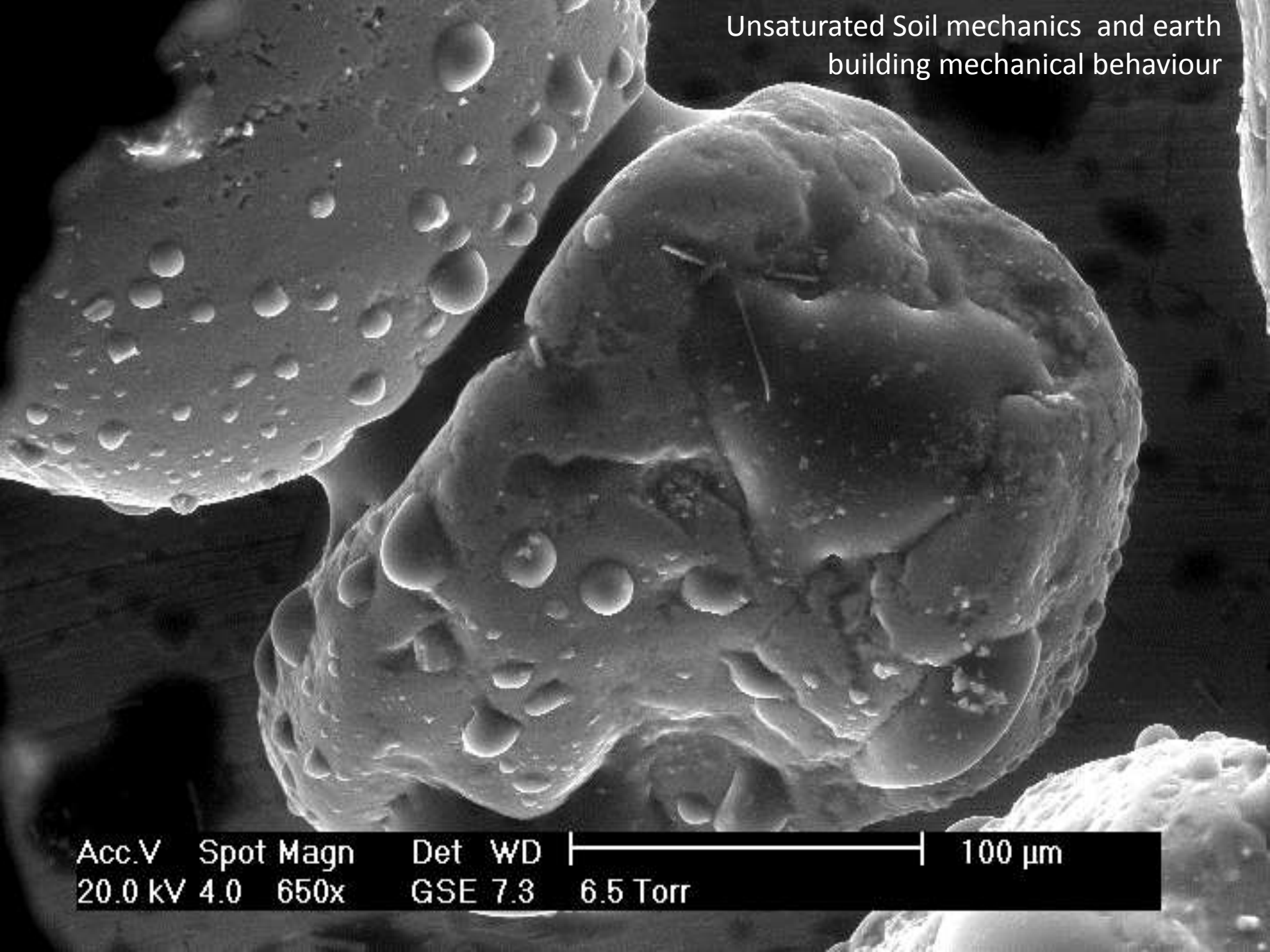
Proposal for an international earth building design guidance document

Paul Jaquin

PhD – Analysis of Historic
Rammed Earth Construction


Unsaturated Soil mechanics and earth building mechanical behaviour
Acc.V Spot Magn Det WD 100 µm
20.0 kV 4.0 650x GSE 7.3 6.5 Torr

Structural Engineer UK

El

Rammed earth wed

Structural Engineer UK

ModCell
Straw bale panel
Fire test


Structural and Geotechnical Engineer
Land Development and Exploration
Warkworth
New Zealand

Part of NZ government team to Nepal in August- October 2015
Assisting with earthquake assessments and teaching

