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Case study of TVNZ Refurbishment - Specific Design of Seismic Restraints for Non-Structural Elements

John Newall, Paul Campbell, Tom Parker, Kristian Jensen

WSP Opus, New Zealand (Auckland).

ABSTRACT

The TVNZ Television Centre in the Auckland CBD, underwent a substantial internal refurbishment which was completed in 2016. Given the important function of the building, there was a specific emphasis on resilience. As part of the resilience, there was a focus on the seismic performance of all components of the building. The contractor, Fletcher Construction, were keen to be proactive with the design and installation of the seismic restraint.

The design process highlighted the importance of a close collaboration between designer, lead contractor and the various sub-contractors. The new services were extensive and had to be installed within an existing structure with some features that made the design challenging. Adding to the complexity was the visually exposed nature of all the services, bringing architectural considerations into the design.

The timing of this project coincided with WSP Opus completing a piece of industry research for MBIE. This was titled the Economic Benefits of Good Seismic Performance of Non-Structural Elements in New Buildings. Learnings from the TVNZ project made up part of the research and offered an opportunity to expand our evidence base and reinforce our conclusions.

1 INTRODUCTION

Non-structural elements (NSE's) within a building are generally classified into three broad categories:

- Architectural elements, ie exterior cladding, glazing, ceilings, partitions and stairs;
- Services components and equipment, including air conditioning plant, ducts, lifts, escalators, pumps and emergency generators; and
- Building contents, such as movable furniture, bookshelves, computers and entertainment equipment.

Paper 4

This paper focuses mainly on the services with specific attention to the Seismic Performance of Non-Structural Elements (SPONSE) of these elements.

1.1 The Client Brief & Scope

Fletcher Construction engaged WSP Opus as part of a significant refurbishment of TVNZ Television Centre in Auckland. The refurbishment included a complete upgrade of the internal fit out, including a large proportion of the Building Service Elements. The project was completed in two stages, with WSP Opus doing the second stage.

WSP Opus' scope focused on three main tasks. Firstly, familiarise ourselves with the existing structure in order to be able to overlay and co-ordinate the non-structural elements. Secondly, complete the structural design of the bracing solutions. Finally, we were to carry out Construction Monitoring. The target level was CM3, which approached CM4 for some of the more complex situations. Our scope was specifically focused on the lateral restraint only of the NSE's. Gravity support of the NSE's remained the responsibility of the sub-contractors installing the services.

The structural assessment of the building and design of alterations to the primary structure was carried out by Harrison Grierson.

1.2 Building Description

The TVNZ Television Centre was designed in 1987 and is effectively separated into two areas. The "front" of the building is an eight storey tower for office and administration type activities that includes the main entrance and lobby. This was the area included in Stage 1 of the refurbishment. The "rear" of the building is a large four storey space, housing office type spaces, along with studios, heavy plant areas and basement car park and delivery bay. This area was covered by Stage 2 of the refurbishment completed by WSP Opus.

The primary structure for both the "front" and the "rear" of the building is a two-way concrete frame, with some shear walls. The floor for both areas is a hollowcore floor (typically 200 thick) with 60mm topping. The building has piled foundations, with light weight steel framed roofs over both sections of the building.

2 PROJECT CONSTRAINTS

The project overall was a refurbishment rather than any large scale extensions or structural alterations. The focus of the project was to upgrade the internal layout and fit out, improve functionality and generally modernise the building. The Architectural concept for the spaces was open plan. There are minimal internal partitions and, for most of the spaces, the ceilings were made from acoustic panels directly stuck to the underside of the slab over. This meant the majority of our effort was focused on mechanical duct work and cable trays for electrical and data and some hydraulic pipework. Fire sprinkler restraint was excluded from our scope, although consideration was needed for coordination and proximity of our work.

At the time we joined the project for stage two, significant time and budgetary pressures existed. Stage 1 of the refurbishment was essentially finished and occupied and the soft strip out for stage two was complete. The Architectural and Building Services designs were complete and the installation of non-structural elements was awaiting our design.

2.1 Architectural Considerations

Adding to the time and cost pressure was the relatively late inclusion of visual constraints from the Architects. The open plan architectural philosophy meant that the vast majority of the restraints were to be visible and the Architect wanted the final solution to be as light looking as possible. This essentially ruled out the use of angles or unistrut members as tension/compression braces and, in some cases, braces of any style were discouraged. This meant that our solution had to be sympathetic to the architectural constraints and we needed to employ solutions such as inverted portal frames or one-off cantilever hangers. This also meant that we had to 'bundle' services to make efficient use of the inverted portal frames.

