Parts and Components

Draft TS1170.5, Section 8

The Problem

- The loading formulation for Parts and Components needed review –
  - it led to extremely high values, particularly in the low period range, lower levels of buildings
  - not clear if people understand its application well (part ductility).
  - Sometimes unconservative.

- Proposed A1/2 extended P5 designation from IL4 only to all buildings – are we ready for this!?
  - There is not a clear objective for all buildings being occupiable soon after the (SLS2) earthquake.
  - There is some possible confusion on what this may apply to and how to apply it.

Recent Developments of Note

- Local research:
  - Haymes, K, and Sullivan, T. *Recommended Revisions to the Approach in NZS 1170.5:2004 for the Seismic Design of Parts and Components.* Rev 2 Christchurch: University of Canterbury: 2023.
  - Haymes, K. *Developing Procedures for the Prediction of Floor Response Spectra*. PhD Thesis Christchurch: University of Canterbury, 2023.
- International:
  - American Society of Civil Engineers, ASCE/SEI 7-22 Minimum Design Loads and Associated Criteria for Buildings and Other Structures.

Significant Findings

- When components are in resonance, a small amount of effective ductility provides a significant reduction in the actions on the part, more so than 1170.5 currently suggests. But conversely, the elastic demand at resonance may be much higher than 1170.5 suggests.
- The amount of effective ductility may be nothing more than the amount of movement provided by some bolt slip.
- When very stiff parts are directly fixed to a floor, with no slip, the part will experience only the floor acceleration
- Non-linear response of the supporting structure will limit peak floor accelerations, also limiting demand on parts and components. This effect is not currently acknowledged in 1170.5, but is covered in ASCE7-22.

The recommended approach in New Zealand technical standard

$$\boxed{F_{ph}} = \frac{C_p(T_p)}{\boxed{\Omega_p}} R_p\, W_p \le \frac{7.5\, PGA\, W_p}{\Omega_p} \qquad C_p(T_p) = \boxed{PGA} \left[\frac{\boxed{C_{Hi}}}{\boxed{C_{str}}}\right] \left[\frac{\boxed{C_i(T_p)}}{\boxed{C_{ph}}}\right]$$

3. *Amplification of part response*

reduced by
component response factor

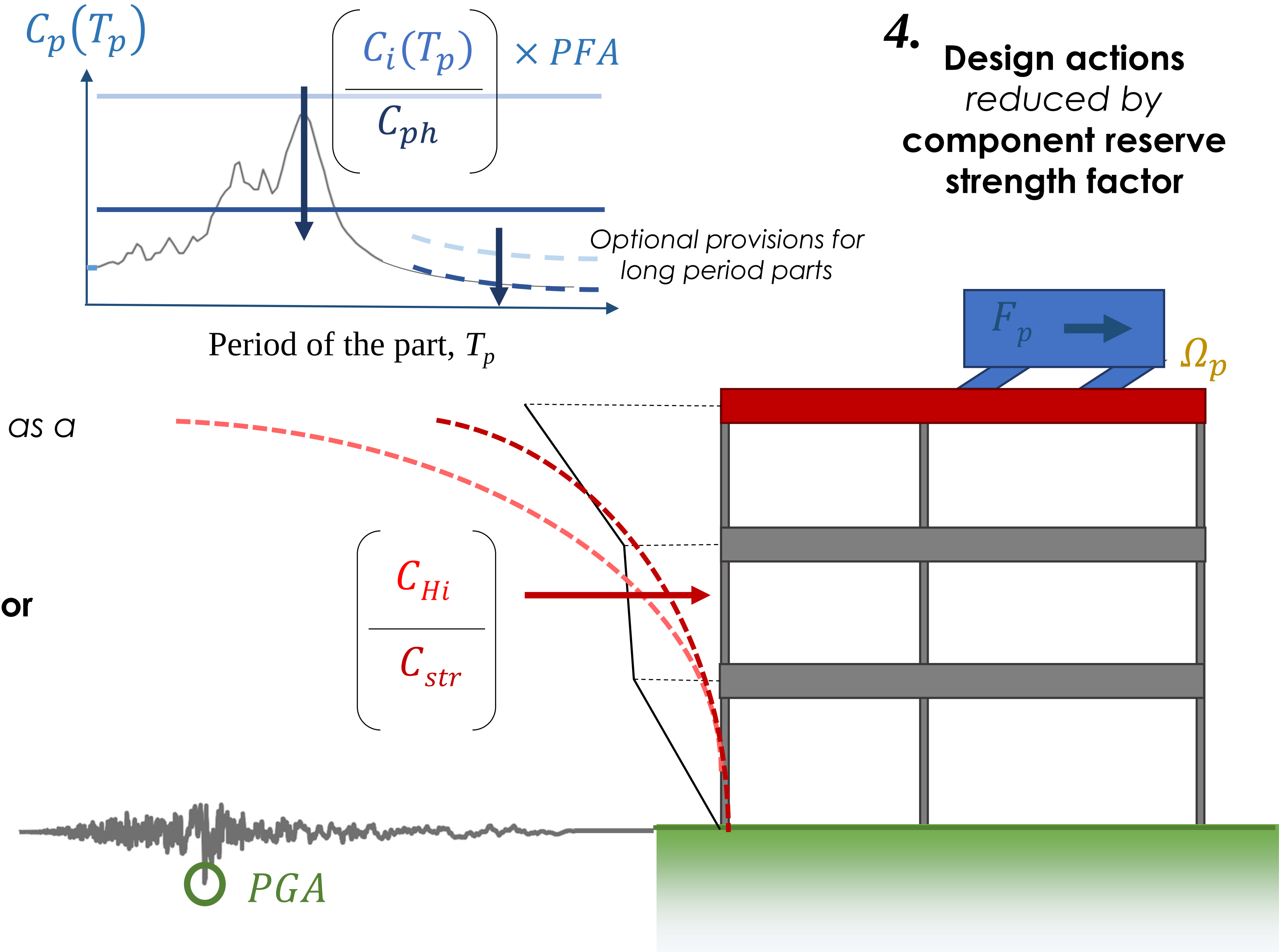
↑

2. *Distribution of peak floor accelerations as a function of peak ground acceleration*

reduced by
structural nonlinearity reduction factor

↑

1. *Ground motion excitation at base considering limit state design*
peak ground acceleration



4. **Design actions**
reduced by
component reserve strength factor

Haymes, K., & Sullivan, T. (2023). *Recommended Revisions to the Approach in NZS 1170.5:2004 for the Seismic Design of Parts and Components*

How do demands get transferred to the floors?
Described using the *Floor Height Coefficient*