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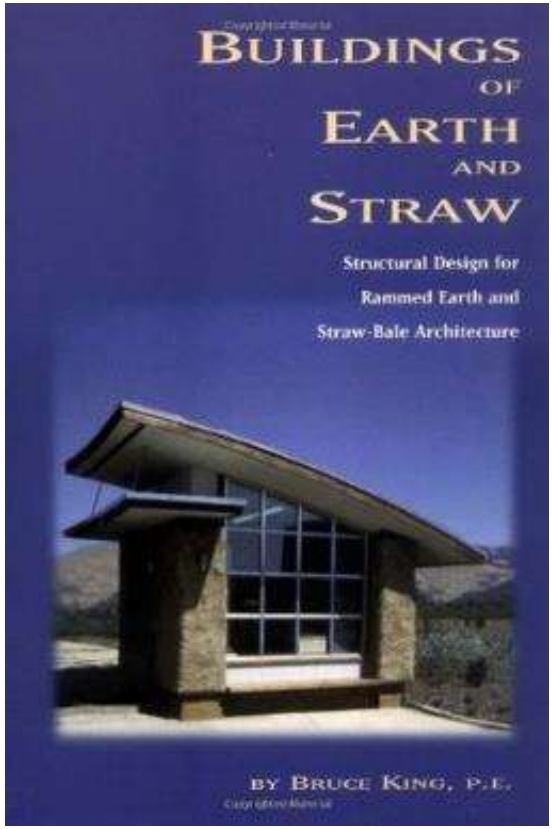
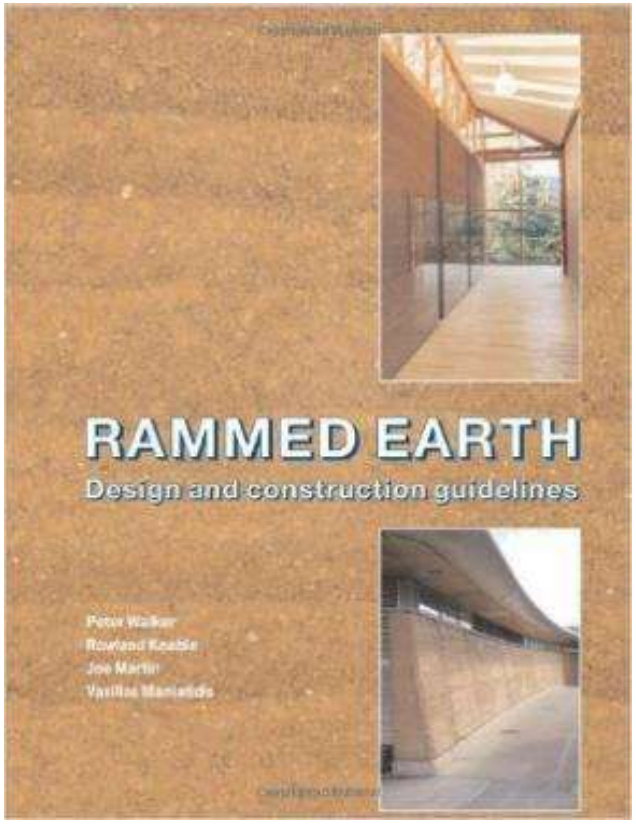
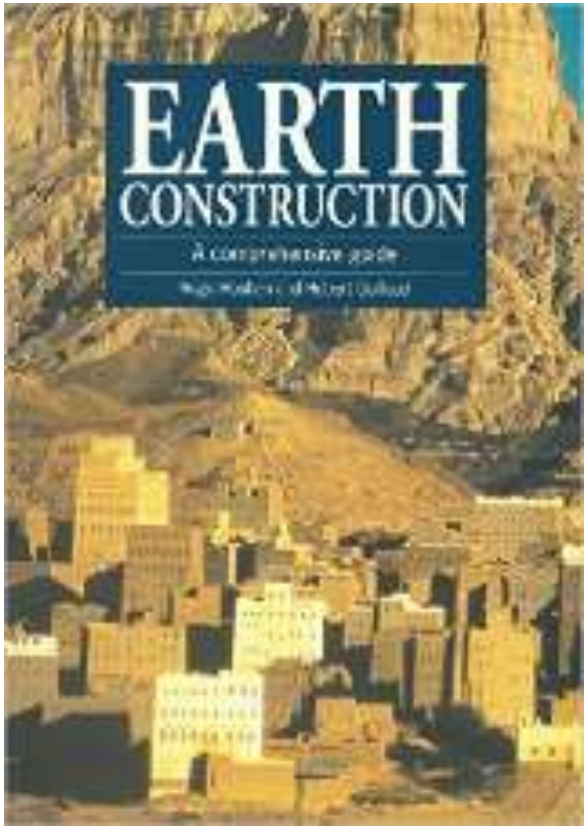
Paul Jaquin

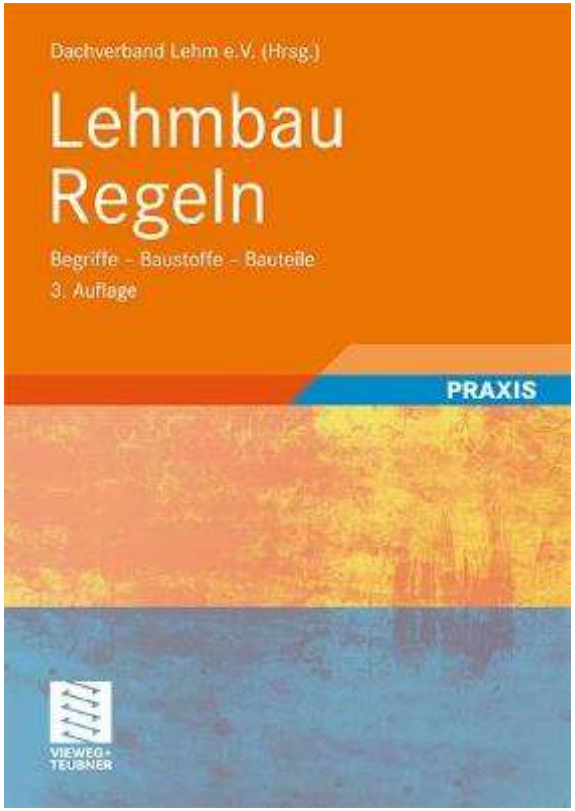
Guidance books







What do we have at the moment?



Designation: E2392/E2392M – 10

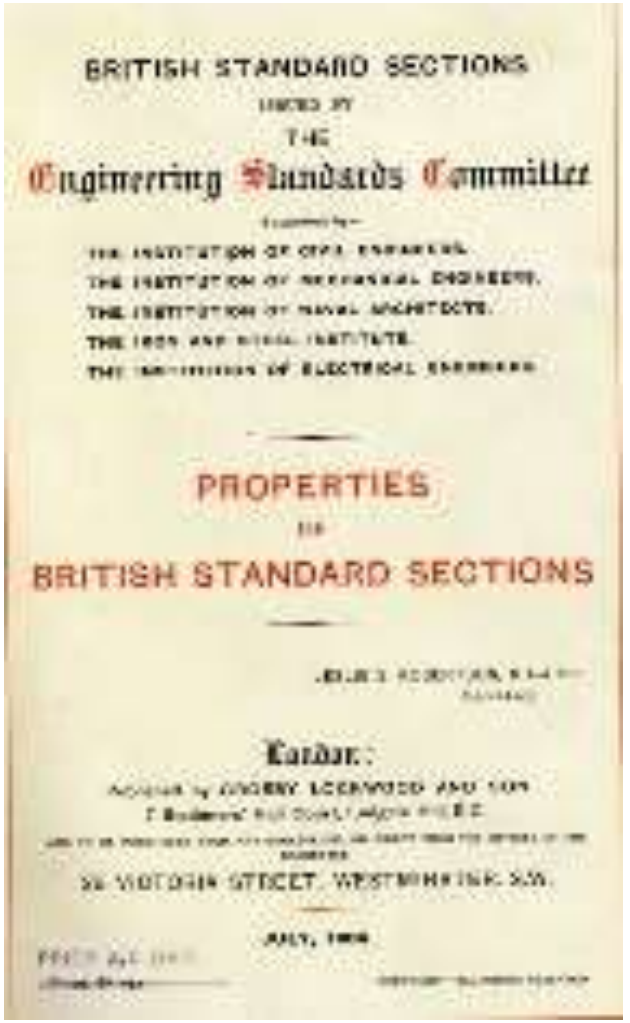
Standard Guide for
Design of Earthen Wall Building Systems[1]

