NZS4541:2013
Seismic Design

April 2015

Chris Mak

Introduction

- Christchurch 2010/2011 Events and Wellington – 2013 Event
  - Other than large tanks – sprinkler systems performed reasonably well
  - One high profile Wellington incident has resulted in greater emphasis on all trades

- Why did Sprinklers perform well
  - Edgecumbe Earthquake -1987
    - Significant upgrade on NZS4541 in 1996
      - Written by a Professional Structural Engineer
  - NZ installation practices
  - Inspection regime?
  - Good luck, not good management?
- All of the above

- NZS4541:2013 has changed seismic design requirements
  - Are installers or designers aware of this?
  - Does it matter?

- This presentation is intended to concentrate on pipework bracing requirements Clause 403.13.2

Requirements

- Clause 105 - Seismic Resistance
  - *Remain operation at Ultimate Limit State Earthquake Loading*
    - *If building still standing, sprinkler system needs to remain operational.*
    - *Building may not be serviceable (Serviceability Limit State.)*
  - *Movement or failure of other services cannot impair Sprinkler System*
  - *Water supply tanks to be designed to same Importance Level as the Building itself.*

- Clause 112.2 - Completion Documents
  - *As-built sprinkler and pipe layout plans with seismic resistance provisions, including whether the design is to 403.12.1(a) or (b)*

- Clause 403.12. Seismic Resistance of Pipework
  - Reviewed next slide

- Actions
  - Aon to issue a Technical Note on requirements of clause 112.2 May 2015.
  - Aon to review Technical Note 09-04 (Seismic Design of Water Supply Tanks) May/June 2015
    - Are your tank suppliers up to date with what NZS4541 requires?

Clause 403.12 – Seismic Resistance of Pipework

- Provides two options
  a) Seismic design to equal that of the Building Structure under NZS1170.5
     - May define seismic accelerations of up to 3 or 4 g.
     - Probably needs input from a structural engineer
       - Need to understand issues such as distances to fault lines, ground conditions and the like.

  b) Seismic Design to 403.12.1 to 403.13.4 inclusive
     - The "Cook Book" approach
       - Clause 403.12.2
         - *All pipework shall be designed to resist repeated forces due to seismic acceleration of 1.0 g acting on the mass of the pipework in any direction in addition to the gravity force.*
         - *Note: This load may be greater than the requirements of NZS 1170.5, and may increase the support size but it eliminates the need for a more detailed study.*

Seismic Design – The Cookbook Approach

- Stage 1 – Pipework Layout and Sizing
- Stage 2 – Bracing Locations
- Stage 3 – Bracing Loads
- Stage 4 – Bracing Sizing
- Stage 5 – Fasteners/Fixings