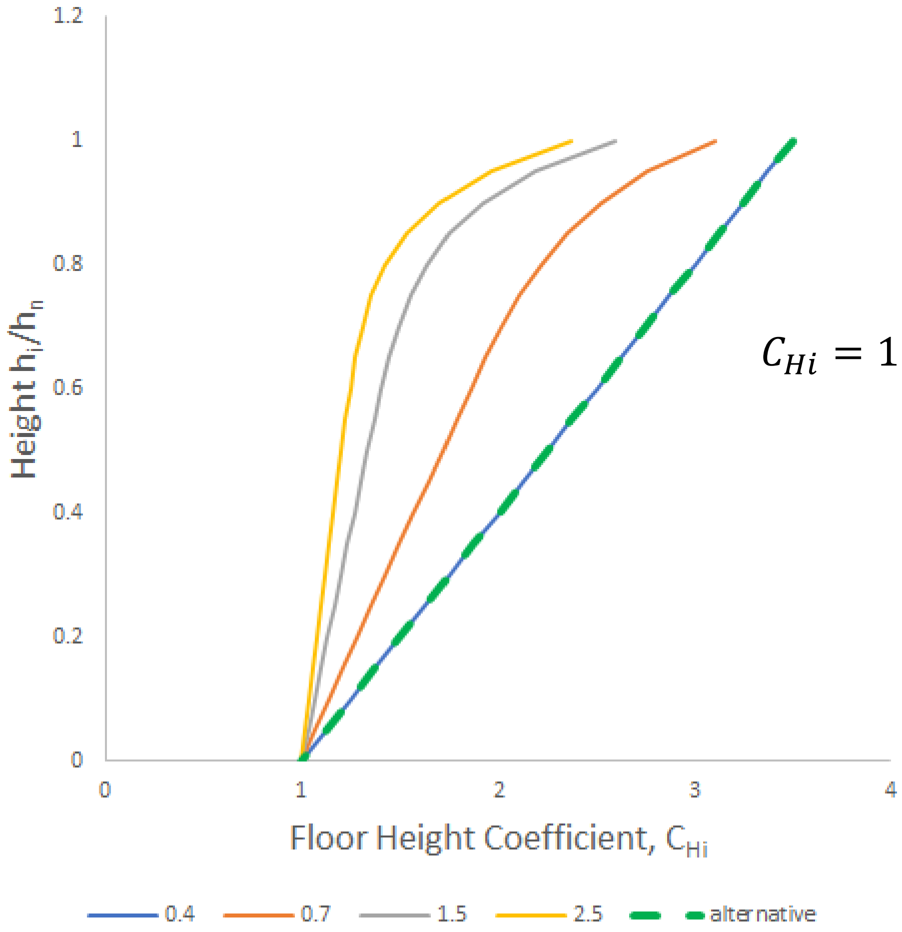
$$C_p(T_p) = PGA\left[\frac{\boxed{C_{Hi}}}{C_{str}}\right]\left[\frac{C_i(T_p)}{C_{ph}}\right]$$

ASCE 7-22 approach, adopted here, was developed using records from ***over 100 instrumented buildings***

Examined
peak floor acc. / peak ground acc.
> PGA may be a good measure if using this approach

Function of ***T_1***, the fundamental building period, but can be applied without it

Significantly ***less conservative over lower levels***, observed to be accurate in a range of studies



$$C_{Hi} = 1 + \frac{1}{T_1}\left(\frac{h_i}{h_n}\right) + \left[1 - \left(\frac{0.4}{T_1}\right)^2\right]\left(\frac{h_i}{h_n}\right)^{10}$$

Alternatively,

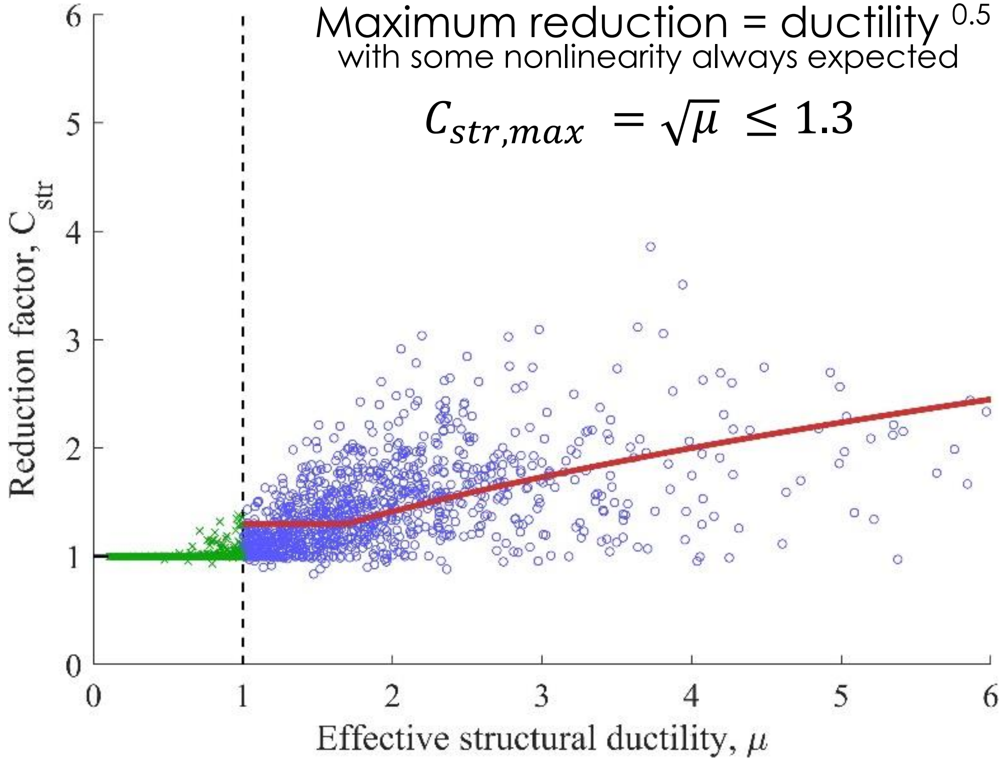
$$C_{Hi} = 1 + 2.5\left(\frac{h_i}{h_n}\right)$$

How are the demands that get transferred to the floors reduced by structural nonlinearity?
Described using the *Structural Nonlinearity Reduction Factor*

$$C_p(T_p) = PGA\left[\frac{C_{Hi}}{\boxed{C_{str}}}\right]\left[\frac{C_i(T_p)}{C_{ph}}\right]$$