NZS 4297:1998

Engineering Design of Earth Buildings

The issues

1. Keep people safe
2. Build better stuff
3. Make more stuff


BRITISH STANDARD SECTIONS

THE

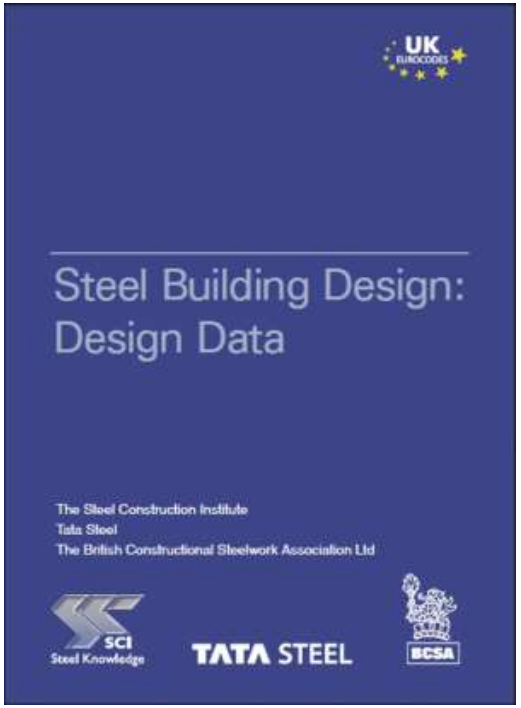
Engineering Standards Committee

PROPERTIES

OF

BRITISH STANDARD SECTIONS

How do other industries work



GIB EzyBrace® Systems

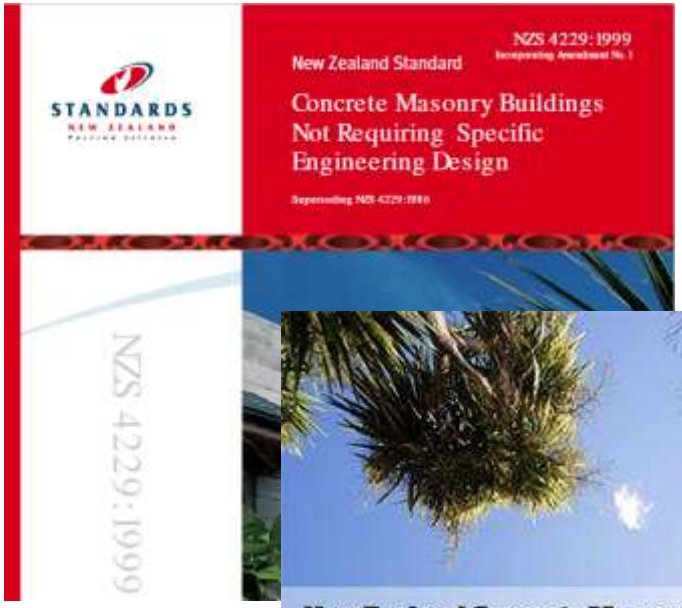
GIB **Bracing Resistance** JUNE 2011

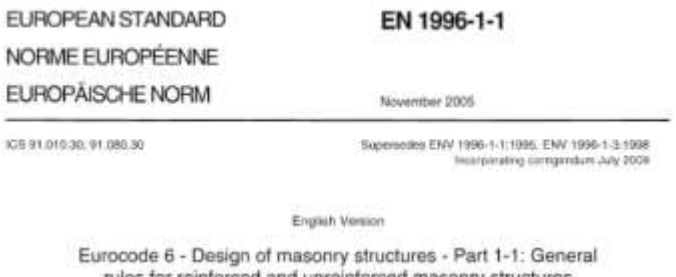
Table 1: GIB® Standard Plasterboard Bracing Unit ratings

Type	Minimum Length (m)	Lining	Other Requirements	BU/m	
				W	EQ
GS1-N	0.4	GIB® Standard Plasterboard one side	N/A	50	55
	1.2			70	60
GS2-N	0.4	GIB® Standard Plasterboard both sides	N/A	70	65
	1.2			95	85
GSP-H	0.4	GIB® Standard Plasterboard one side plywood the other	Panel hold-down fixings	100	115
	1.2			150*	150*

