2] by the building services seismic specialist(s), the following is suggested as a guide.

CM2 Review at the earliest opportunity a sample of each important work procedure, material of construction and component for compliance with the requirements of the plans and specifications and review a representative sample of each important completed work prior to enclosure or completion as appropriate. Be available to provide the constructor with technical interpretation of the plans and specification.

Appropriate for IL1 or IL2 buildings being undertaken by an experienced and competent constructor and where a higher than normal risk of non-compliance is acceptable.

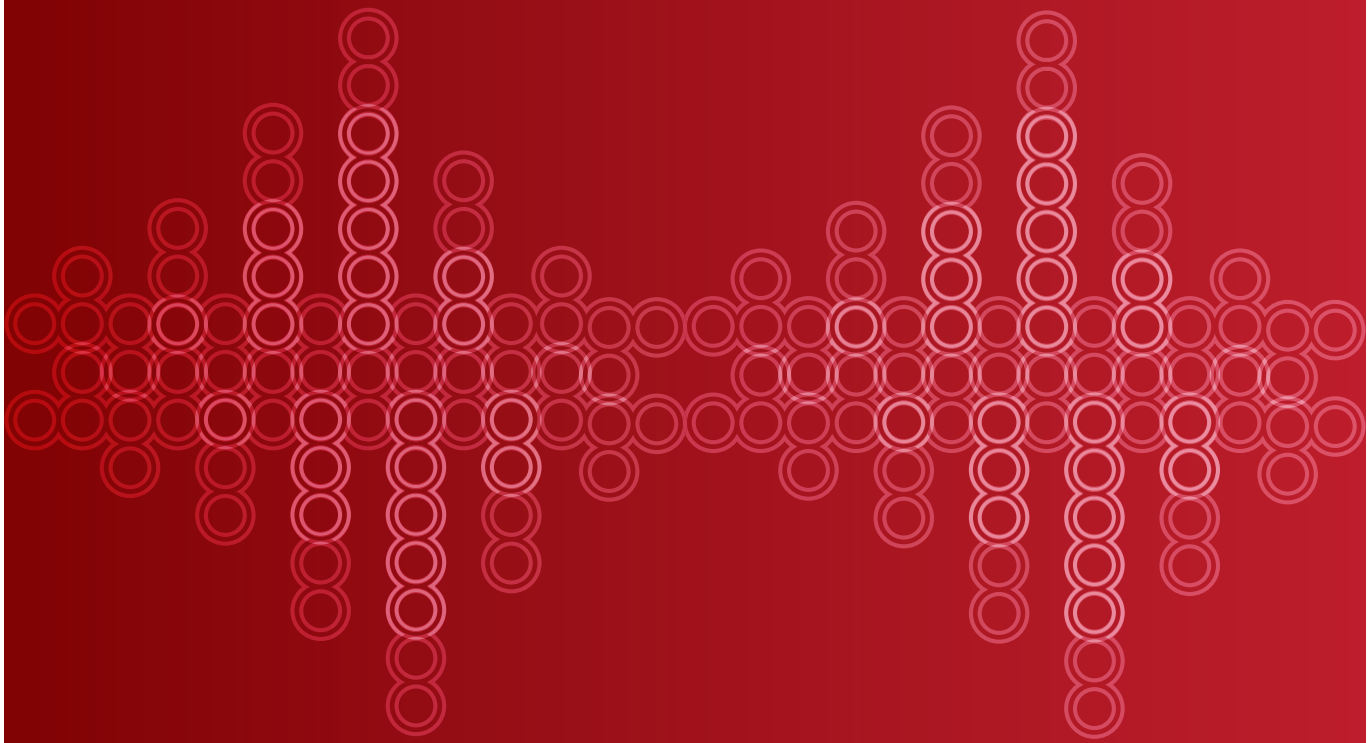
CM3 Review random samples of important work procedures for compliance with the requirements of the plans and specifications and review important completed work prior to enclosure or on completion as appropriate. Be available to provide the constructor with technical interpretation of the plans and specifications.

Appropriate for IL3 buildings being undertaken by an experienced constructor when a normal risk of non-compliance is acceptable and IL1 or IL2 buildings where the services trade contractor is not experienced in seismic restraint in accordance with NZS 4219:2009.

CM4 Review regular samples of work procedures, materials of construction and components for compliance with the requirements of the plans and specifications and review the majority of completed work prior to the enclosure or on completion as appropriate.

Appropriate for all IL4 buildings where a lower than normal risk of non-compliance is required and IL3 buildings where the services trade contractor is not experienced in seismic restraint in accordance with NZS 4219:2009.

2 A defined level of construction monitoring provides the "reasonable grounds" for the seismic specialist's Construction Review Producer Statement (PS4). Construction monitoring (CM) levels and guidelines are based on IPENZ Engineering Practice Guideline – Construction Monitoring Services (www.ipenz.org.nz/ipenz/forms/pdfs/Construction_Monitoring_Services.pdf). IPENZ CM1 (monitor outputs from another party's quality assurance programme) and CM5 (full-time on-site monitoring) are not relevant/appropriate for construction monitoring by building services seismic specialist(s).



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