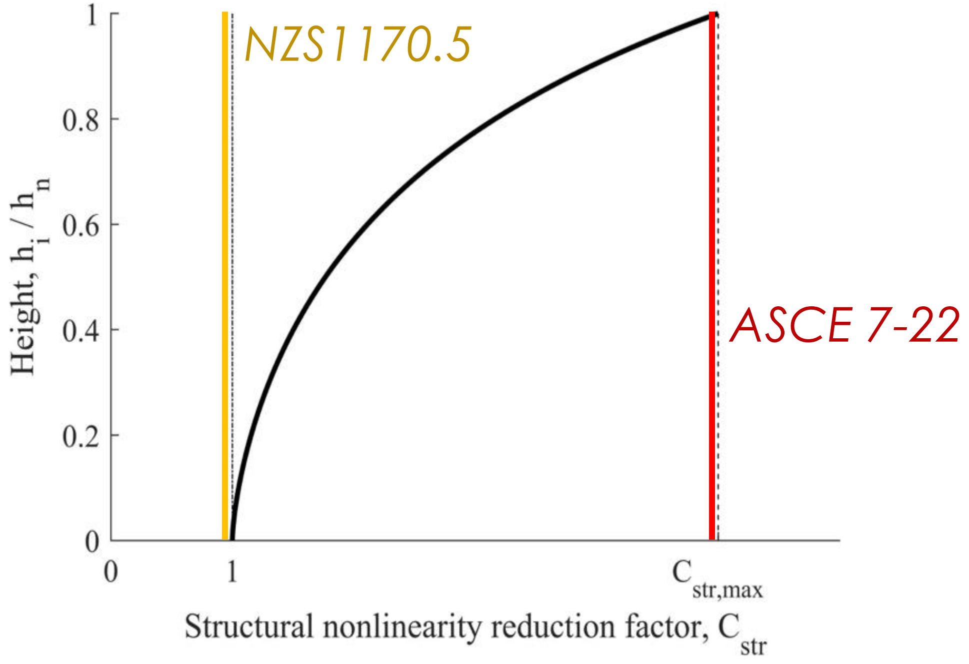
Structural nonlinearity primarily reduces the response of the ***first structural mode***

Higher structural modes exhibit ***less reduction***


Maximum reduction = ductility $^{0.5}$
with some nonlinearity always expected

$$C_{str,max} = \sqrt{\mu} \leq 1.3$$

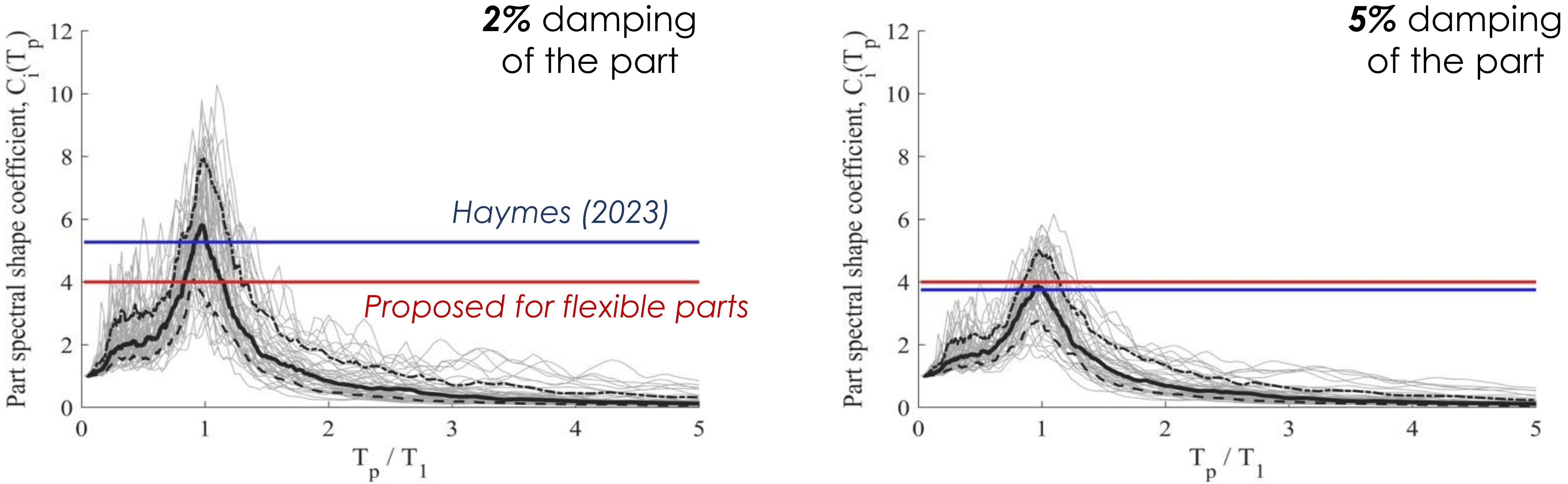
Maximum reduction at roof
Less over lower levels



How do demands from the floors amplified by the part?
Described using the ***Part Spectral Shape Coefficient***

$$C_p(T_p) = PGA\left[\frac{C_{Hi}}{C_{str}}\right]\left[\frac{\boxed{C_i(T_p)}}{C_{ph}}\right]$$

Parts experience "dynamic amplification" where their vibrational periods are close to those of the supporting structure