No Product seller who will produce guides at their own cost

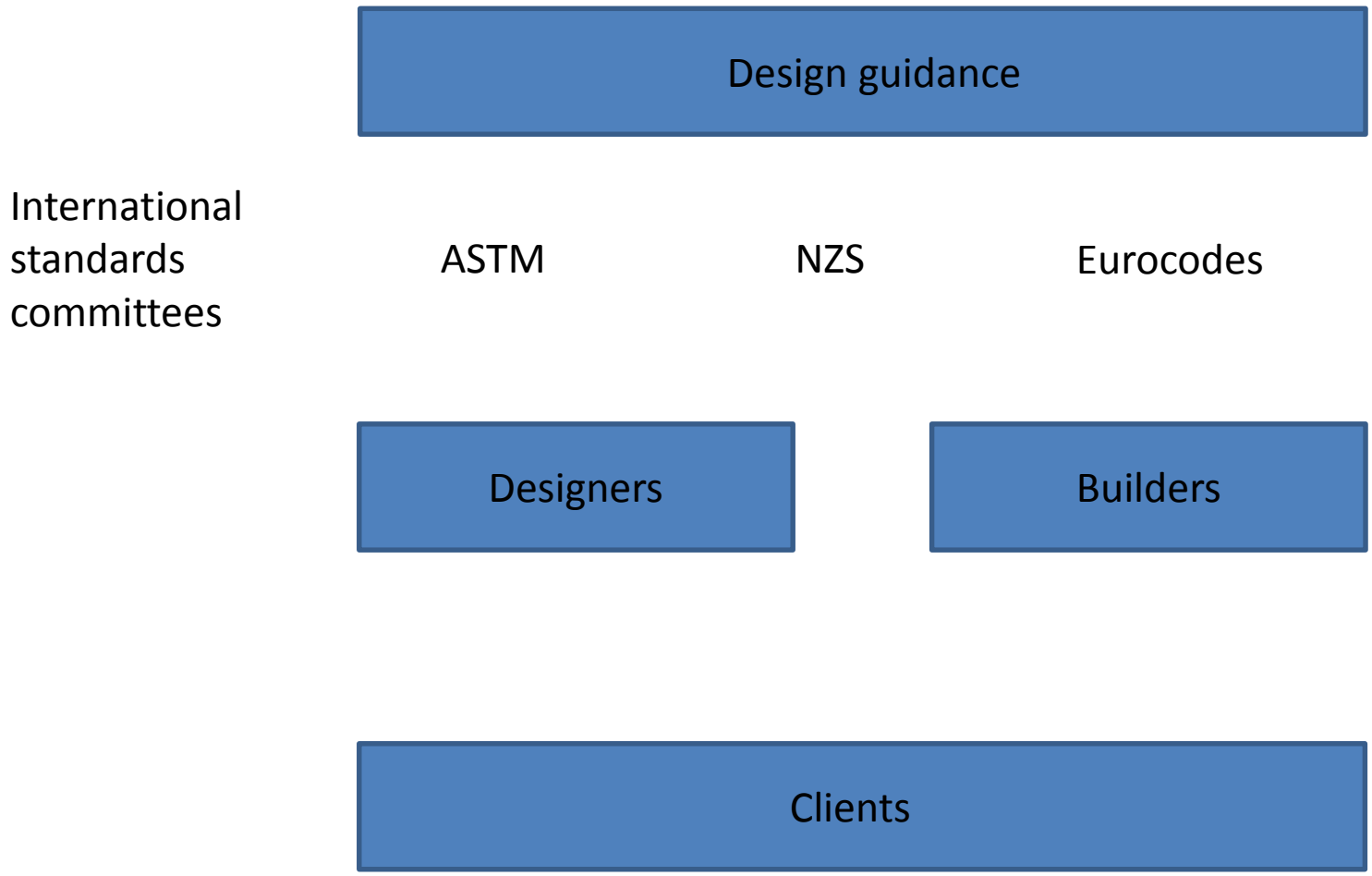
What do we need?





- In order to go Mainstream
- We need to allow non-specialists to design and specify earth buildings


CLAYTEC
LEHMPUTZ
LEHMKLEBER
CLAYFIX


Design guidance
International standards committees
ASTM
NZS
Eurocodes
Designers
Builders
Clients

Poor design and construction happens without good guidance

Poor design and construction happens without good guidance

Contents

- Investigation
- Material selection
  - Stabilised
  - Unstabilised
  - Reinforced
  - Unreinforced
- Structural design
  - Structural systems
  - Vertical compression
  - Out of plane
  - In plane
  - Uplift

- Thermal performance
- Fire performance
- Weathertightness
- Construction detailing
- Specification
- Site testing