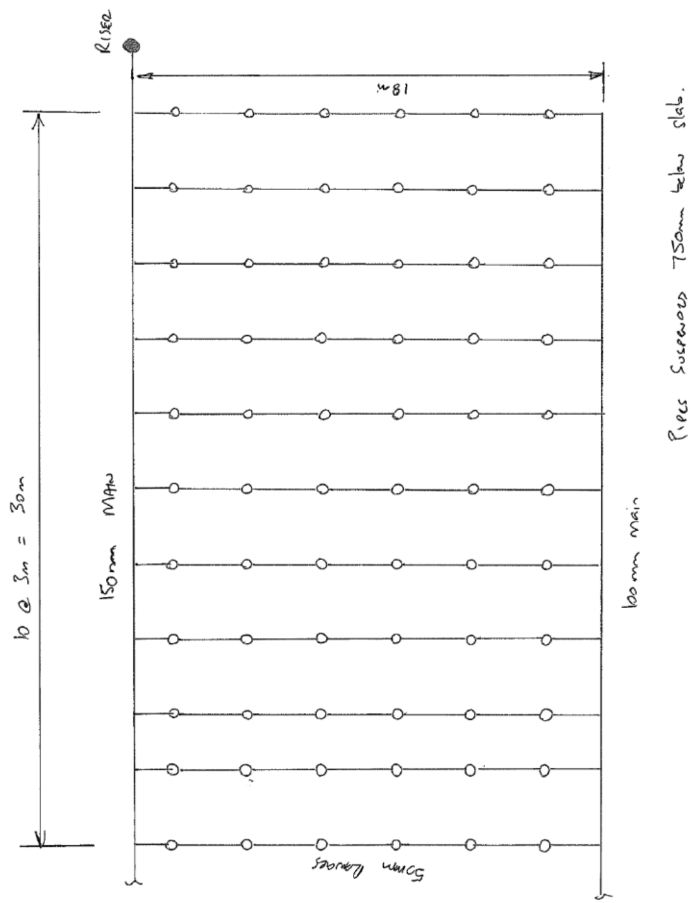
Stage 1 – Pipework Layout

- Pipework design
  - Layout and size pipework in normal manner
    - Where are you going to brace too?
    - By shifting pipe, can you reduce bracing costs?
      - Can you clamp to structure?
      - Can main runs be located near main structural elements?

Aon

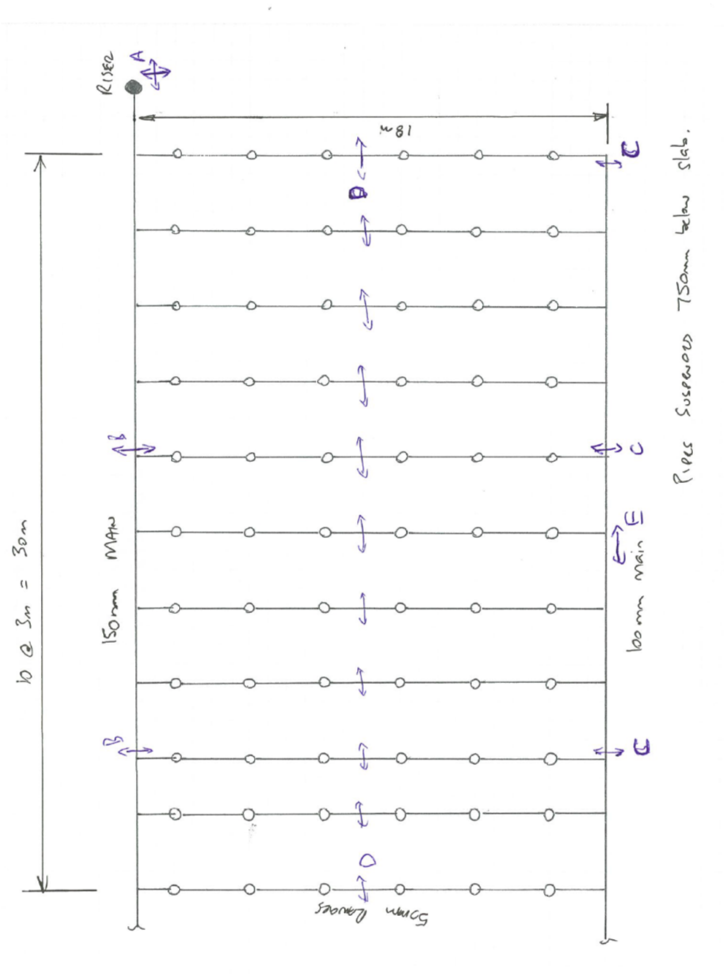
Hypothetical Exercise – Stage 1

- Worked example
- 3 x 3 grid
- Mains suspended 750mm below slab.
  - Why?
- 150mm front main
- 100mm back main
- 50mm ranges