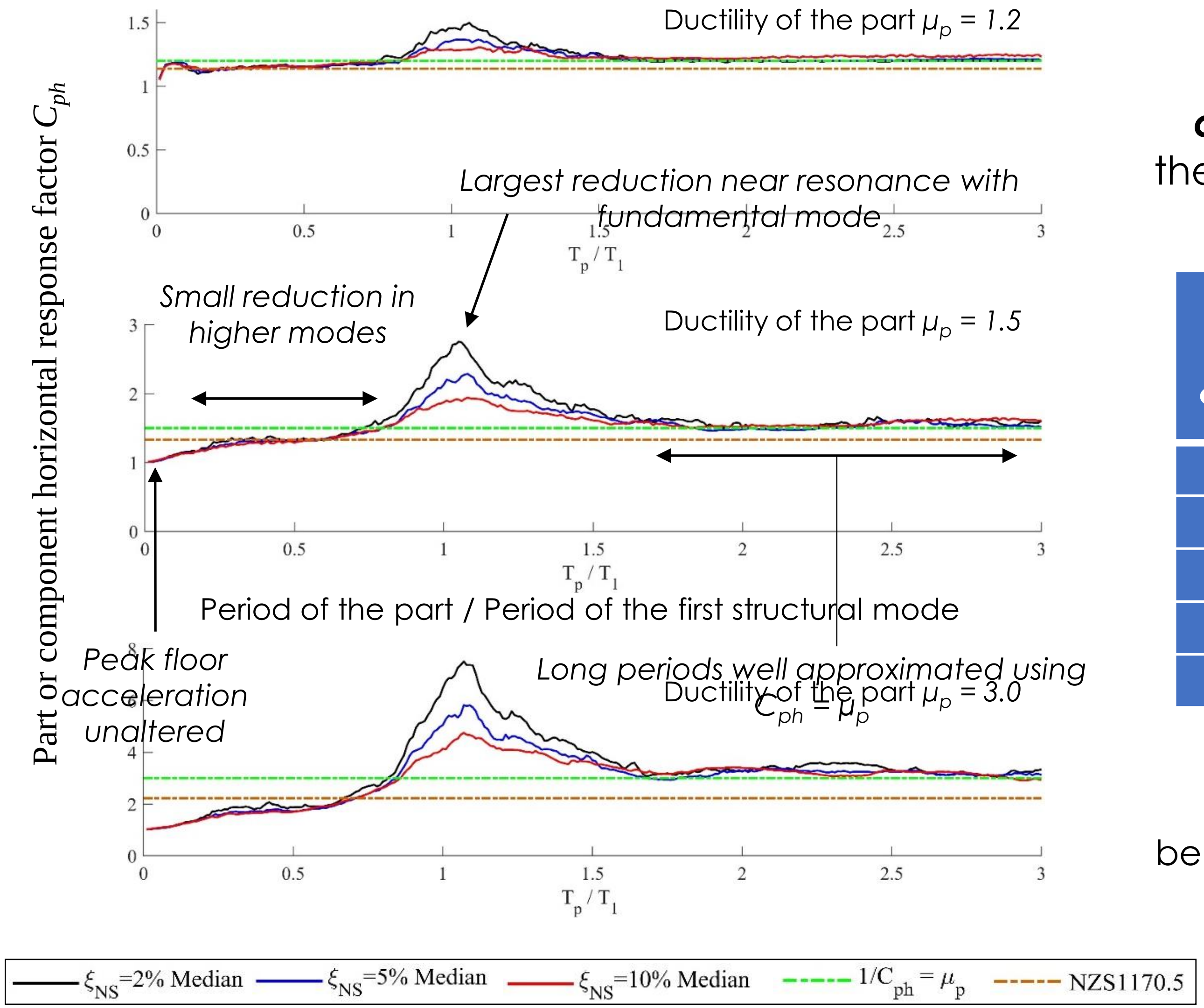
2% damping of the part

5% damping of the part

Acceleration response spectra, normalised by peak floor accelerations, from NZ instrumented buildings

How are demands on parts reduced by ductile part responses?
Described using the ***part or component horizontal response factor***

$$C_p(T_p) = PGA\left[\frac{C_{Hi}}{C_{str}}\right]\left[\frac{C_i(T_p)}{\boxed{C_{ph}}}\right]$$



Largest reduction near resonance with fundamental mode

Small reduction in higher modes

Period of the part / Period of the first structural mode

Peak floor acceleration unaltered

Long periods well approximated using $C_{ph} = \mu_p$

Part nonlinearity can ***reduce demands*** on ***flexible components***, depending on dynamic amplification and therefore ***proximity of periods of part to the structural modes***

Ductility of the part or component, μ_p	**Rigid parts**	**Flexible parts**		**Long period parts***
	All levels	At or below ground	Above ground level	All levels
1.0	1.0	1.0	1.0	1.0
1.25	1.0	1.25	1.4	1.25
1.5	1.0	1.5	1.85	1.5
2.0	1.0	2.0	2.8	2.0
2.5 or greater	1.0	2.5	4.0	2.5

Current NZS1170.5 does not fully capitalise on this beneficial behaviour, and ***does not consider rigid parts*** (not reducing) explicitly

Kazantzi, A. K., Miranda, E., & Vamvatsikos, D. (2020). Strength-reduction factors for the design of light nonstructural elements in buildings. *Earthquake Engineering & Structural Dynamics*, 49(13), 1329–1343

Applied Technology Council. (2018). *Recommendations for improved seismic performance of nonstructural components*. https://doi.org/10.6028/NIST.GCR.18-917-43

Key Point

8.6 Part or Component Response Factor

The part or component horizontal response factor, Cph, shall be as provided in Table 8.3 with the ductility of the part $\mu p = 1.0$ for SLS1 design and $\mu p = 1.25$ for SLS2 design. Part ductility values for ULS design shall be determined based on analysis or testing. Alternatively, the recommendations of Table C8.X may be used, directly or by interpolation, without further verification.

The intention of this is to steer designers toward using the default values – noting comments above eg, bolt slip will often provide enough movement to assume effective ductility.

Table C8.2 – General classification of parts or components and design ductility values

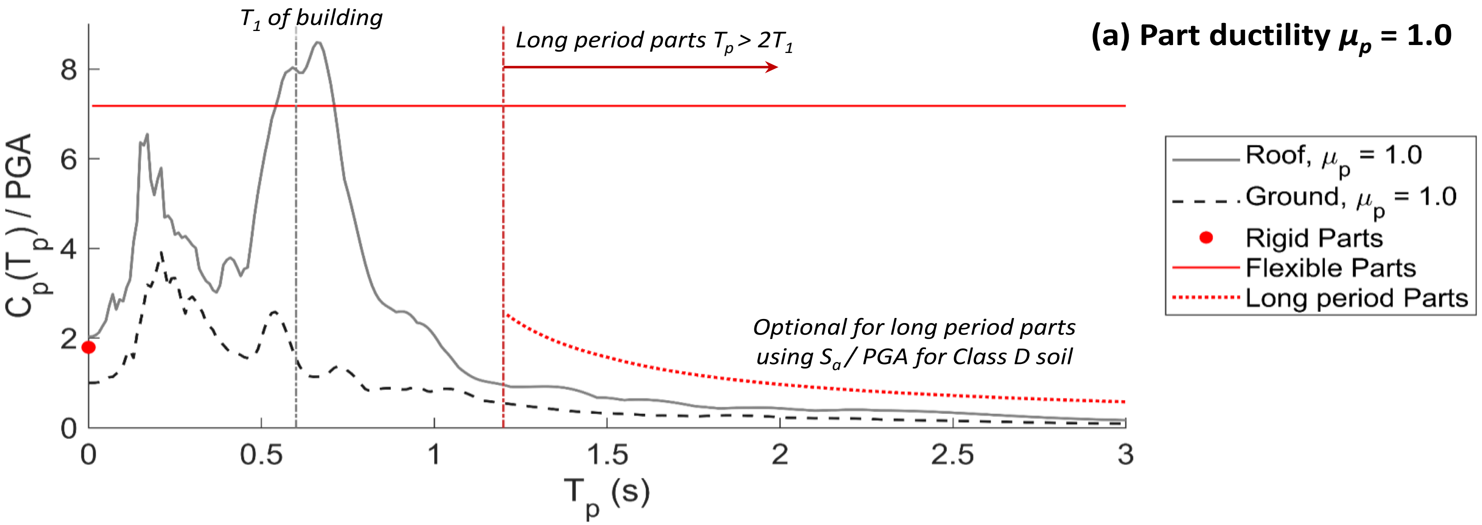
Description of part or component	**Class**	**Part Design Ductility**		
		SLS1	**SLS2**	**ULS**
Rigid parts or components	Rigid	N/A	N/A	N/A
Flexible parts or components				
Parts with good post-yield deformation capacity	Flexible	1.0	1.0	2.5
Parts with unknown post-yield behaviour but some expected inelastic displacement capacity or ability to slip or rock	Flexible	1.0	1.0	1.5
Parts with unknown post-yield behaviour and potentially brittle	Flexible	1.0	1.0	1.25

