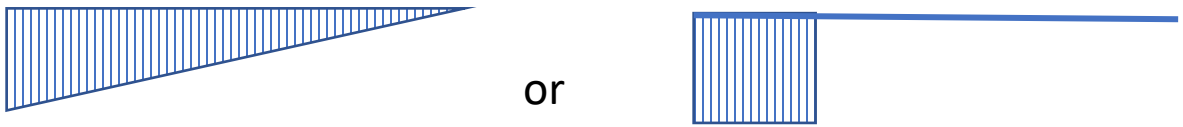
Rocking Foundations

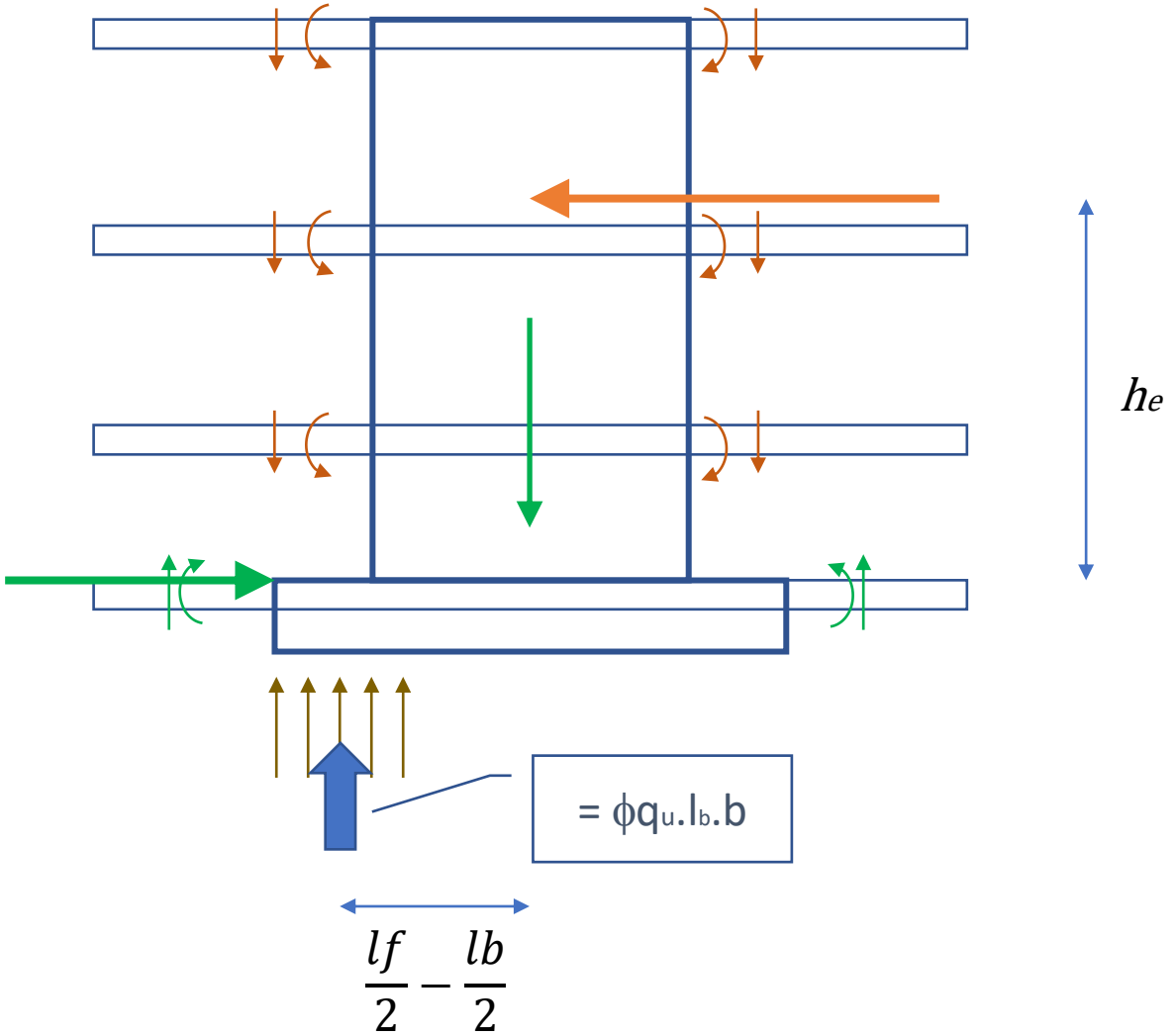
Draft TS1170.5, Sections 5.9 and 6.6

The Problem

- All rocking systems currently require special study, not defined by NZS1170.5 (but was in NZS4203 previously)
- Simple rocking systems are economic and reliable solution for small buildings, but deep or oversized foundations being used instead



or



The Proposed Solution

- Allow use of rocking systems for buildings that meet certain limitations without special study
- By (2023):
  - Setting parameters sufficiently conservatively that reliable performance can be reasonably assured, and
  - Keeping methodology simple, so that it can be used without extensive analytical effort
- This can be considered for further extension in 2025, after other aspects of B1 are more fully considered