Stage 2 – Bracing Layout

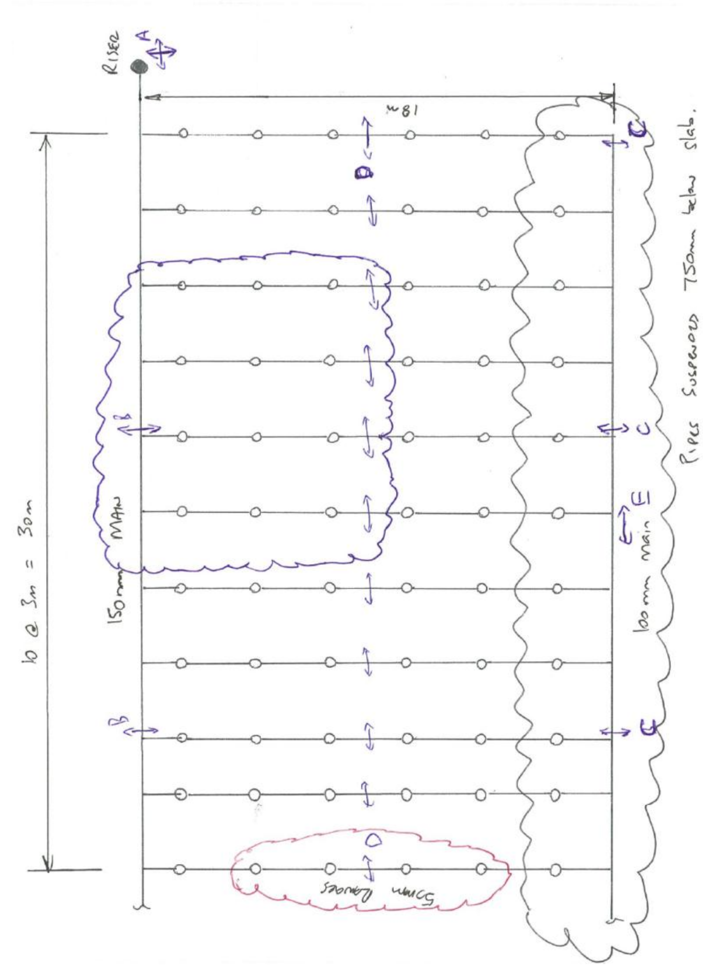
- Clause 403.2.4 - 403.2.6
  - Brace Locations
  - At riser
  - Mains
    - Lateral - maximum 12m centres
    - At *least* 1 longitudinal
    - Within 600mm of flexible couplings/seismic joints
  - Ranges
    - At last hanger
    - Laterally – at least every 12m
  - 5 different braces shown here



Stage 3 – Bracing Loads

- Refer Figure 4.3 and Table 4.5
  - Load distribution to pipework bracing
  - Each pipe needs to be factor in once
    - Both lateral and longitudinal
  - No “right” answer

  - **Brace B – Lateral brace**
    - 12m 150 pipe at 38.8kg/m= 465.6kg
    - 9m 50 pipe x 4 ranges x 7.73kg/m= 278.2kg
    - Total load = (743.8kg +*10%)* x 9.8m/s^2= 8.0kN
  - **Brace D –Lateral brace**
    - 12m 50 pipe x 7.73kg/m = 92.76kg
    - Load = (92.76kg + 10%) x 9.8m/s^2 =1.0kN
  - **Brace E –Longitudinal brace**
    - 30m 100mm pipe x 21.1kg/m = 633kg
    - 3m 50 pipe x 11 ranges x 7.37kg/m = 243.1kg
    - Total Load = (876.1 + 10%) x 9.8m/s^2 =9.4kN



Brace Loads

Table 4.5 – Weight calculations

Pipe size (nominal diameter) (mm)	Weight including water (W_p) (kg/m)	Material
25	3.05	BS 1387 medium screwed and socketted tube
32	4.19	
40	5.03	
50	7.37	
65	10.3	
80	13.7	
100	21.1	
150	38.8	
200	62.6	BS 3600 tube

NOTE – For a seismic acceleration of 1.0 g the required restraining force F_p is given by:

$F_P = W_P \times 0.00981 \times L_P$ (kN)

where L_P = length of pipe under restraint.

Calculating Bracing Loads

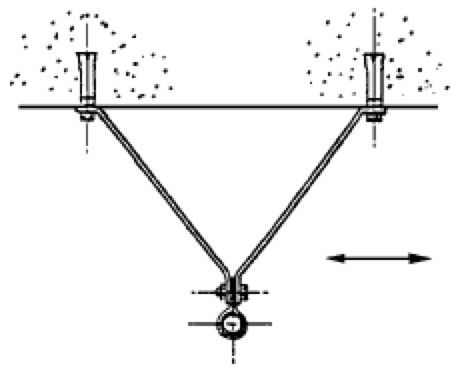
- Force =mass x acceleration/1000
- Force is the load, and is measured in kiloNewtons (kN)
- Mass is the weight of the component, in kilograms (kg)
- Acceleration is 1.0g (for the cookbook approach) or as specified by the structural engineer
  - 1.0g is $9.8 m/s^2$
- Example – at 1.0g (cookbook approach) was is the load for a pipe weighing 320kg
- Force = 320kg x ($9.8 m/s^2$) / 1000

  = 3.1kN

Stage 4 - Bracing Sizing

- Pipes are set 750mm below ceiling
- If braces at 45^0, braces are 1060mm long

- Brace B – 8.0kN
  - Table 4.6 – 40mm pipe.



