Full-scale Fire Tests on Hollowcore Floor System

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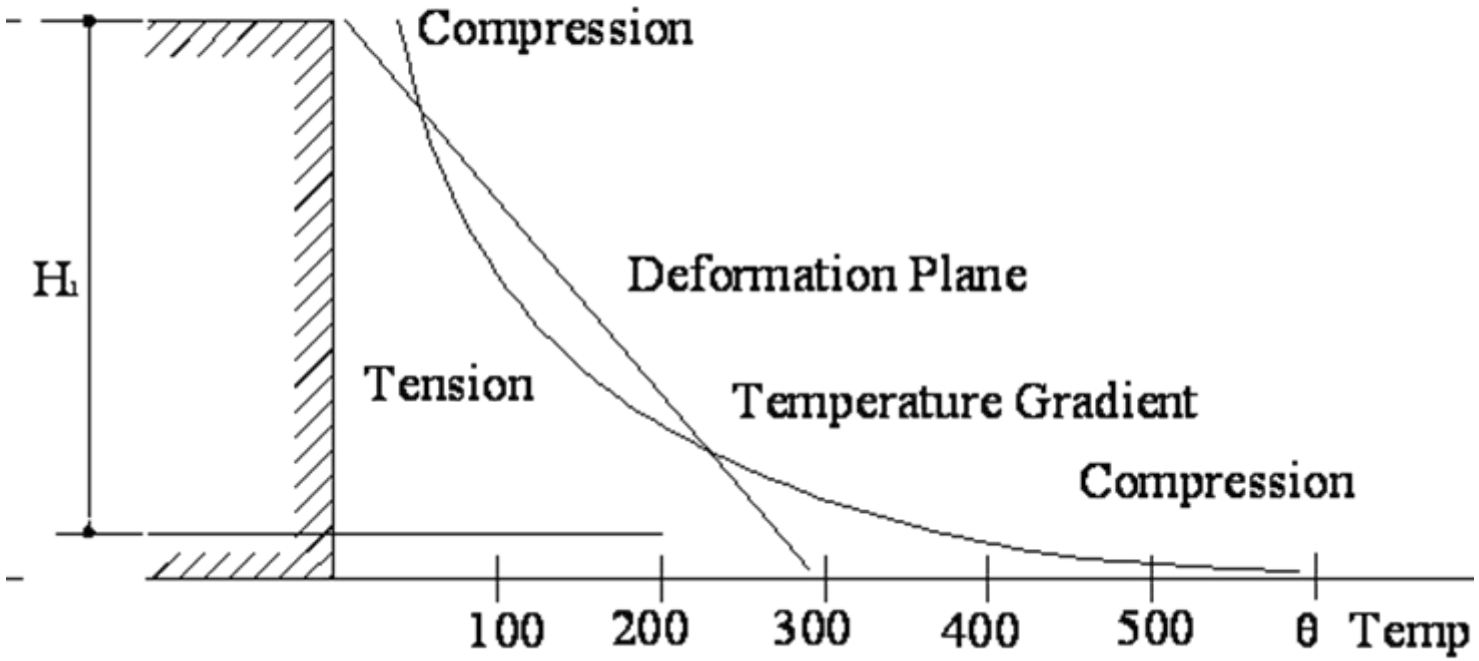
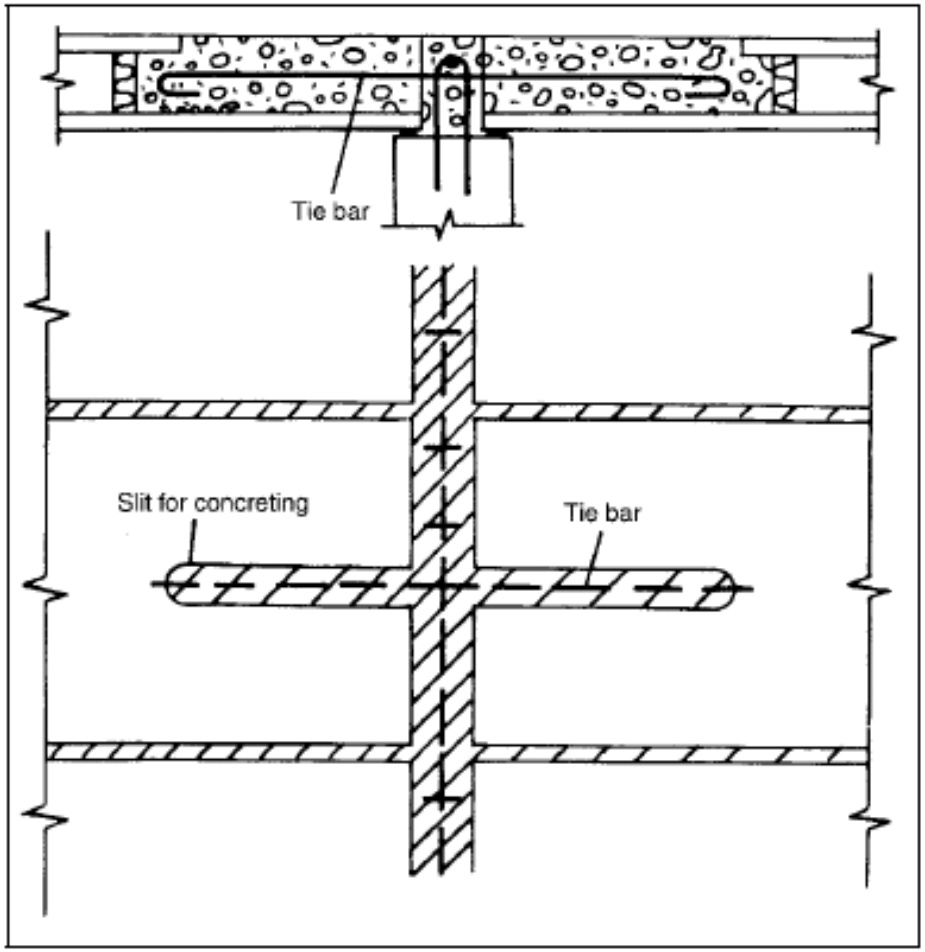
Why ?