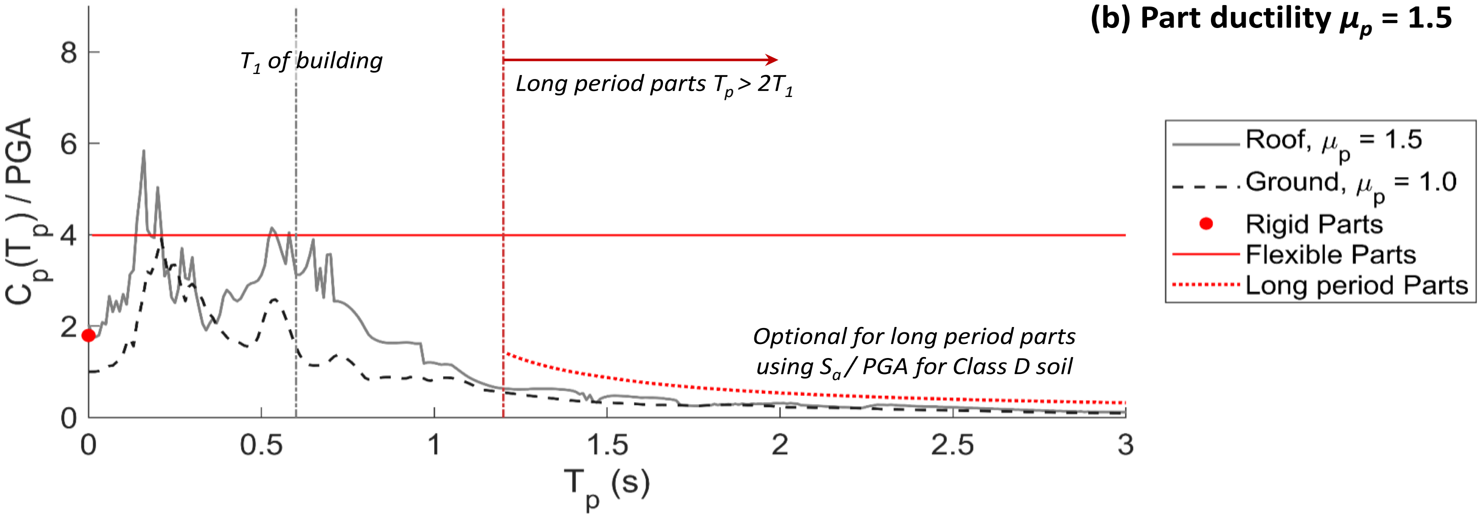
Table C8.3 – Classification of common parts or components and design ductility values

Description of part or component	**Class**	**Part Design Ductility(1)**		
		SLS1	**SLS2 (2)**	**ULS (3)**
Ceilings				
Direct fixed to underside of structural floors	Rigid	N/A	N/A	N/A
Framed and end-fixed to walls	Flexible	1.0	1.0	1.5
Suspended - braced	Flexible	1.0	1.0	1.5
Suspended - unbraced[5]	Flexible	N/A	N/A	N/A
Suspended or framed and with clips restraining vertical movement of ceiling tiles.	Flexible	1.0	1.0	2.0
Pre-cast reinforced concrete cladding panels (out-of-plane loading)(8)	Flexible	1.0	1.0	2.0
Glass facades, balustrades and walls (out-of-plane loading)				

Optional provisions can be used if parts can be demonstrated to exhibit sufficiently *long periods*

$$C_p(T_p) = \frac{S_a(T_p)}{C_{ph}}\left[1+\frac{1}{\left(\frac{T_p}{T_1}-1\right)^2}\right]$$


(a) Part ductility μ_p = 1.0


(b) Part ductility μ_p = 1.5

$$T_p \geq T_{p,long} = T_1\left(1+\sqrt{\mu}\right)$$

Period of the part needs to be greater than ***2x fundamental period of structure***, more if structure exhibits inelastic response due to ***period elongation***

Horizontal force on the part considers additional capacity of part at ULS

Described using ***Part Reserve Capacity Factor***

$$F_{ph} = \frac{\boxed{C_p(T_p)}}{\boxed{\Omega_p}} R_p\, W_p \le \frac{\boxed{7.5PGA}}{\boxed{\Omega_p}} R_p W_p$$

taken as ***1.5 for ULS and 1.0*** for ***SLS1 and SLS2***, unless demonstrated to be greater

Not explicitly considered in current NZS1170.5 approach

ASCE 7-22 uses 1.5 or greater for most parts and components

Maximum spectral acceleration, $C_p(T_p)$, taken as 7.5 PGA

elastic building with a short or unknown fundamental period

flexible part with unknown and potentially brittle behaviour

$$C_p(T_p) = PGA\left[\frac{C_{Hi}}{C_{str}}\right]\left[\frac{C_i(T_p)}{C_{ph}}\right] = PGA\left[\frac{3.5}{1.3}\right]\left[\frac{4.0}{1.4}\right] = 7.69PGA$$