- Brace D – 1kN
  - Table 4.6 – 10mm rod
    - Rod length?

- Brace E – 9.4kN
  - Table 4.6 – 50mm pipe
    - Split into 2 braces –each rated at 4.7kN minimum?
    - Two by 25mm at half spacing

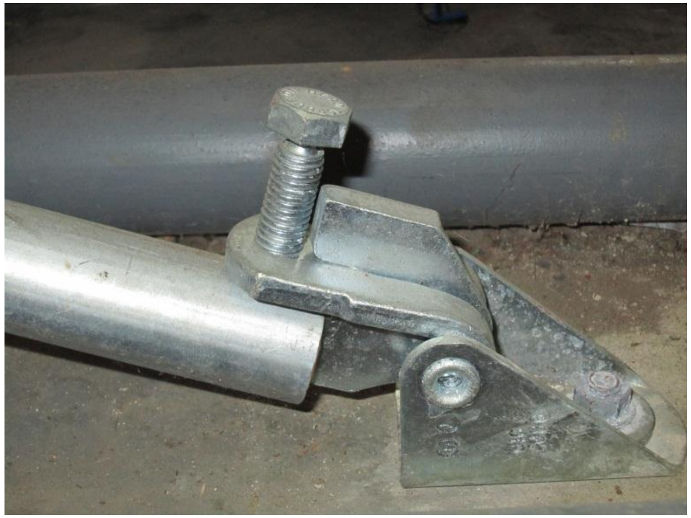
Brace Sizing (In compression)

Table 4.6 – Allowable horizontal loads of typical pipework braces

Shape and size (mm)	Allowable horizontal support load				
	Brace length for $l/r = 200$ (m)	**30° angle from vertical** (kN)	**45° angle from vertical** (kN)	**60° angle from vertical** (kN)	**Horizontal** (kN)
Galvanised steel wire 3.2 dia.	(tension only)	0.23	0.33	0.40	0.45
Mild steel rod					
10 dia.	0.50	1.0	1.4	1.7	1.9
12 dia.	0.60	1.4	2.0	2.4	2.8
16 dia.	0.80	2.5	3.5	4.3	5.0
20 dia.	1.00	3.9	5.5	6.8	7.8
BS 1387 medium tube					
20 NB	1.7	2.5	3.5	4.3	5.0
25 NB	2.2	3.9	5.5	6.8	7.8
32 NB	2.8	5.0	7.1	8.7	10.1
40 NB	3.2	5.7	8.1	9.9	11.5
50 NB	4.0	8.1	11.5	14.0	16.2
65 NB	5.1	10.4	14.7	18.1	20.8
Mild steel flat					
40 x 6	0.35	3.0	4.2	5.2	6.0
50 x 8	0.46	5.0	7.0	8.6	10.0
50 x 10	0.58	6.2	8.8	10.8	12.5
Mild steel angle					
25 x 25 x 3	0.96	1.7	2.5	3.0	3.5
30 x 30 x 5	1.1	3.4	4.9	6.0	6.9
40 x 40 x 5	1.5	4.7	6.7	8.2	9.4
50 x 50 x 5	1.9	6.0	8.4	10.3	12.0
60 x 60 x 6	2.3	8.6	12.2	14.9	17.2
80 x 80 x 6	3.1	11.6	16.5	20.2	23.3