Figure 1: Cantilever post detail where Arch didn't want braces

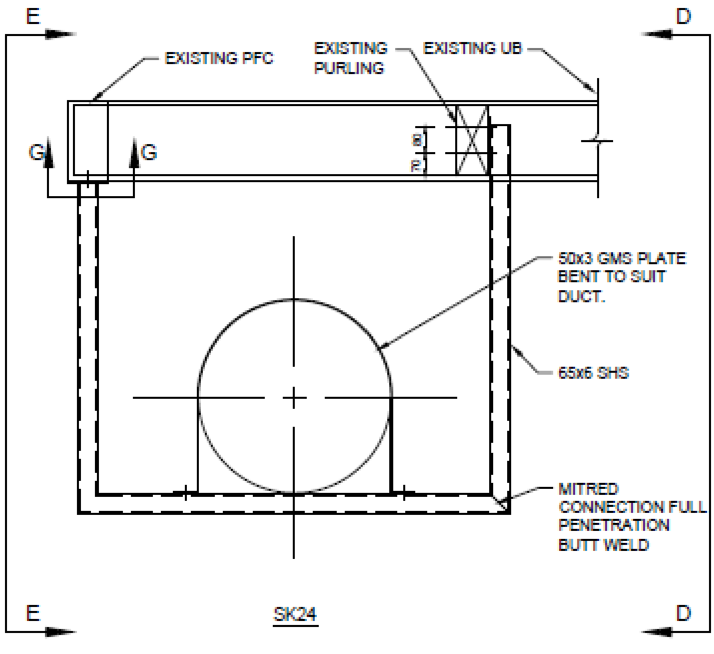

Figure 2: Steel portal solution

3 DESIGN CONSIDERATIONS

Successful installation of seismic restraint for NSE's requires a system type approach for this project we considered:

3.1 Standards

There are currently four commonly used NZ Standards for design of seismic restraint of Non-Structural Elements and one for seismic restraint of contents:

- NZS1170.5 including amendment number 1
- NZS 4219 (Seismic Performance of engineering systems in buildings)
- NZS 4541 (Automated fire sprinkler systems)
- AS/NZS 2785 (Suspended ceilings – Design and Installation) - Not cited as a Verification Method
- NZS 4104 (Seismic Restraint of Building Contents)

The first three are cited as verification methods under the New Zealand Building Code. Various Structural engineering, Architectural and Services engineering specifications refer to these.

Currently, there varying performance requirements between each Standard. NZS 4219 and NZS 4541 have some commonality regarding seismic design loads and interaction between elements, whilst the requirements of AS/NZS 2785 do not align well with the other Standards. Issues with the standards include:

- AS/NZS 2785 refers back to NZS 4203 which has been super seeded by NZS1150.5
- NZS1170.5 had Amendment 1 issued in September 2016 but had not yet been cited at the time of design.

Importantly, Amendment 1 of NZS1170.5 has included updated definitions and notes to table 8.1. Parts P5 now apply to all buildings not just IL4 buildings. This means that there is a requirement for all parts that "are required to be operational/functional for the building to be occupied" to be designed for SLS2 loads. These loads are given in the notes of table 8.1 but are significantly higher than previous.

A summary of the design requirements is presented in table 1 below:

Table 1: Summary of New Zealand Standards for design of Non-Structural Elements

Standard	NZS 4219 (Seismic Performance of engineering systems in buildings)	NZS 4541 (Automated fire sprinkler systems)	AS/NZS 2785 (Suspended ceilings – Design and Installation) *Not cited as a Verification Method*
Performance Requirements	P1, P2, P3, P4 and P5 categories as defined by NZS 1170.5. Performance requirements for ULS cases stated.	All sprinkler system elements shall be designed and installed so as to remain operational at ULS earthquake loads specified in NZS 1170.5	ULS performance – ceiling grid and its suspension system to be designed for ULS loads without causing impact with structure or other services and without causing ceiling tiles of 1.5kg or more to dislodge over occupied spaces or egress routes.
	All elements to be restrained so that system retains structural and operational integrity without requiring repairs after SLS1 earthquake	The sprinkler system shall not be damaged or impaired by the movement or failure of other features or elements of the building	SLS performance – Probability of loss of serviceability of the system is acceptably low and the ceiling maintains its intended performance level throughout its intended life