Path

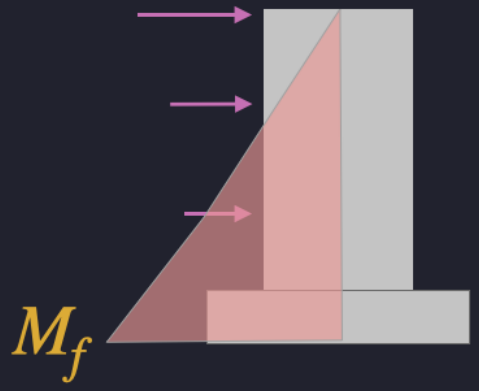
- Section 6.6 – Rocking Structures
  - Separates rocking within structure from rocking foundations
  - Signpost to S 5.9 for simplified foundations

- Section 5.9 – Shallow Foundations
  - S 5.9.1 Allows foundation rocking for buildings meeting certain criteria
  - S 5.9.1.1 – sets criteria
  - S 5.9.1.2 – defines process
  - S 5.9.1.3 – allows sliding above SLS and provided no differential movement

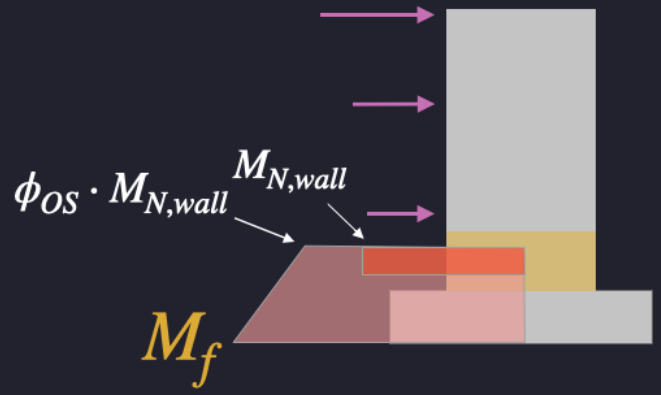
Potential ‘Force-based’ Simplified Rocking design

1) Determine foundation demands (minimum of reduced and overstrength loads)

Reduced design loads (μ=2?)