BMTRADA

CERTIFICATE OF REGISTRATION

This is to certify that

ModCell

The Proving House
21 Saville Street
Bristol
Avon
BS2 9LB

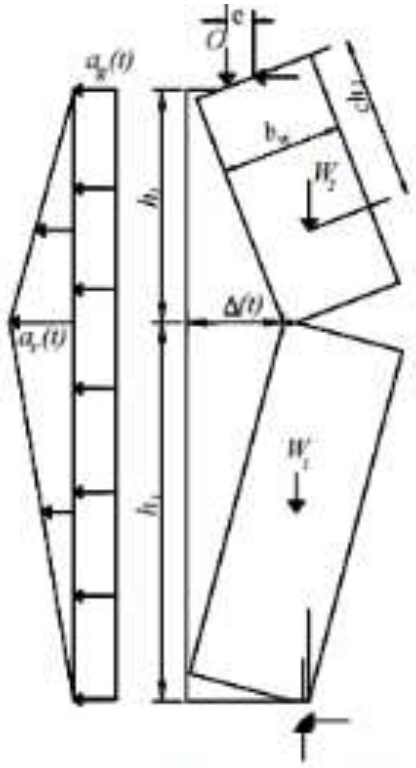


Figure 1: Cracked out-of-plane wall subject to ground motion

Investigation

Insitu material

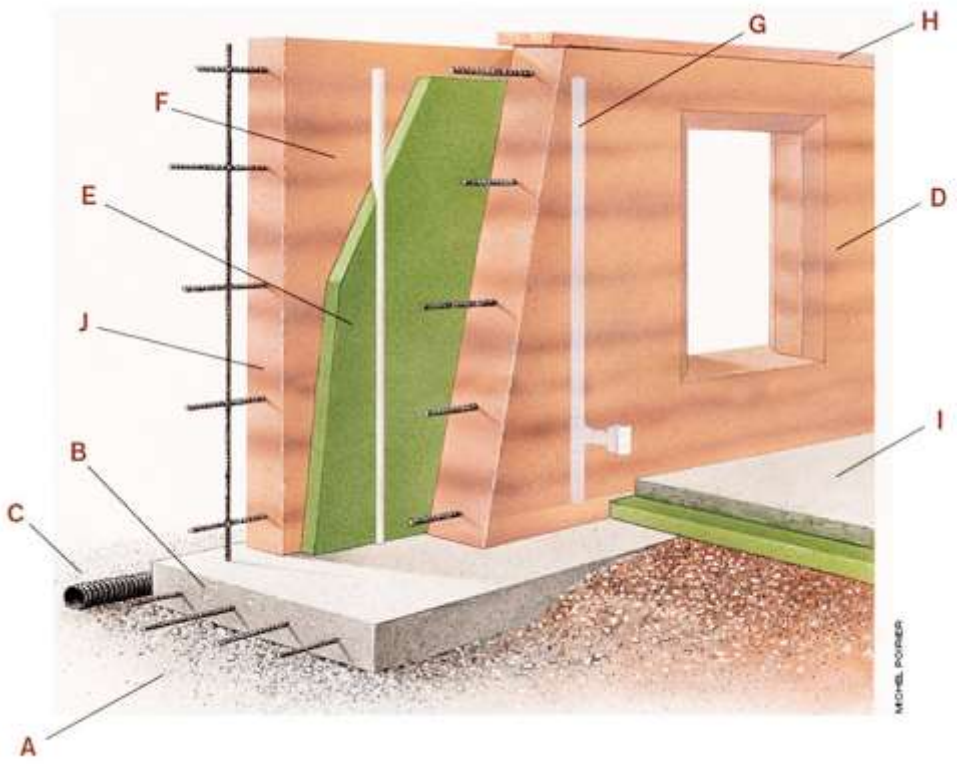
- Particle sizes
- Construction type
- Optimum Water content
- Required design strengths
- Stabilisation