Standard	NZS 4219 (Seismic Performance of engineering systems in buildings)	NZS 4541 (Automated fire sprinkler systems)	AS/NZS 2785 (Suspended ceilings – Design and Installation) *Not cited as a Verification Method*
		Parts category P4 referenced.	Ceiling hangers shall be proportioned such that the failure or removal of a single hanger does not trigger a progressive collapse of the ceiling system
Design Requirements	Specific design using NZS 1170.5 and non-specific design (prescriptive method to determine earthquake loads along with 2.5% drifts and prescriptive capacity of braces for given bolt fixings)	Piping support system based on an assessment using earthquake loadings of NZS 1170.5 (parts category P4), or piping support system to comply with prescriptive requirements	Earthquake design loads refer to NZS 4203. Current version of NZS 1170.5 is ambiguous as to whether or not ceiling systems need to be designed to resist ULS loads or not
	Specific design includes the design of all equipment, their restraints and their fixings to the primary structure such that they have adequate strength, stiffness and ductility in accordance with the provisions of the appropriate material standards	Clause 403.12.2 – All pipework shall be designed to resist repeated forces due to seismic acceleration of 1.0g acting on the mass of the pipework in any direction in addition to the gravity force.	ULS load combinations similar to NZS 1170.0 except gravity which is more onerous at 1.4G & 1.7U Both vertical and horizontal earthquake actions to be considered
Interaction between elements	Prescriptive clearances provided	Clause 5.2 Minimum clearance to building elements (walls, floors, beams, platforms and foundations) are provided.	Partitions shall be fixed to the primary ceiling framing in accordance with the ceiling manufacturer's requirements. Where the partition is face loaded, the top plate of the partition shall be braced within the ceiling plenum or partition continuous from floor to floor
	Equipment supported independently of suspended ceiling shall have a clearance of 25mm all round	Gaps may be sealed with flexible or frangible material (gypsum board is considered frangible).	Mechanical and electrical services shall be completed before installation of the suspension systems
	Plinths – prescriptive detail on connection of plinth to floor slab		Basic guidance provided for mechanical air terminal devices and downlights, all other services which are to be incorporated into the suspended ceiling shall be in accordance with AS 2946 or NZS 4219

3.2 Co-ordination

In order to deliver on an efficient, cost effective solution, we promoted an extra service within our offering. This was to take all of the available information from the sub-contractor shop drawings, along with the Architectural ceiling plans, and overlay these to identify areas where modifications to the proposed layout would lead to a more co-ordinated solution. From there, it was possible to identify common layout arrangements that would be suitable for installation of “standard solutions”.

One of the challenges was working more directly with the sub-contractors than in other situations and trying to implement a new approach to the seismic restraint. Generally, the sub-contractors followed our co-ordinated, design. Having the site manager from the main contractor support us was important for this cooperation, however, there were still a number of examples where the sub-contractors overlooked the solution being provided and installed alternative layout. In most cases these were rejected.