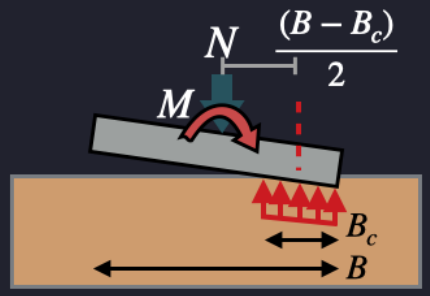


Overstrength loads

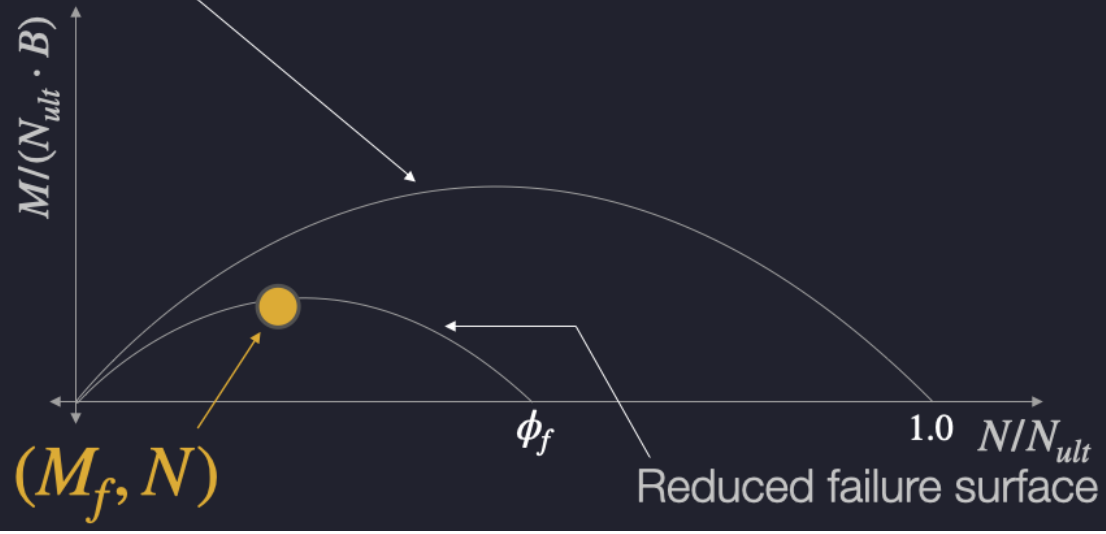


2) Size foundation ~~to prevent uplift and has~~ for sufficient capacity (and settlement requirements)

Failure surface



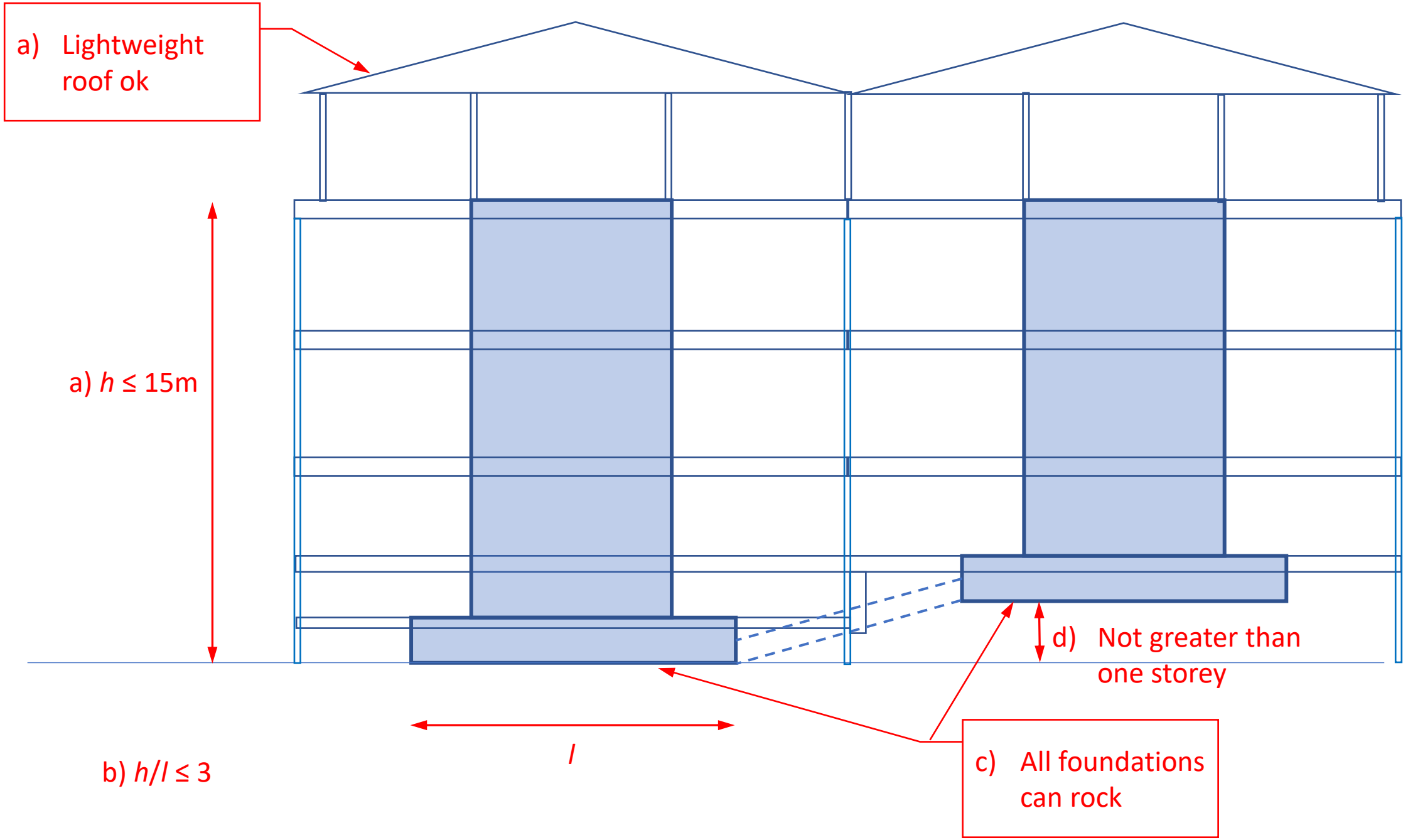
$$M_{f,ult} \approx \frac{N \cdot B}{2}\left(1 - \frac{B_c}{B}\right)$$