- Colour

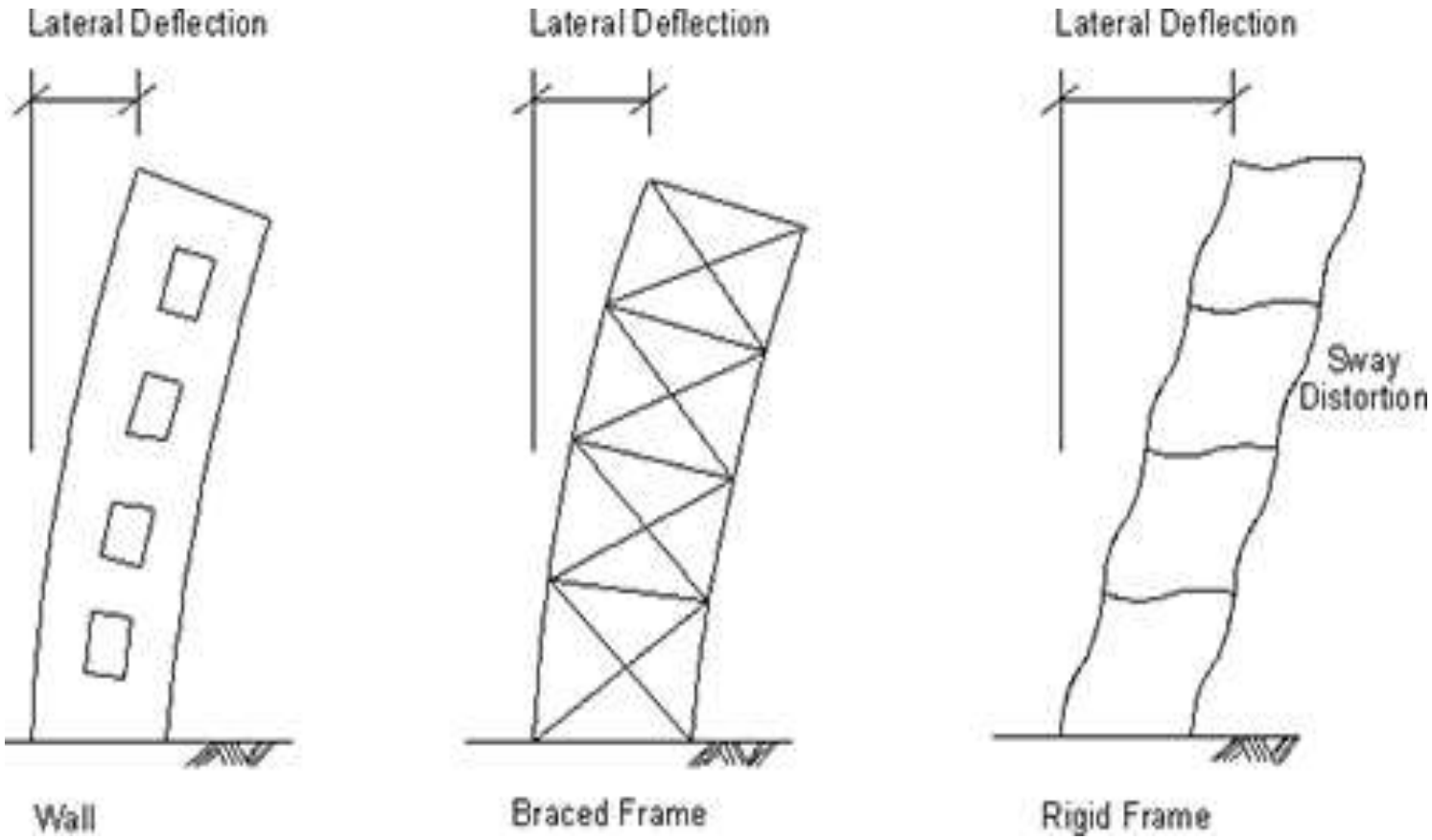
Manufactured

- Previously tested properties

Material Selection



Structural system



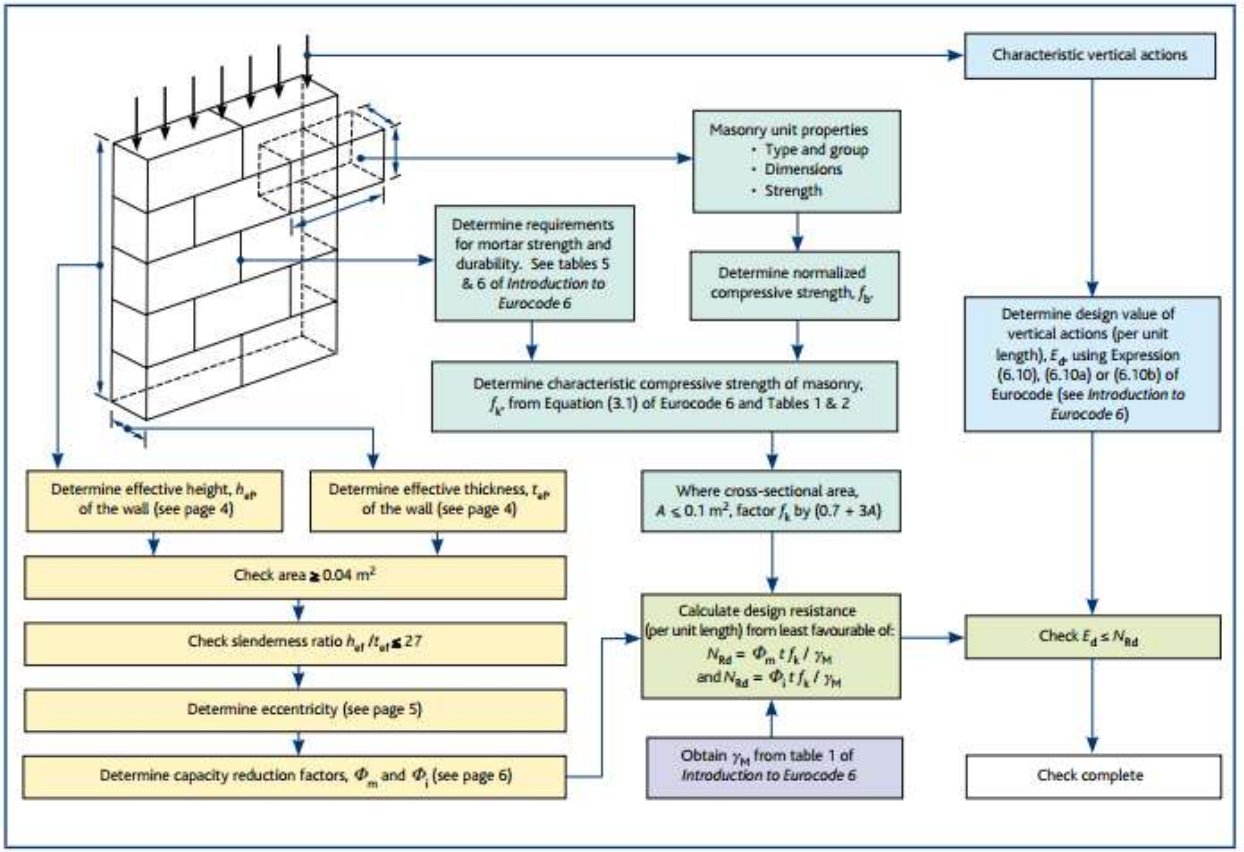
Courtesy of Tata Steel

Vertical load

How to design masonry structures using Eurocode 6

2. Vertical resistance

Figure 1
Flow chart for the design of masonry walls to resist vertical actions



Lateral out of plane

Reinforced

Unreinforced

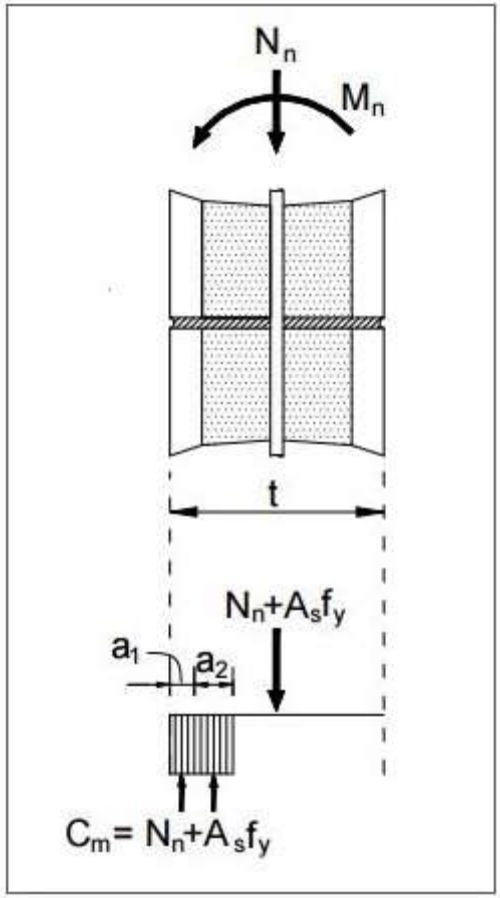


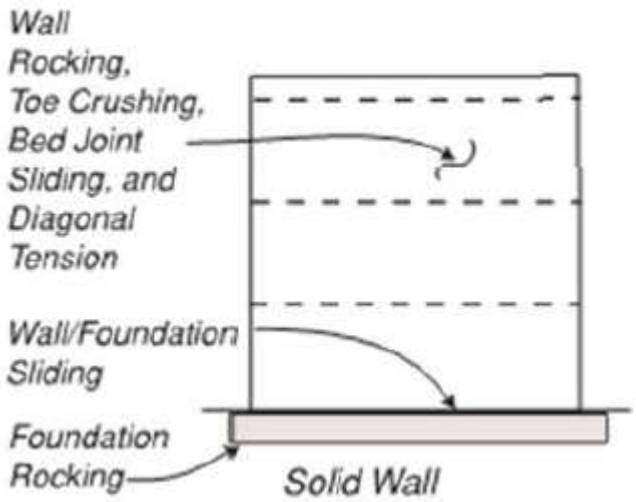
Figure 12: **Forces acting on wall**

Table 10.12: Static instability deflection for uniform walls – various boundary conditions