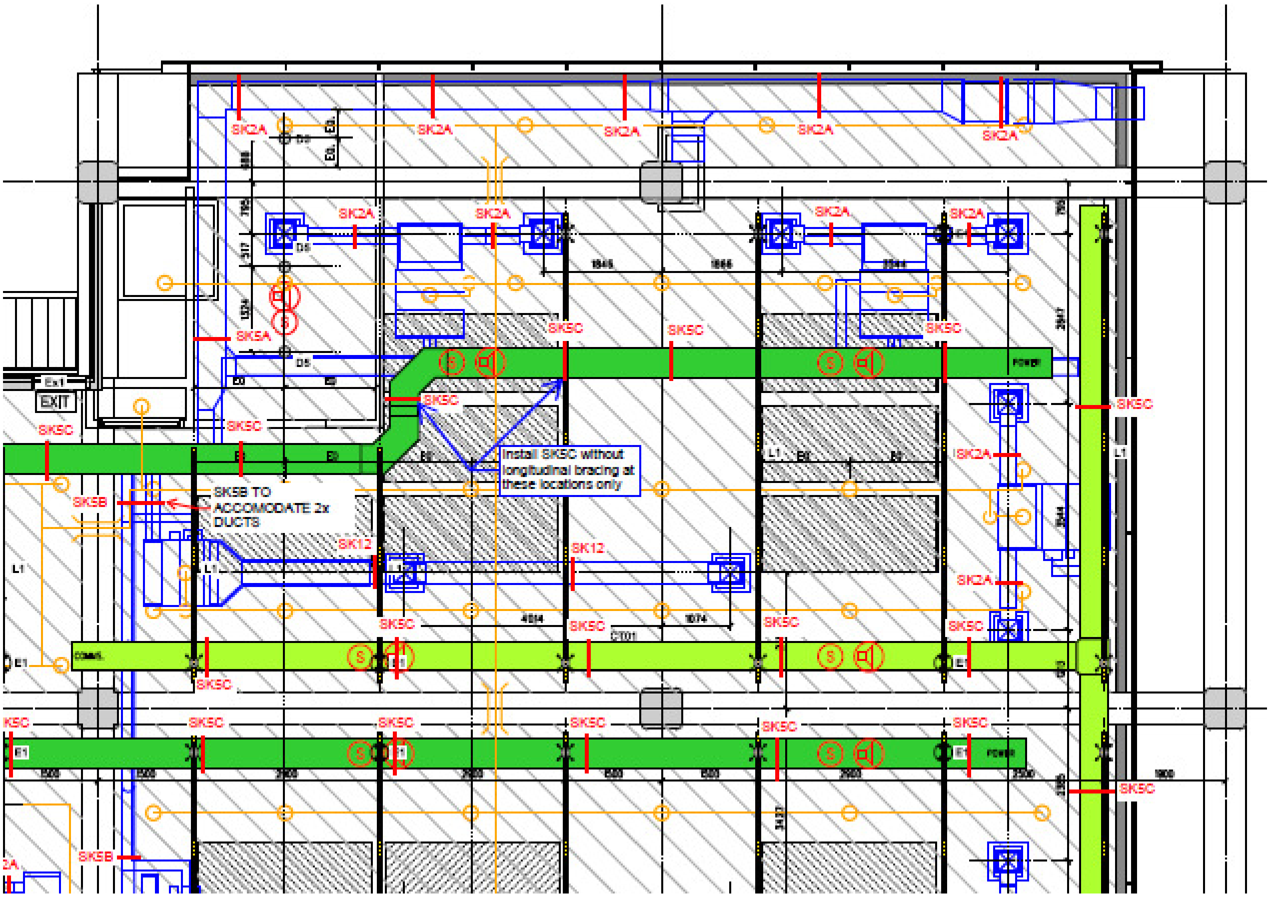

Figure 3: Example of co-ordinated servicse plan with position of seismic braces shown

4 THE SOLUTION

4.1 Philosophy

The overall aim of our engagement was to improve the general efficiency of the seismic bracing design and reduce the overall cost and time of completing the project. Our design approach was to provide standard details that would cover as many situations as possible (approximately 80%) of the installations. At the completion of the co-ordination stage, we identified the 15 most common building services arrangements and provide details for these. These included single linear items, such as stand-alone ducts, cable trays and hydraulic pipework, and those areas of co-ordinated services.

To make the standard details versatile, we included tables of bracing sizes and configurations options, depending on the hung height and size of the item.

Figure 4: Simple configuration on unistrut lengths off underside of slab, to allow for some positional tolerance