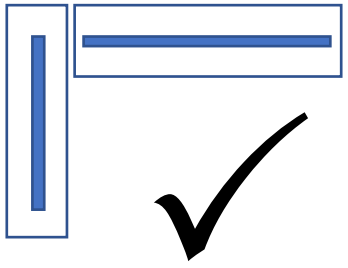


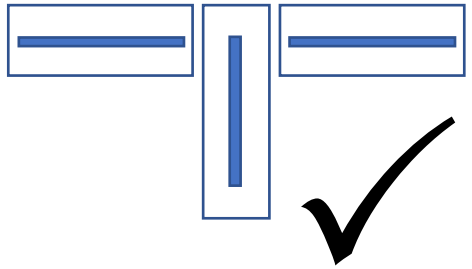
Simplified Design of Rocking Foundations

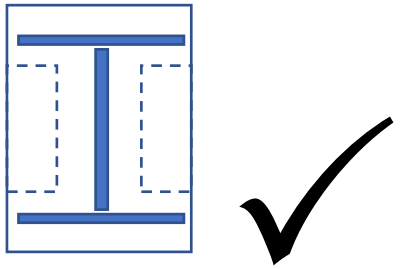
5.9.1.1 – Limitations for Simplified Design

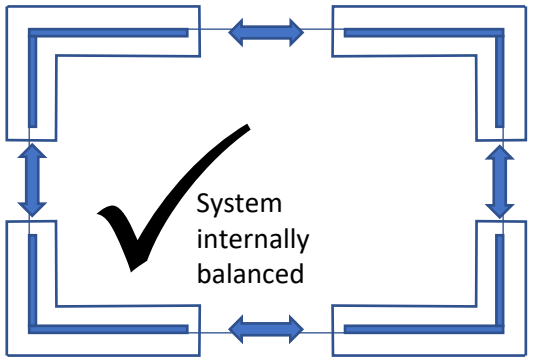
a) h<15m to uppermost floor or heavy roof
b) Aspect ratio of assemblies ≤ 3 vert : 1 horiz
c) All foundations unrestrained, i.e. cannot mix and match
d) Underside of foundations within one storey
e) All foundations are symmetric unless out-of-plane actions are restrained.


a) Lightweight roof ok
a) $h \leq 15$m
b) $h/l \leq 3$
l
d) Not greater than one storey
c) All foundations can rock

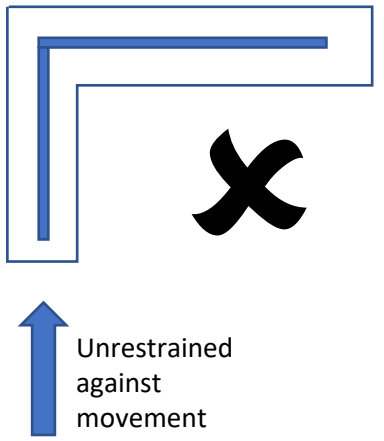


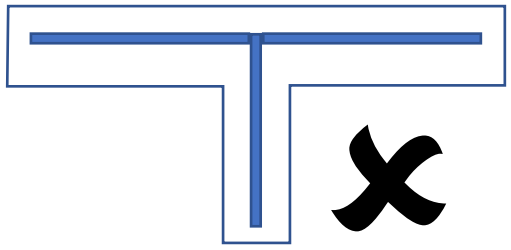






e) All foundations are symmetric unless out-of-plane actions are restrained.