Boundary Condition Number	0	1	2	3
				
e_b	0	0	$t/2$	$t/2$
e_b	0	$t/2$	0	$t/2$
b	$(W/2+P)t$	$(W+3P/2)t$	$(W/2+3P/2)t$	$(W+2P)t$
a	$(W/2+P)h$	$(W/2+P)h$	$(W/2+P)h$	$(W/2+P)h$
$\Delta_i = bh/(2a)$	$t/2$	$(2W+3P)t$ $(2W+4P)$	$(W+3P)t$ $(2W+4P)$	t
J	$\{[(W/12)[h^2+7t^2]$ $+Pt^2\}/g$	$\{[(W/12)[h^2+16t^2]$ $+9Pt^2/4\}/g$	$\{[(W/12)[h^2+7t^2]$ $+9Pt^2/4\}/g$	$\{[(W/12)[h^2+16t^2]$ $+4Pt^2\}/g$
C_m	$(2+4P/W)t/h$	$(4+6P/W)t/h$	$(2+6P/W)t/h$	$4(1+2P/W)t/h$

Lateral out of plane

Lateral – in plane



$$V_{dt} = f_{dt} A_n \beta \sqrt{1 + \frac{f_a}{f_{dt}}}$$

$$V_{tc} = (\alpha\ P + 0.5\ P_w)\left(\frac{L_w}{h_{eff}}\right)\left(1 - \frac{f_a}{0.7 f'_m}\right)$$

$$V_r = 0.9\ (\alpha P + 0.5 P_w)\frac{L_w}{h_{eff}}$$

$$V_s = 0.7(t_{nom} L_w c + \mu_f (P + P_w))$$

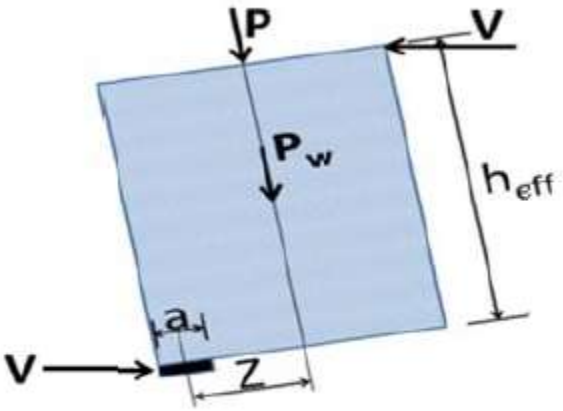
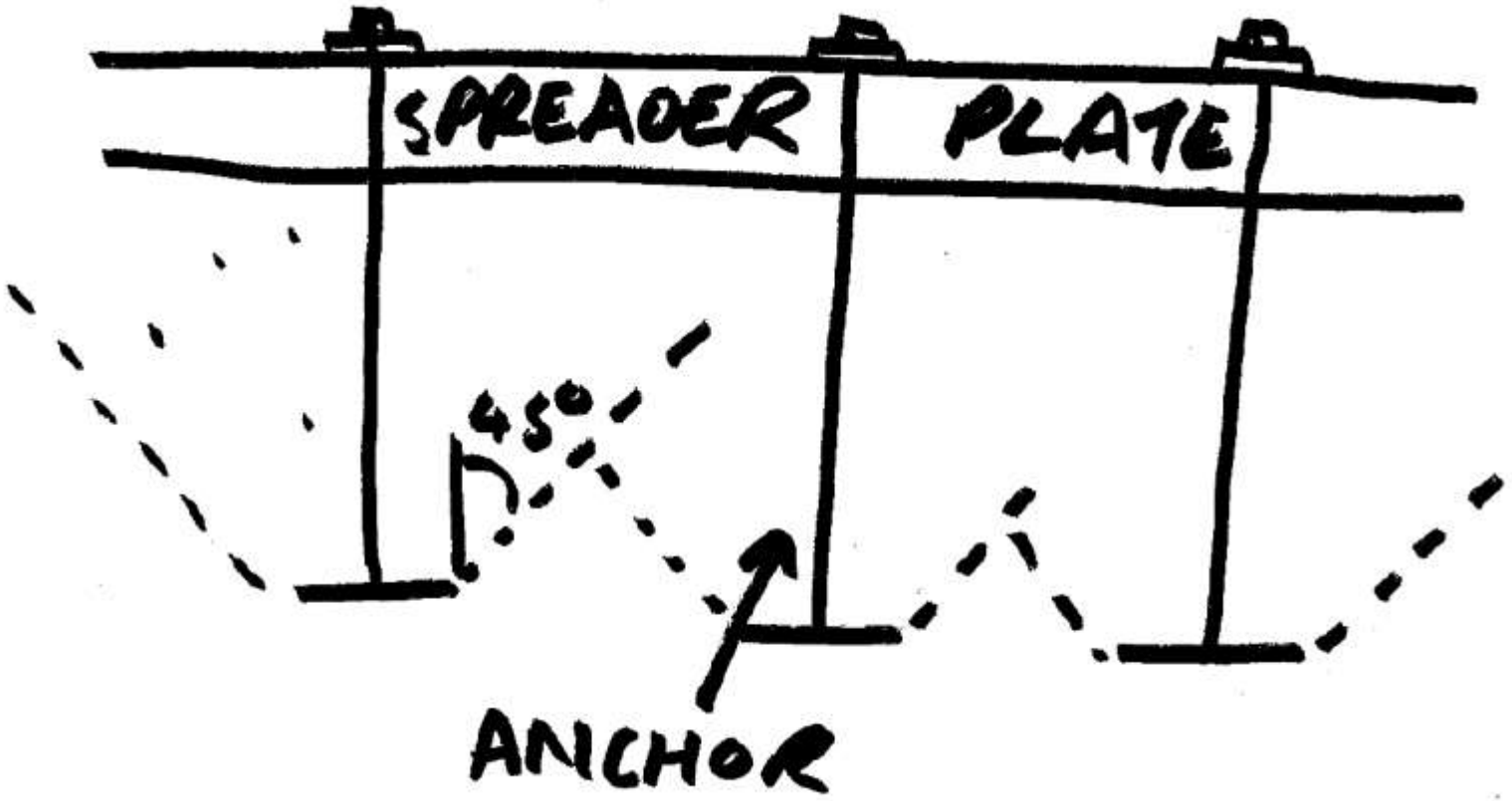


Figure 10.65: A rocking pier

Uplift



Control joints - Shrinkage

- Back wall of a plant room
- Temperature and humidity change to one side of the wall

Thermal resistance

- Quoted R value (U value)

Fire resistance

- Cinva Ram fire test CSIRO
- Fire rating probably ok
- Formaldehyde release?