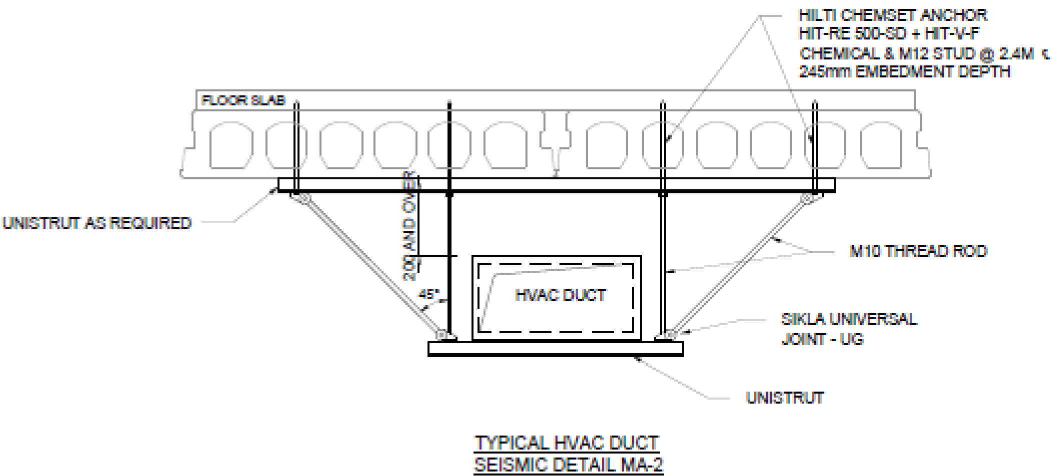

Figure 5: Example of standard detail

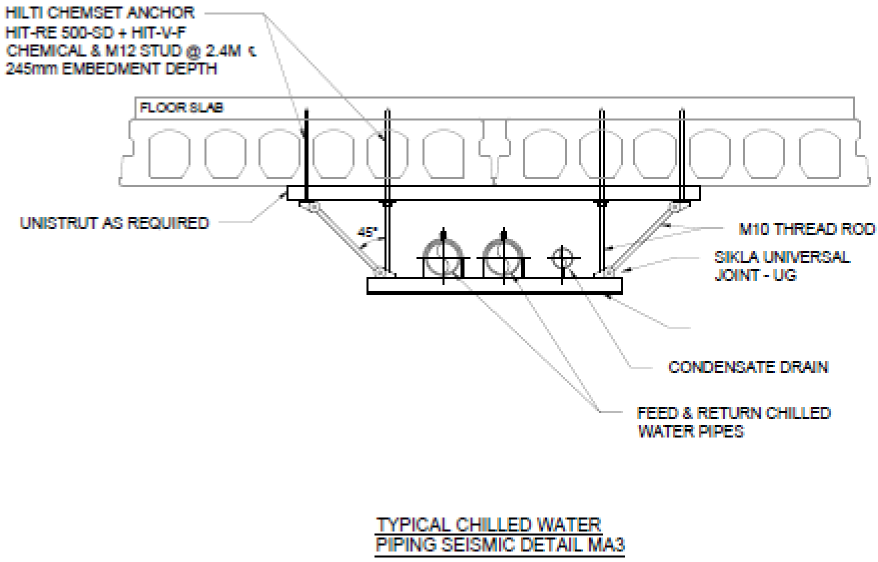

Figure 6: Example of standard detail

Bespoke items were designed and documented individually. Typically, these items included those services identified as requiring a higher architectural finish, services in the "back of house" plant areas where larger plant items are located and those services that required specific acoustic treatment.

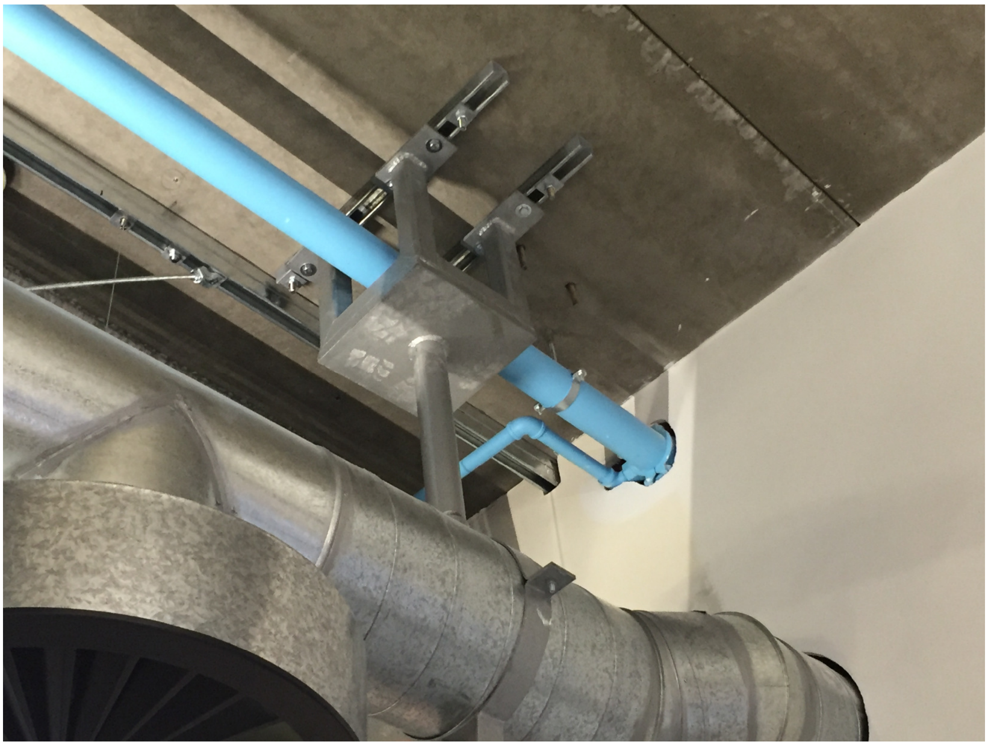

Figure 7: Specific solution for area where services clashed and could not be moved