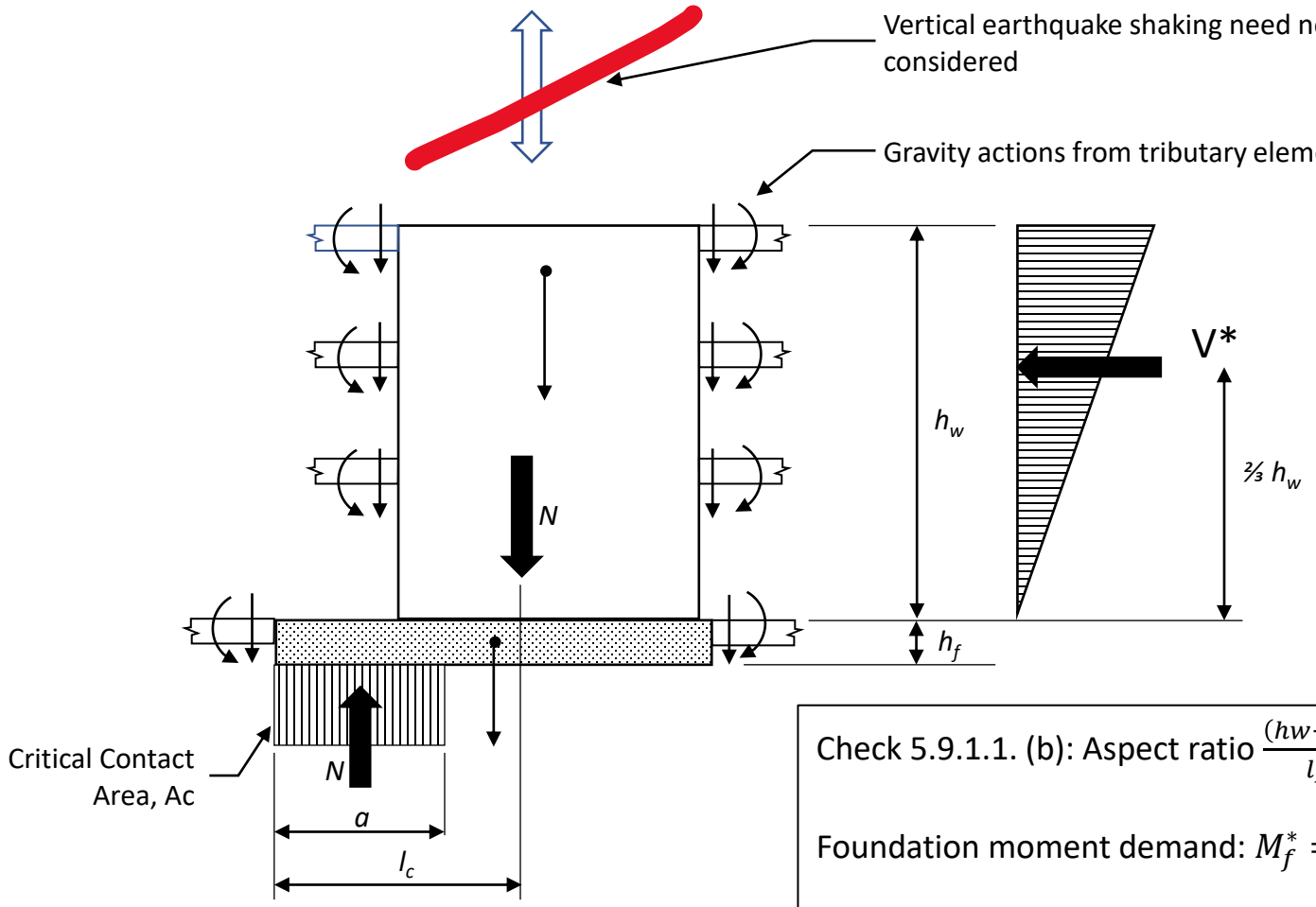




Simplified Design of Rocking Foundations

5.9.1.2 –Simplified Design of Rocking Foundations

a) For design, $\mu = 2$
b) Lateral load redistribution between elements ok, provided torsional resistance not reduced
c) Vertical actions from earthquake shaking may be ignored
d) Additional displacements from rocking need not be specifically checked against displacement limits, but when providing displacements (eg for non-structural element design), add Pre-rocking Rotation .



l_f = length of foundation
h_w = height of wall
h_f = height of foundation
a = bearing length
a/2 = distance to centroid of critical contact area (assuming rectangular stress block)
l_c = length to centroid of vertical loads, accounting for any applied moments from gravity actions and including foundation and tie beams etc.