Stage 5 – Pipe Fixings

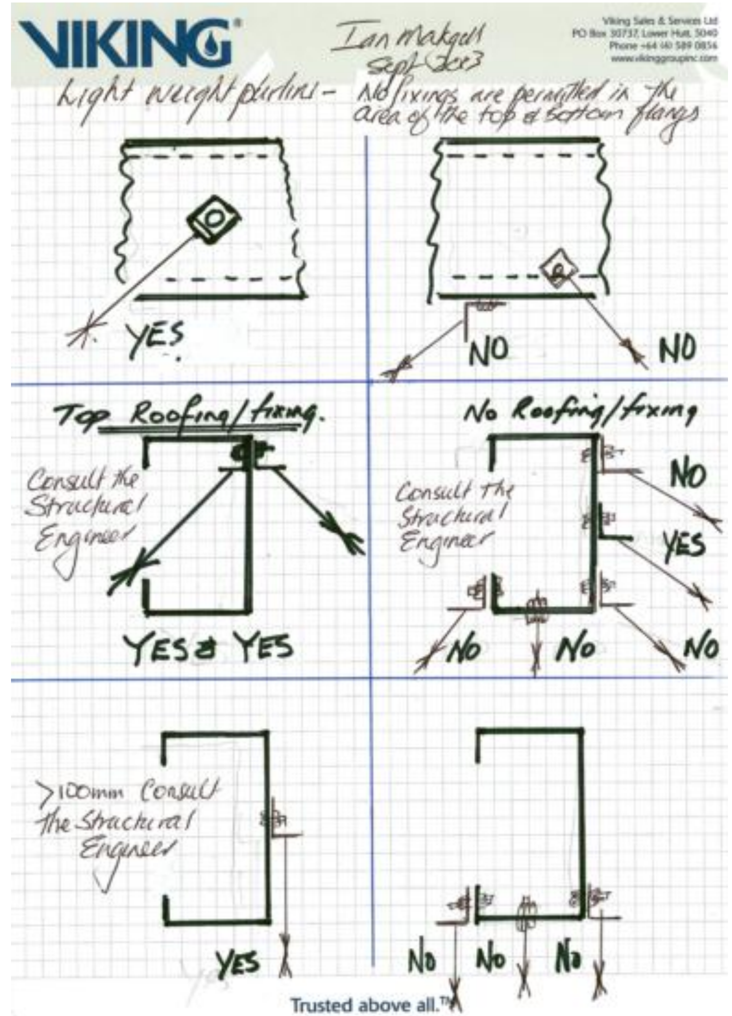
- How are you going to fix to pipe?
  - Pipe clamps?
  - Proprietary Seismic Fixings
    - Do your fitters know installation requirements?



Stage 5 – Fixings to Structure

Courtesy Ian Makgill

- Generic “rules”
- Show on drawings and seek approval where possible
    - Have seen this approach save one contractors bacon in the past



Stage 5 – Fixings to structure

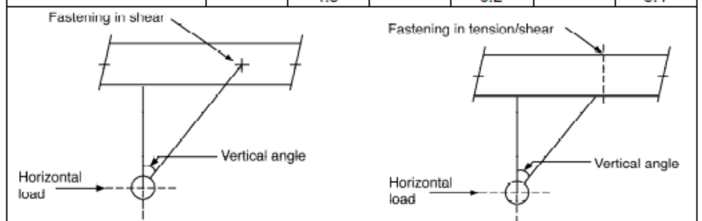
- In all examples here – Type B

- Brace B – M16 masonry anchor
- Brace D - M6 masonry anchor
- Brace E – two M10 masonry anchor

- What are you fixing too?
- Are anchor seismically rated
  - Dynasets?
  - Edge distances
  - Material condition?
- How strong is structure?

Table 4.7 – Horizontal load capacity of typical connections

Fastening type	Horizontal load capacity					
	Vertical angle 30°		Vertical angle 45°		Vertical angle 60°	
	Type A (kN)	Type B (kN)	Type A (kN)	Type B (kN)	Type A (kN)	Type B (kN)
Masonry anchors						
M6	1.7	1.3	2.4	2.0	2.9	2.6
M8	3.0	2.0	4.2	2.9	5.2	3.8
M10	4.4	2.9	6.2	4.3	7.6	5.5
M12	6.8	4.3	9.5	6.3	11.7	8.7
M16	12.0	5.7	17.0	8.7	20.9	12.3
Bolts to steel						
M6	1.7	1.9	2.4	2.6	2.9	3.0
M8	3.0	3.5	4.2	4.6	5.2	5.4
M10	4.7	5.5	6.7	7.3	8.1	8.5
M12	6.8	7.9	9.5	10.5	11.7	12.3
M16	12.0	14.4	17.0	19.1	20.9	22.0
Bolts to BP 450 purlins						
M6	1.7	–	2.4	–	2.9	–
M8	2.9	–	4.1	–	5.0	–
M10	3.6	–	5.1	–	6.2	–
M12	4.3	–	6.1	–	7.4	–
M16	5.7	–	8.1	–	9.9	–
Bolts to timber						
M12	2.1	–	3.3	–	4.4	–
M16	2.9	–	4.8	–	7.1	–
M20	3.7	–	6.4	–	10.0	–
Coach screws to timber						
M8	–	0.75	–	0.95	–	1.1
M10	–	1.3	–	1.8	–	2.2
M12	–	1.8	–	2.6	–	3.4
M16	–	3.0	–	4.2	–	5.6
M20	–	4.3	–	6.2	–	8.4



Type A **Type B**

NOTE –
(1) Bolted shear (type A) connections to timber assume a nominal timber thickness of 50 mm.
(2) Tension/shear (type B) connections to timber assume coach screws penetrate timber 10 times the shank diameter and have a minimum thread length 6 times the shank diameter.
(3) The loads for timber connections are for dry timber. For green timber reduce the loads by 30%.