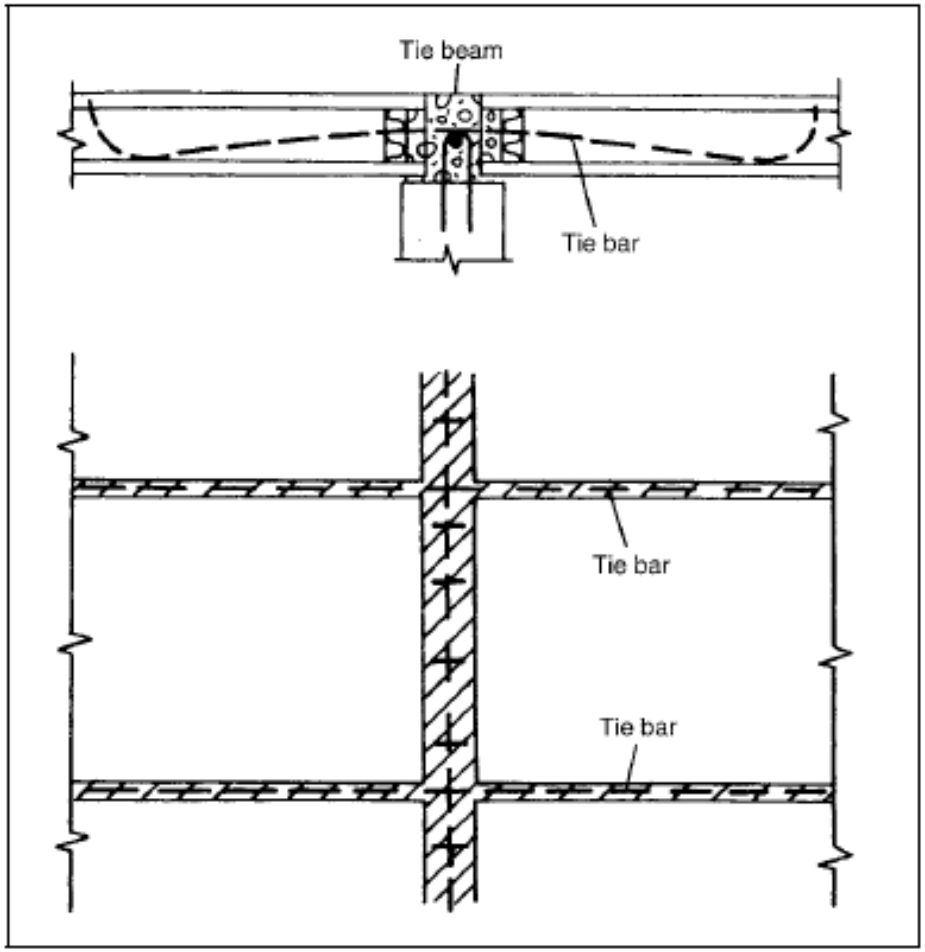
Evidence from small-scale tests of possible premature shear failure