$$F_{ph} < 3.6W_p$$

In current NZS1170.5 with no clear basis

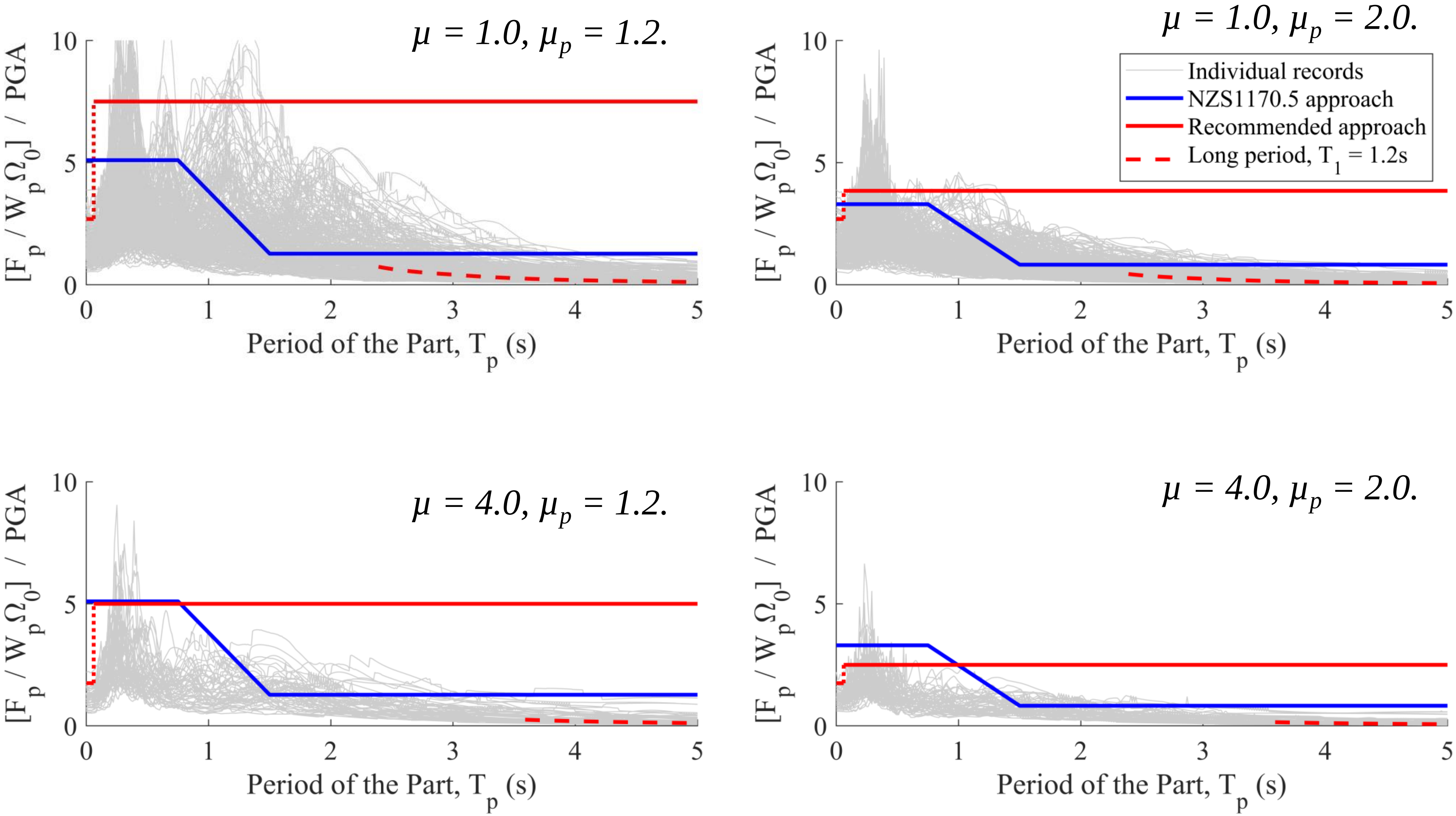
$$F_{ph} < 3.6W_p$$

ASCE 7-22 uses 4 PGA Ω_p ,
ATC report (2018) proposed 5 PGA Ω_p

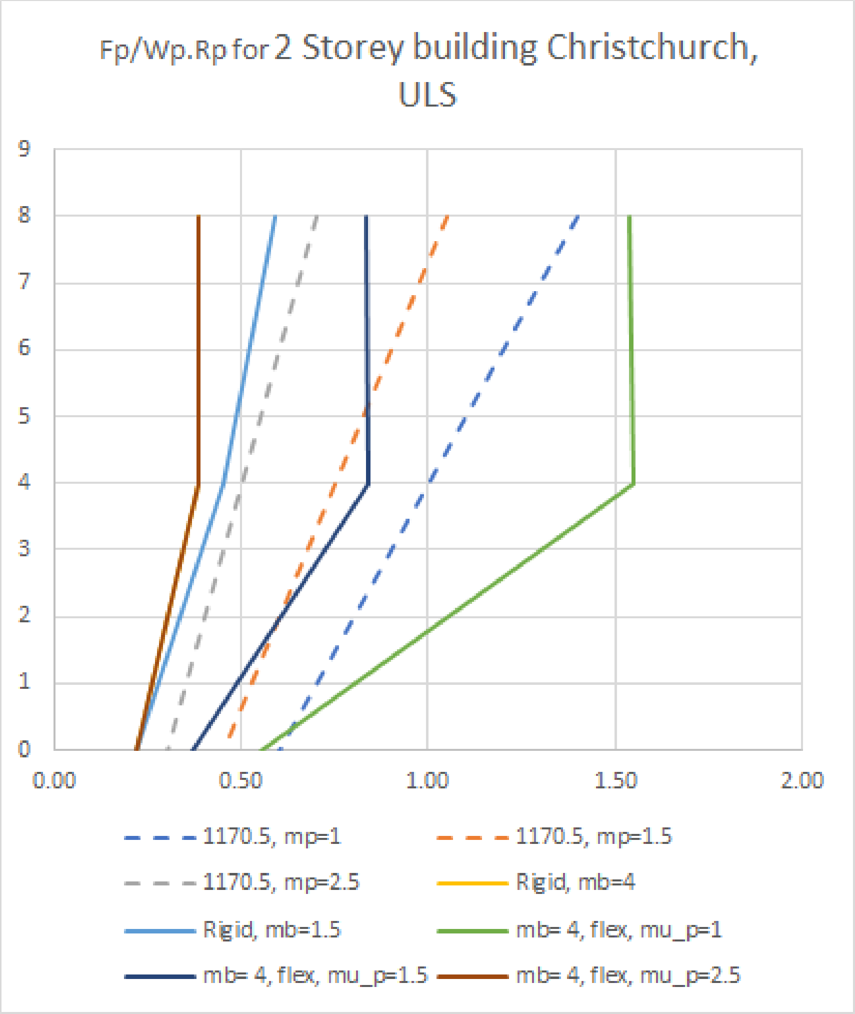
Comparison between current and proposed NZ approaches

Recommended approach is:

- More accurate for rigid parts
- More accurate (optional) long period provisions
- More accurate if T_1>0.75 s with elastic building response
- Describes effects of structural nonlinearity
- Does not require accurate periods of building or parts
- Does not result in significantly greater loading (often even lower)