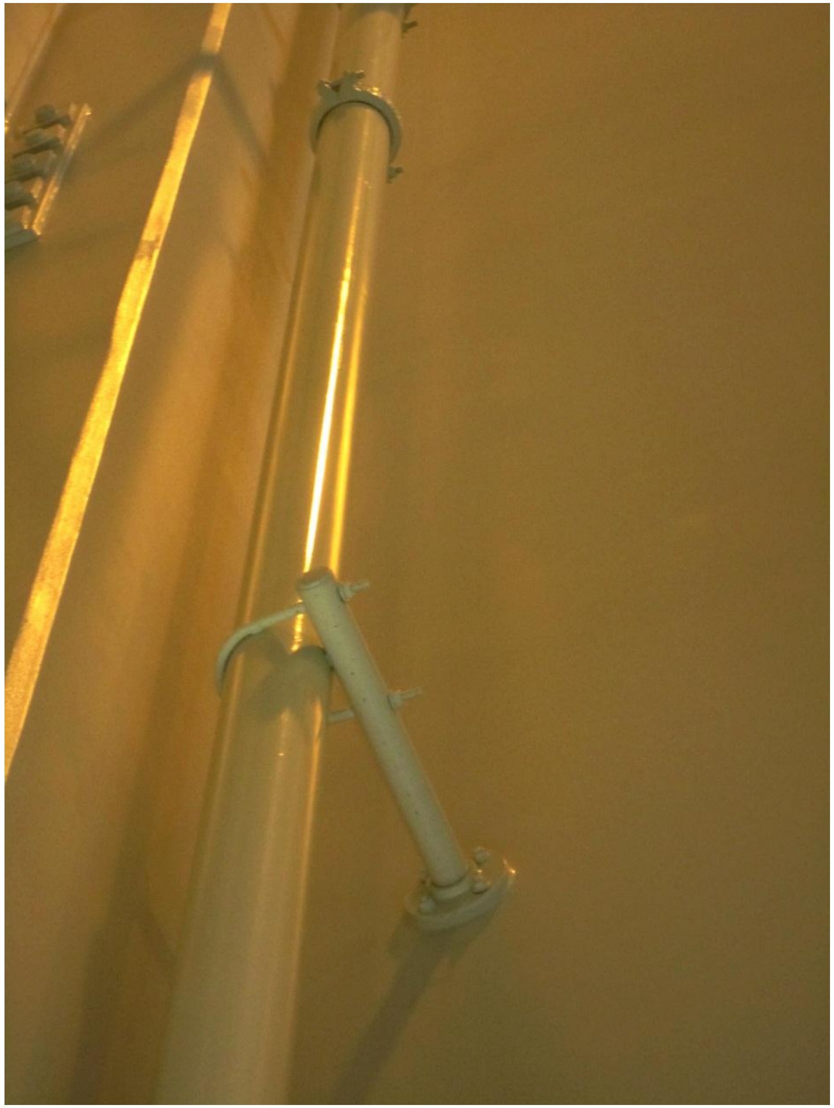
Aon

Errors and Omissions

Errors and Omissions

Errors and Omissions

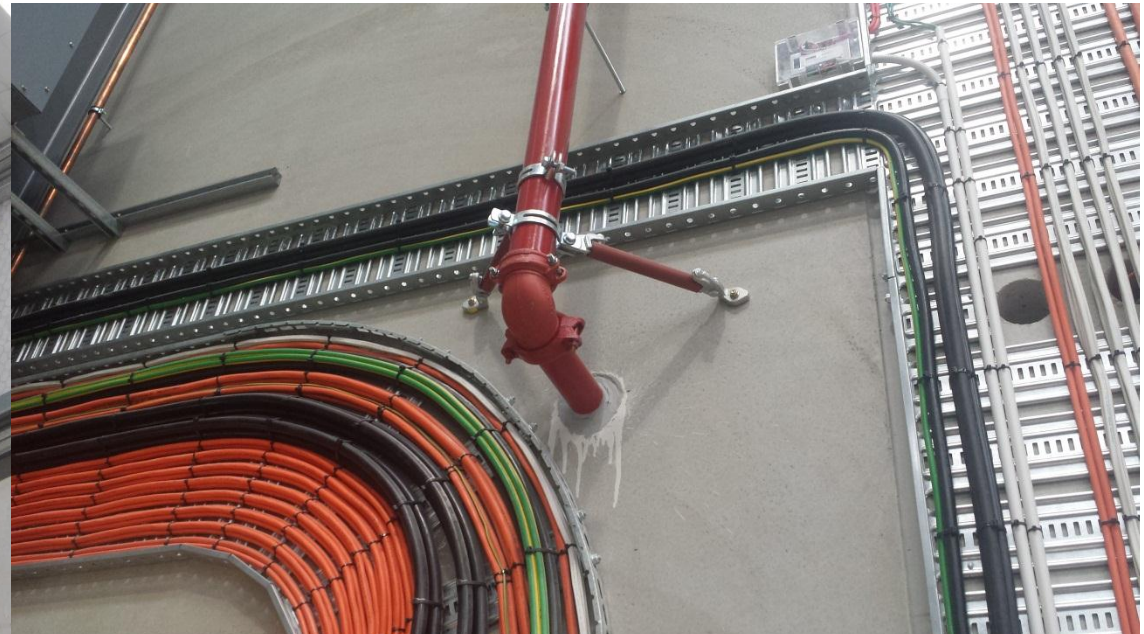
Errors and Omissions



Errors and Omissions

Errors and Omissions – Name 2 errors

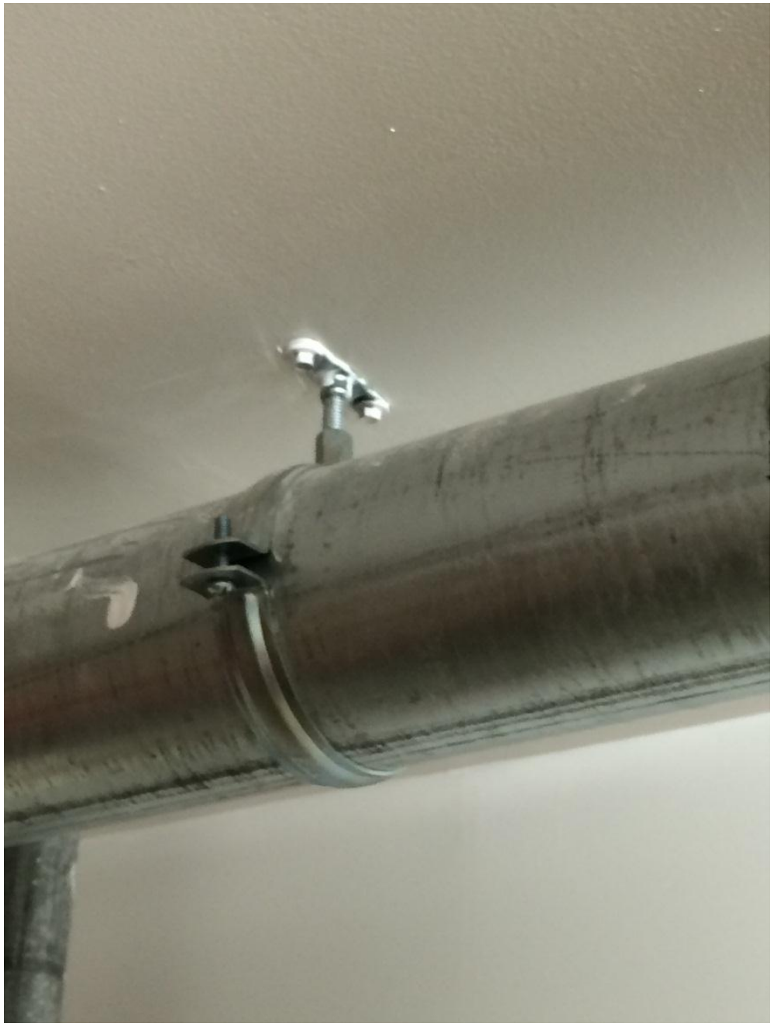
Good, bad and ugly

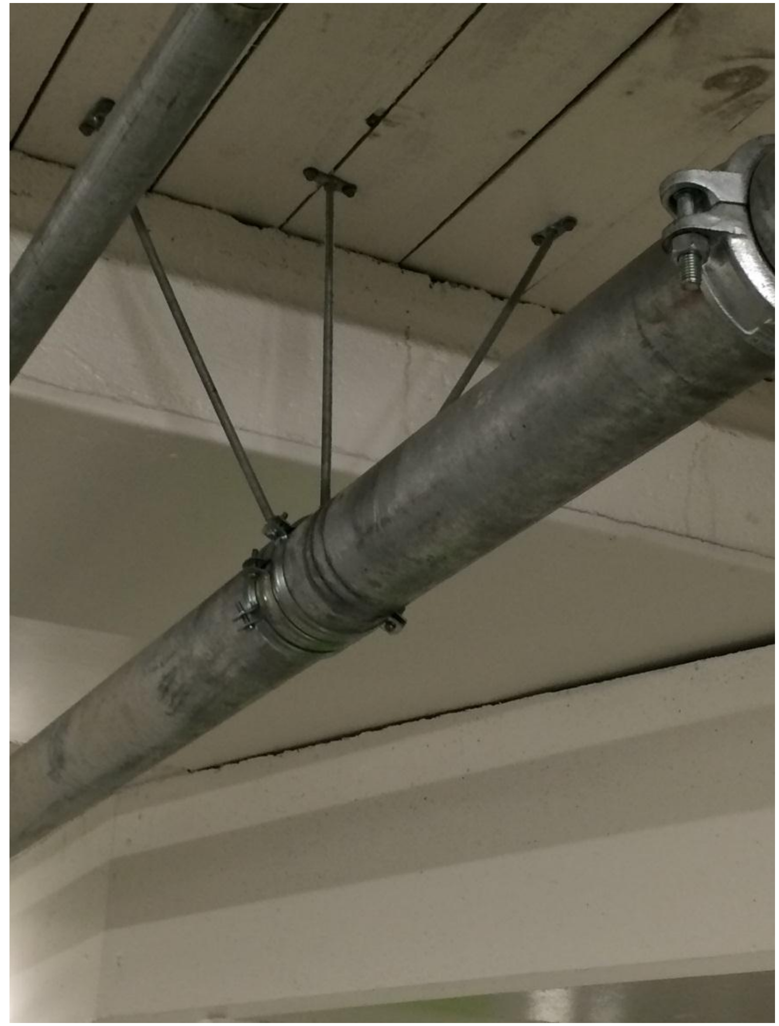


Good, bad and ugly

Good, bad and ugly

Good, bad and ugly





Errors and Omissions

- Threaded rod lengths
  - 10mm rod has a maximum length of 500mm if used in one direction
  - Bending threaded rod
- Inadequate structure
  - Bracing to weak building elements
  - Not taking advantage of primary structure
- Fasteners
  - Non-seismically rated concrete fasteners
    - Dynasets and the like
    - Refer Aon Technical Note 14-14 (June 2014.)
    - Edge distances
    - Timber size
- Risers
  - Require 4 way braces at top (and every six meters if all buildings)

Summary

- Bracing design is not rocket science
  - Simple calculations, with attention to detail
- Aon will be requiring evidence that it has been addressed
  - Will need to be documented as part of the design process
  - Some builders already are (PS from CPEng engineers)
- Clients can specify what they want
  - Much higher than 1.0g
  - We are encouraging them to clearly outline their design loads
  - Design concepts stay the same
  - 150mm rod length rule not applicable at higher loads
- There may be some errors in NZS4541, but fundamentally it is sound

- The Christchurch and (particularly) Wellington events have shaken up the construction industry
  - Builders and consultants have sat up and taken notice
  - Emphasis on all trades to brace correctly
    - Increased scrutiny on fire trades

Other Issues

- Presentation has concentrated on bracing
  - Hanger design and strength
  - Pipework
    - Flexibility
    - Rigidity
  - Clearances
    - Structure
    - Other trades
  - Building Seismic Joints
  - Pumps, batteries, controllers, tanks, etc
  - Racks and floating ceilings
  - Ceilings