Weathertightness / Durability

Tests for stabilized walls don’t give same results for unstabilised walls

Construction details

Colour

NK’Mip Desert Centre – Courtesy of SireWall

Specification

2.2 RAMMED EARTH MATERIALS

.1 Portland Cement: CAN/CSAA3001, Grey colour.

.2 Proprietary mix of amended soil and admixtures.

.3 Water: CSAA23.1, clean and not detrimental to rammed earth.

.4 Colour as per Prime Consultant selection.

2.3 ADMIXTURES

.1 Chemical Admixtures: as recommended by rammed earth installer

2.4 INSULATION

.1 Polyisocyanurate Insulation (Faced): CAN/ULCS704 Type 1 , ASTM C1289 Type I , closed cell insulation conforming to the following:

.2 Compressive Strength: 172 kPa

.3 Thermal Resistance: Aged RSI of 1.145/ 25mm (R 6.5/inch)

.4 Facing: Factory applied facing of aluminum/poly/kraft on both faces.

.5 Board Size: 1220x2440 mm

Site testing

Conclusions

- We know how to do it
- Designed buildings usually perform much better than non designed ones
- Achieving national standards is difficult and expensive
- Earth building doesn't have a supplier to pay for design information
- In order to go mainstream we must allow others to design earth buildings without super specialist knowledge

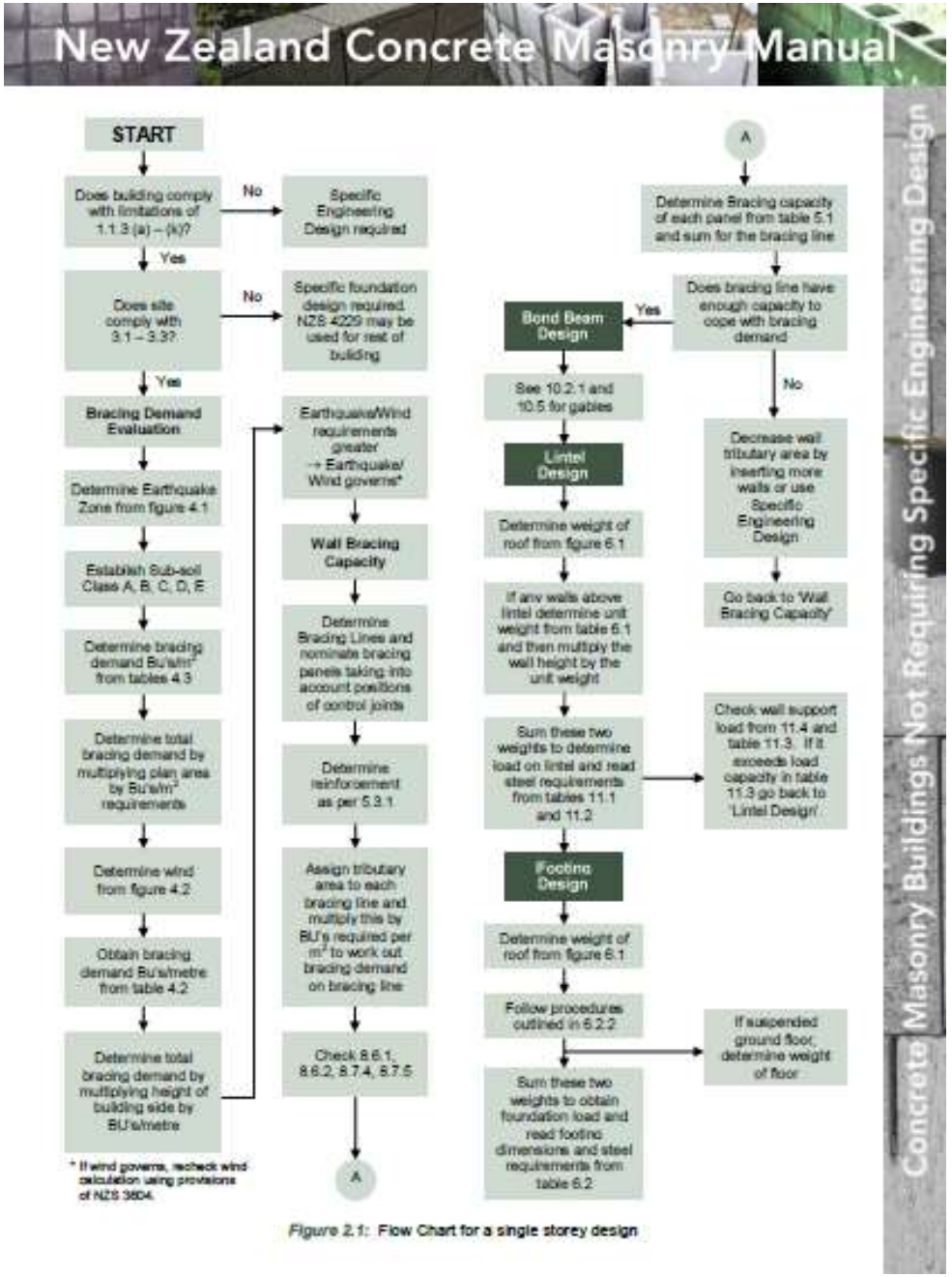


Figure 2.1: **Flow Chart for a single storey design**

ECVET *Earth building*

http://ecvetearth.hypotheses.org/

- Train the builders
- European Initiative – completed December 2015

Thanks

Dr Chris Beckett - UWA

Dr Daniela Cianco - UWA

Prof Charles Augarde – University of Durham

Dr James Norman – University of Bristol

LDE LAND DEVELOPMENT & EXPLORATION LTD

Durham University

integral engineering design

UNIVERSITY OF BATH