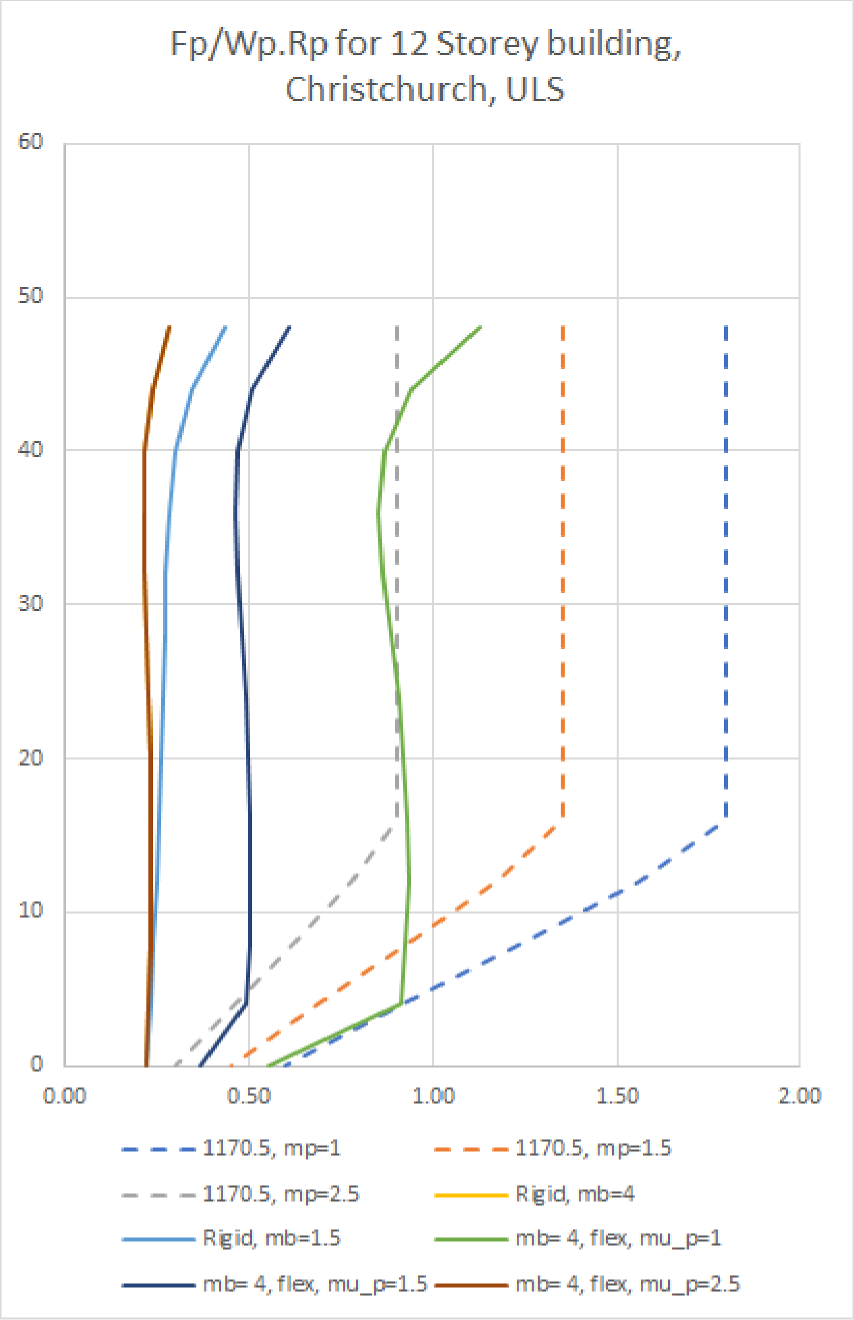


Comparison 1170.5:2004 to TS1170.5

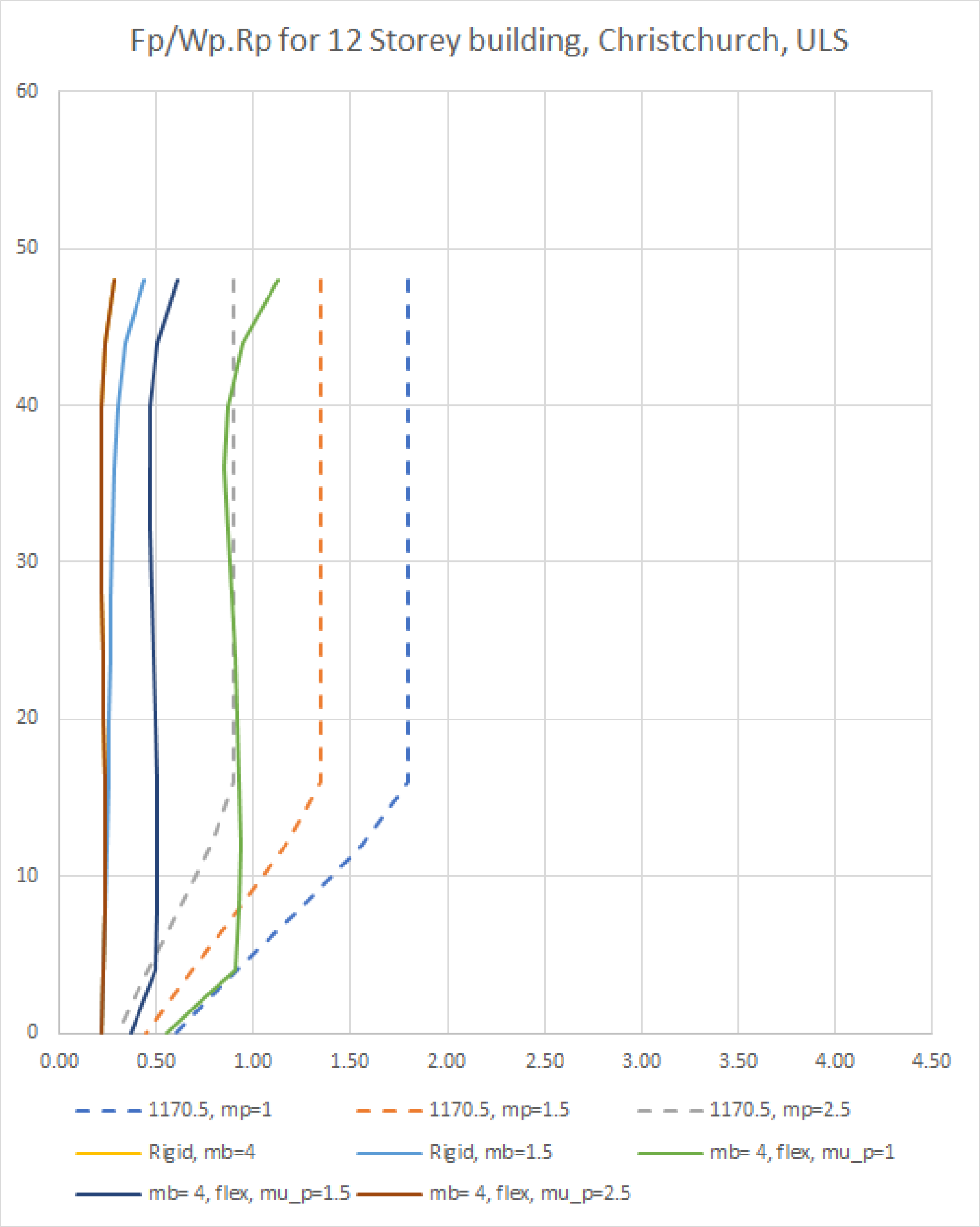


μ building = 4

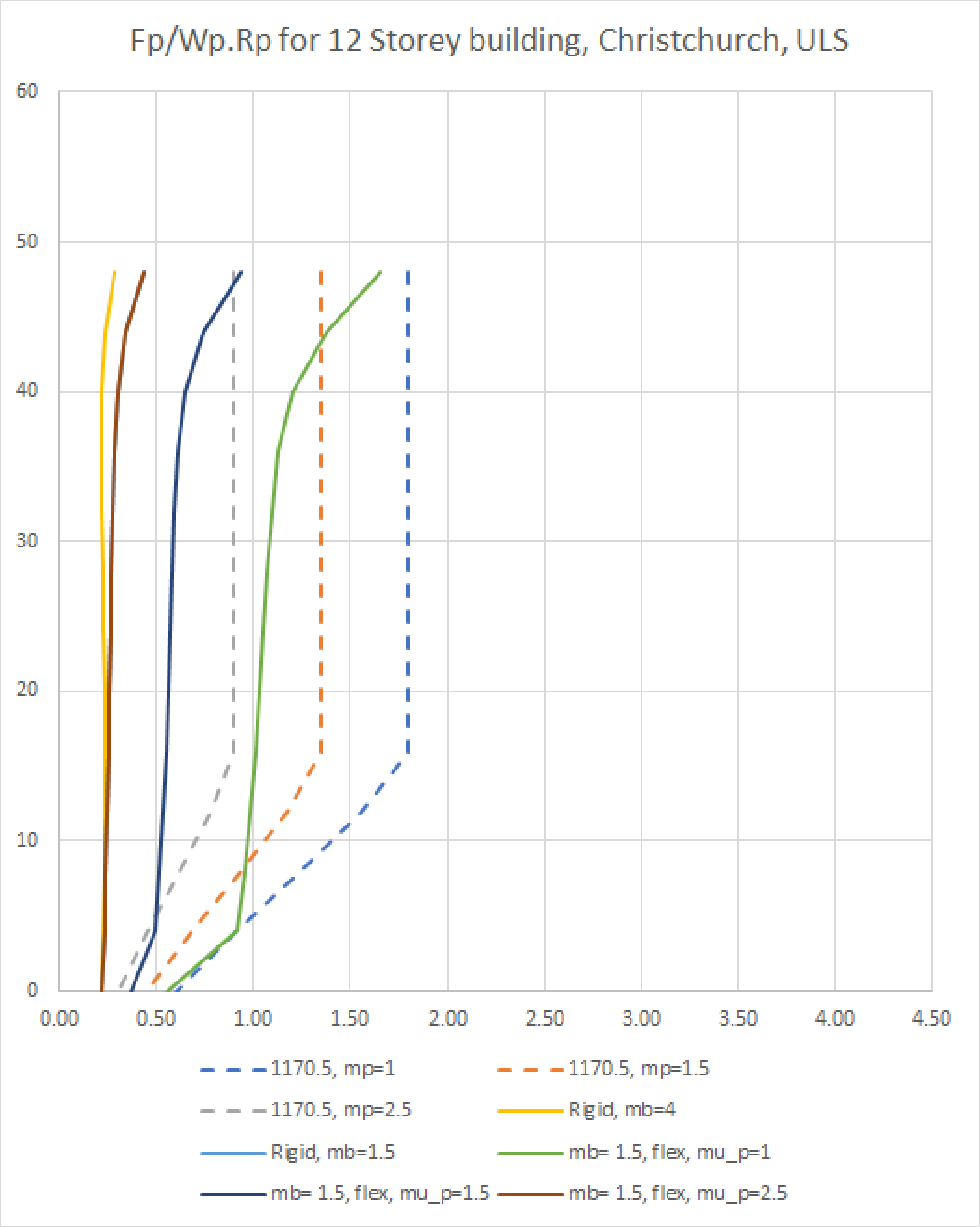