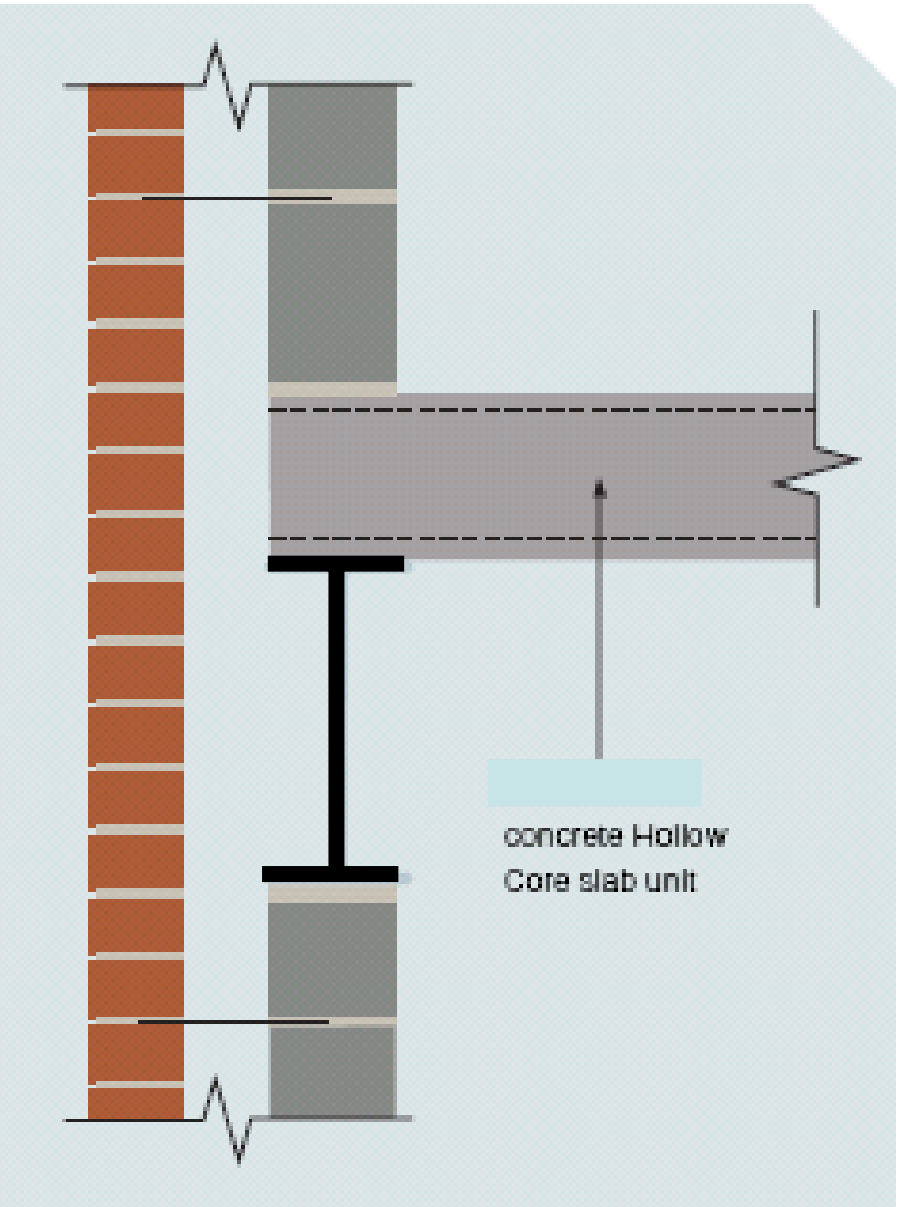
Evidence from real fires suggests that hollowcore floors have a inherent FR