5 LEASSONS LEARNT/DISCUSSION

Given that this project was being designed and delivered to a different model from the traditional sub-contractor led process, there were a number of lessons taken from our experiences:

- Support and a good relationship between the designer and main contractor with agreed lines of communication to the sub-contractor was critical to the success of the project. The support of the main contractor was critical to moving through impasses and towards a finished installation when the design was challenged.
- A series of early meetings with key sub-contractors to communicate and coordinate the design was generally successful.
- For refurbishment projects, understanding the structural constraints of the existing structure is critical. For this project, the concrete elements were generally able to resist the restraint loads, however, for the lighter weight structure, we needed to work closely with the structural engineer responsible for the primary structure. In some cases, new secondary structure was required.
- Fixing to the underside of hollow core floors required special attention where there are limited options for seismically rated anchors on the market. Most fixing types can adequately resist relatively low gravity loads but we could not satisfy ourselves of their suitability for cyclic, lateral loads. The solution adopted was that of Stage 1, where a chemical anchor was fixed into the slab topping from below. A short section of Unistrut provided some flexibility in position.

Figure 8: Simple configuration on unistrut lengths off underside of slab, to allow for some positional tolerance

- Despite efforts to communicate design and be available on site to resolve issues, we still had issues where sub-contractors reverted back to a more traditional model of operation. Part of the reason for this was the overlap and/or discrepancies between various standards and the interpretation of them.
- NZS4219 includes a number of short cuts and "rules of thumb" such as not needing to provide restraint if the service is hung close to the floor soffit. These rules can provide strong motivation for sub-contractors to revert back to "first in best dressed" type behaviour to avoid providing restraint. The result of this

behaviour is that one sub-contractor has a relatively easy time and the others require additional effort and expense to work around installed work.

- While much co-ordination can be carried out during a ‘design phase’, site supervision and construction monitoring is important. Significant effort is required to educate the industry to deliver to a new model. Sub-contractors are sometimes stuck in their ways, and sometimes reluctant to follow the details.
- Until the sector fully embraces a different procurement model, attendance on site to rectify any issues in a timely manner is critical. In our experience, this is a significant component of the designer commission.
- As project budget and time pressure increases, the willingness to use a new model decreases and the temptation to revert back to traditional ways increases.
- Standard details are good as they provide certainty and efficiency, they should be used where possible.
- Just as the design and installation of NSE restraint requires a different mindset, you also need to apply a different mindset to the contractual relationship and commission of the design team.
- As with all projects, communication was a critical component to the success of this project.

Figure 9: Wrong sized washer that got bent during installation

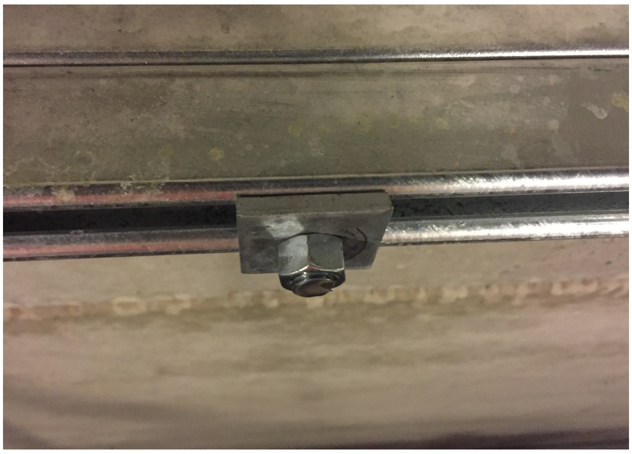

Figure 10: correct washer size

Figure 11: Poor installation. If in doubt, chuck in more washers

Figure 12: Standard Solution

Figure 13: Gravity system of light weight structure with braces to be installed

6 REFERENCES

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