N = Resultant of all gravity actions acting on the system

Check 5.9.1.1. (b): Aspect ratio $\frac{(hw+hf)}{lf} \leq 3$

Foundation moment demand: $M_f^* = V^*.(^2/_3\, h_w + h_f)$

Foundation moment capacity: $M_{f,N} = N.(l_c - \frac{a}{2})$

Validation

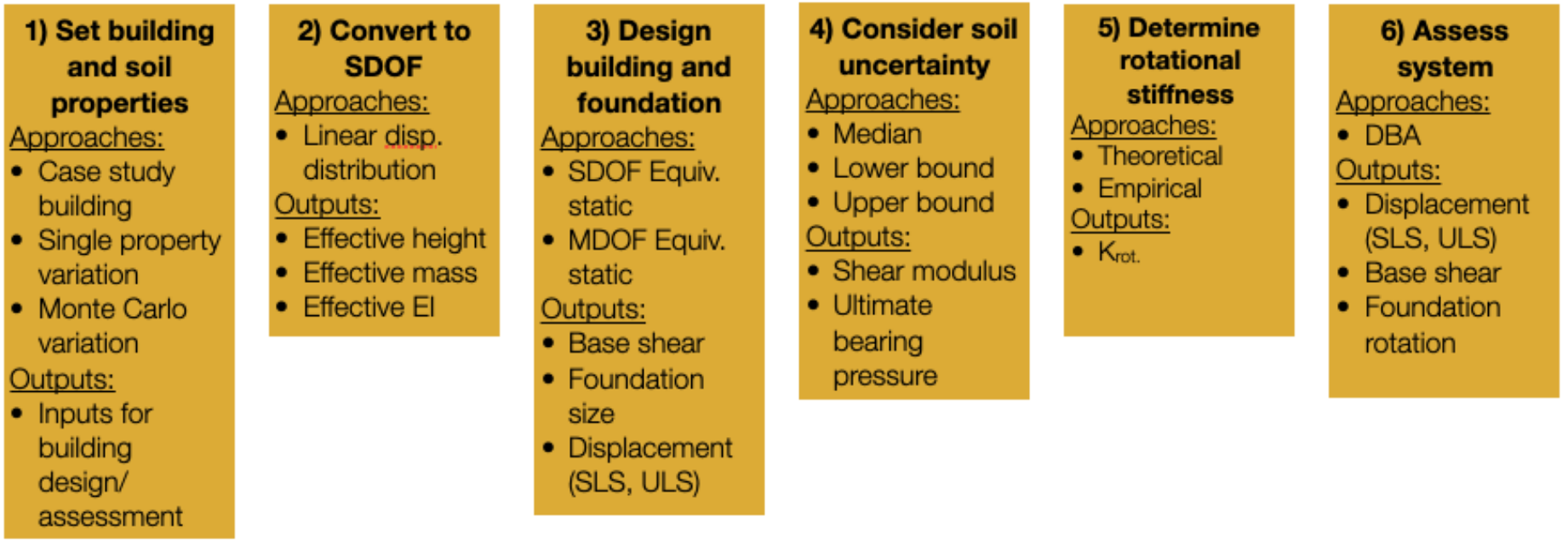
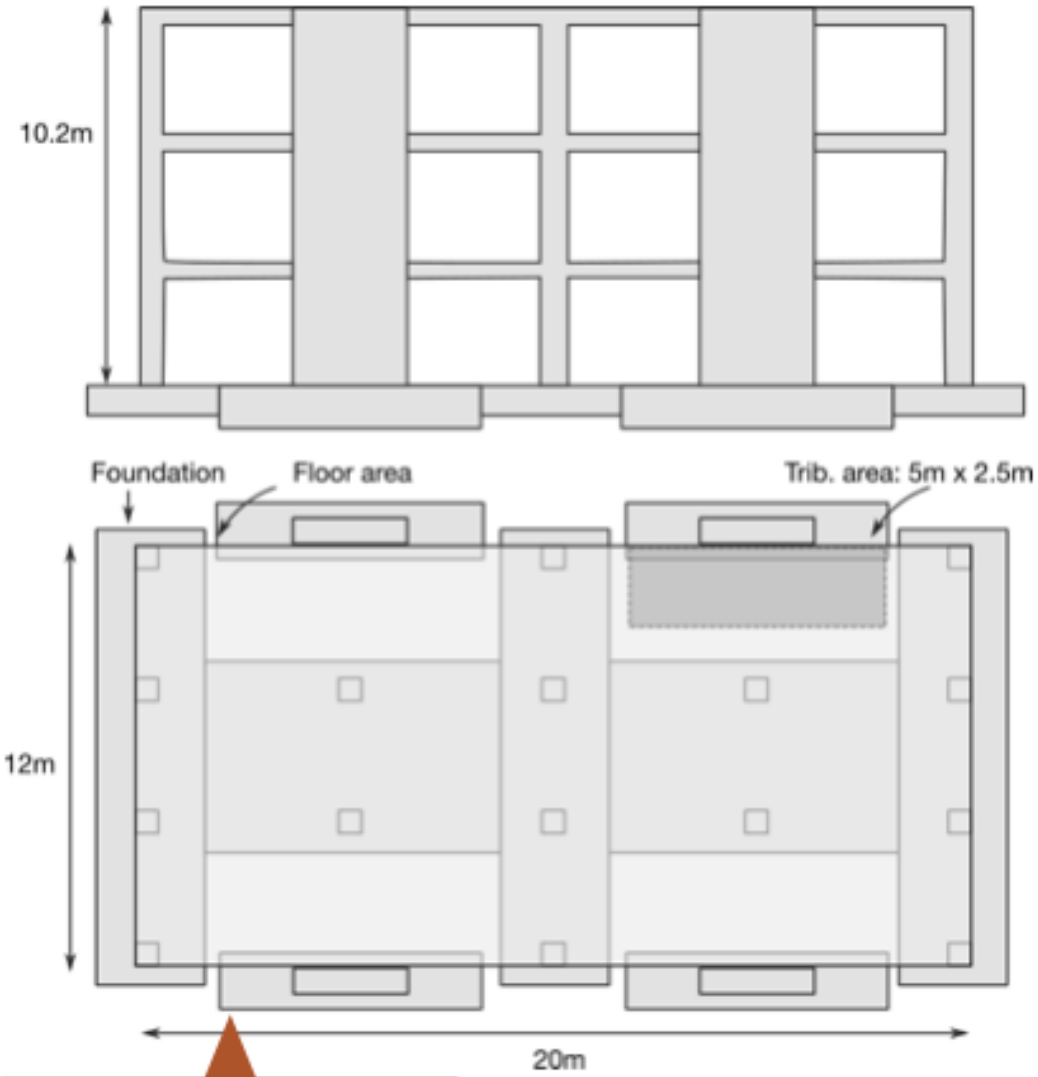
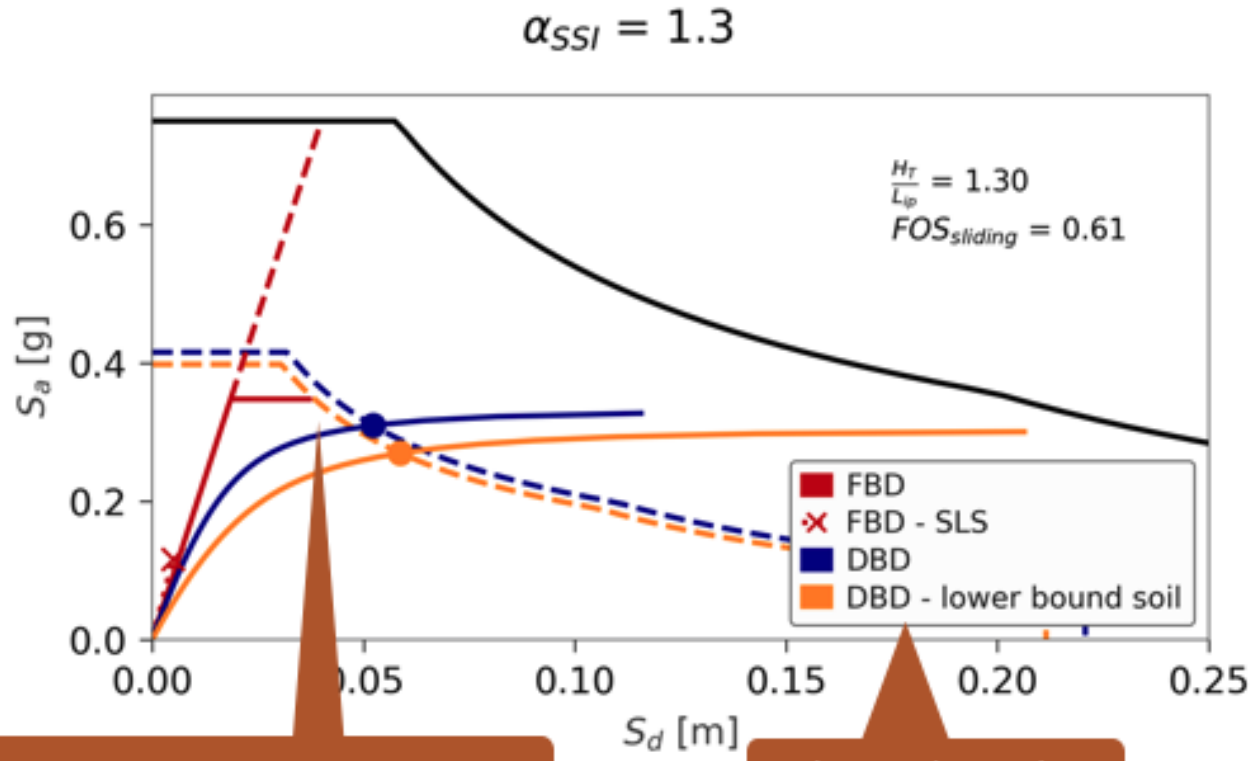