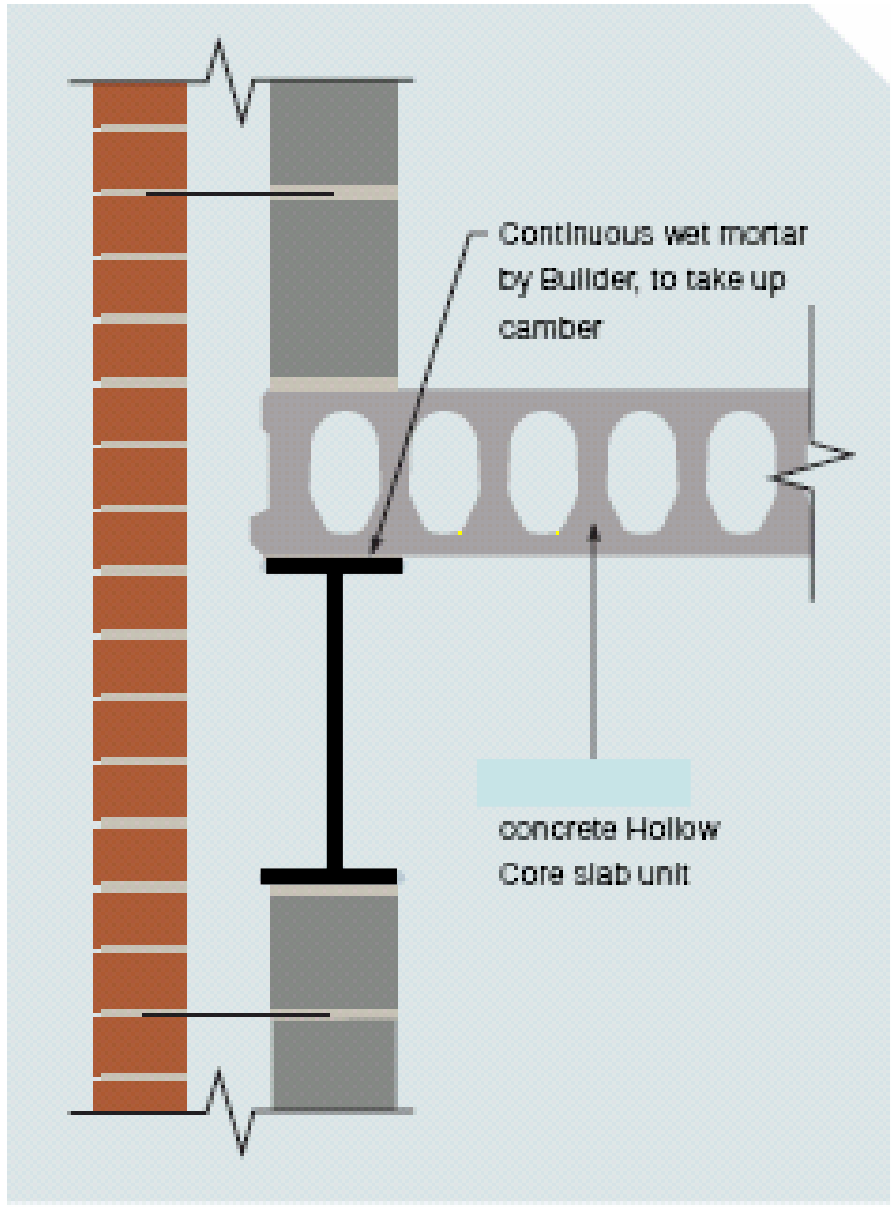
Pragmatic approach: Provided units are tied (together with a peripheral tie) then shear failure should not occur