Note:
Dashed lines are NZS1170.5, solid lines are TS1170.5



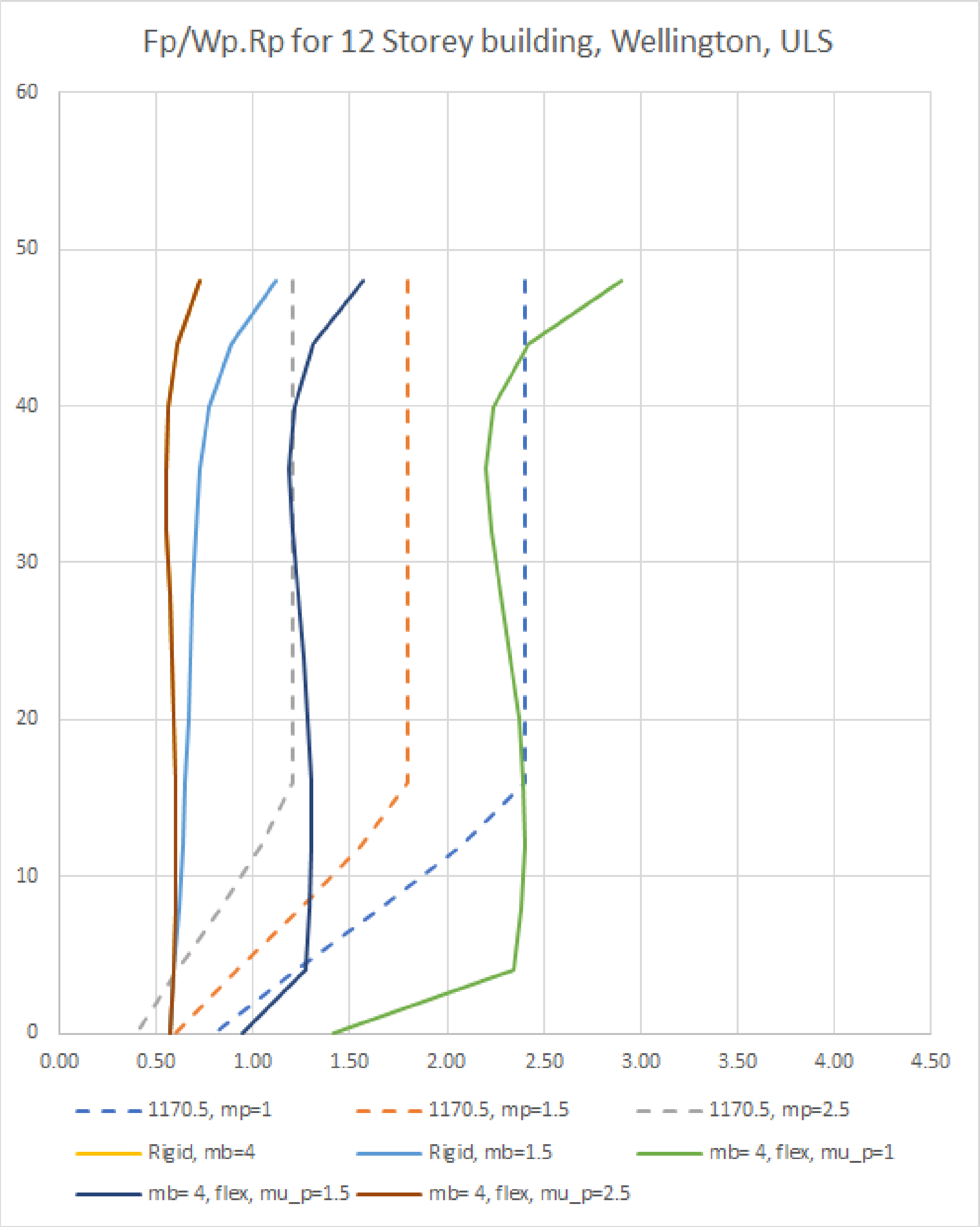
μ building = 4



μ building = 1.5



μ building = 4



μ building = 1.5