Figure 2: Validation Methodology

Key Principle: Don’t sacrifice simplicity for accuracy



Deliberately no tie beams to simplify analysis



Notice difference in displacement between FBD and DBA

Lower bound:
G_{LB} = 0.5 G
q_{LB} = 0.5 q

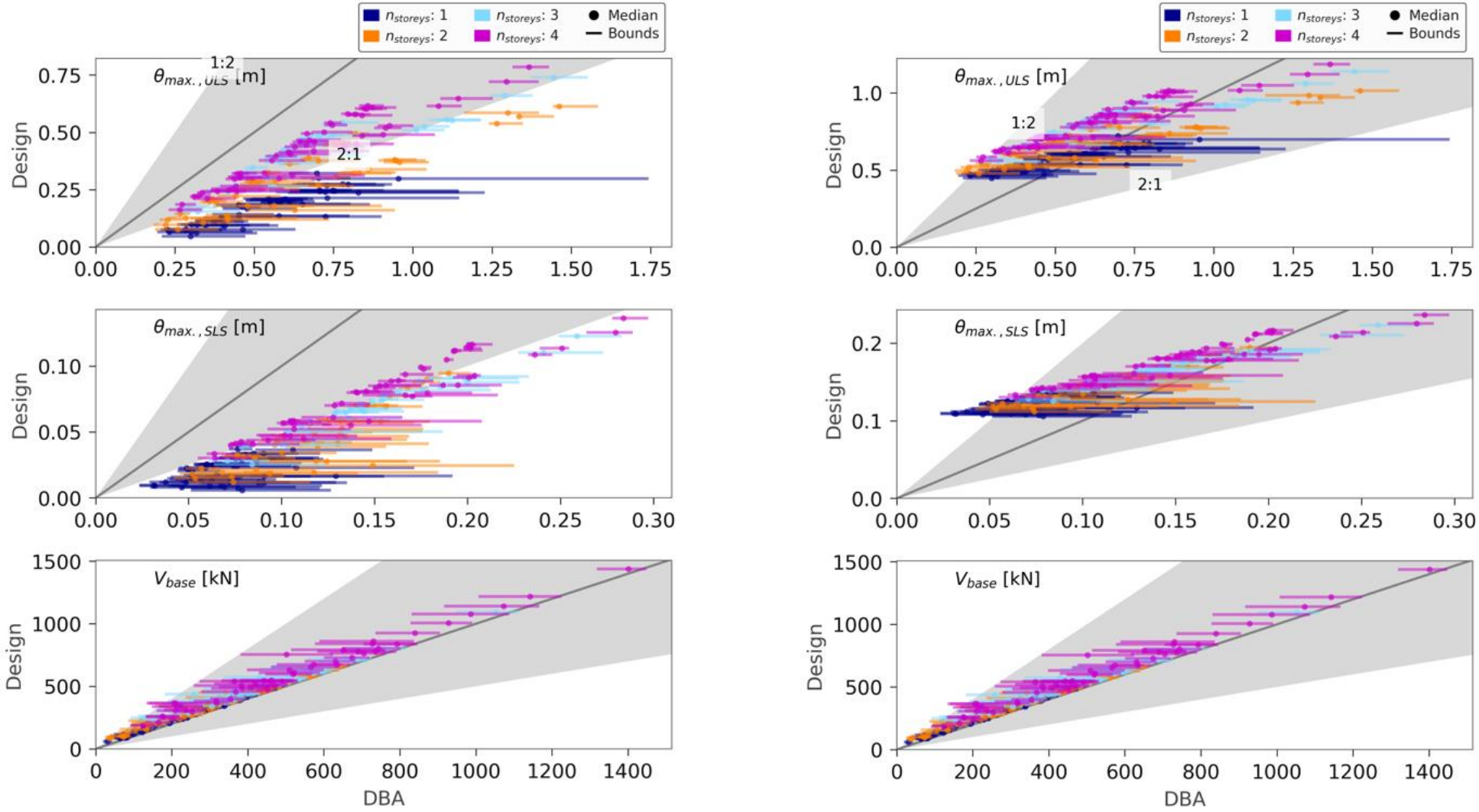


Figure 3: Comparison of Assessment Outcomes to Design Values. Left, Design displacements directly from NZS1170.5, Right, Design displacements adjusted for 'pre-rocking foundation rotation allowance' of 1/250.