But ! Class 2A buildings





Class 2A Buildings

Offices, hotels, and residential buildings not exceeding 4 storeys

Industrial buildings not exceeding 3 storeys

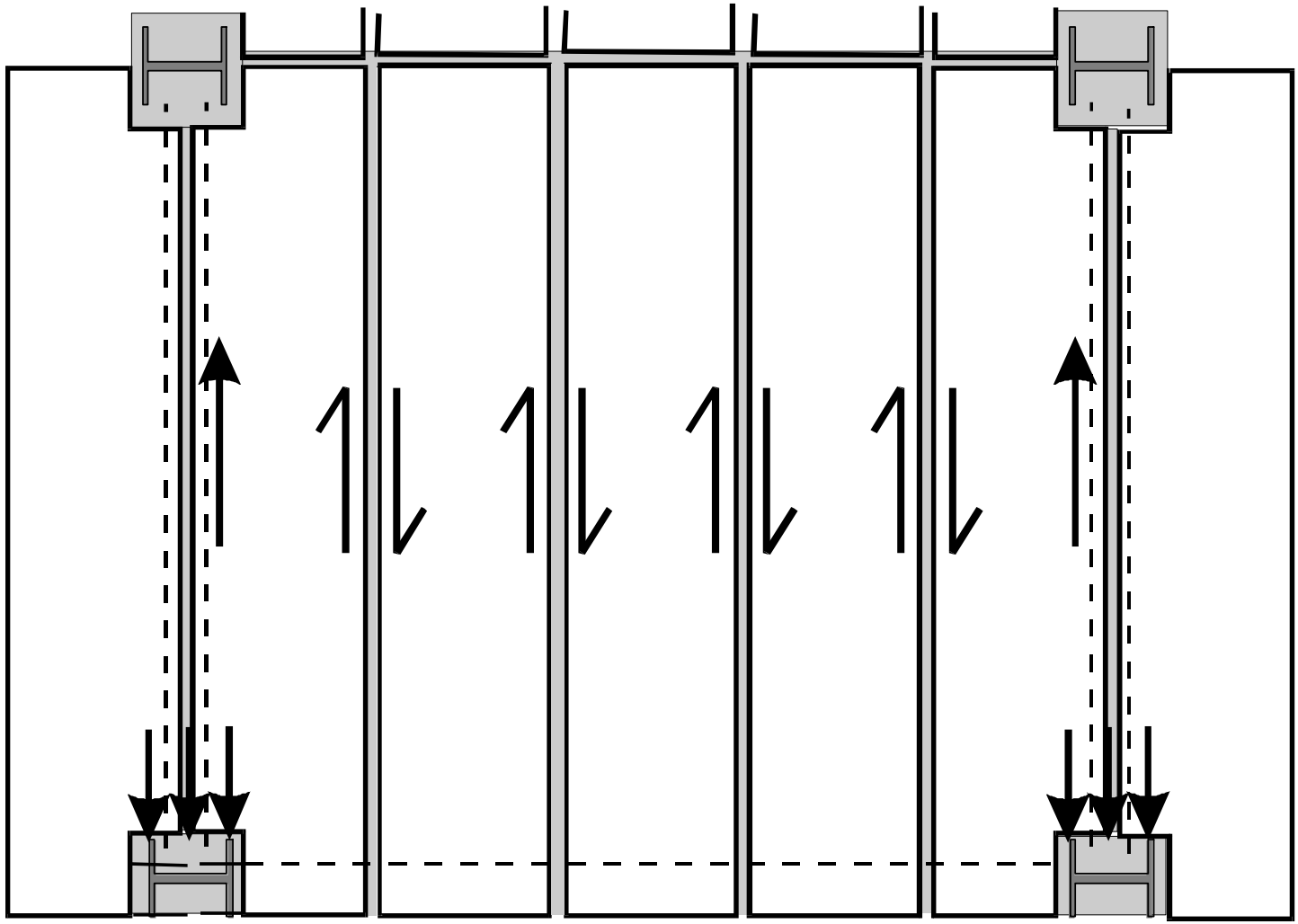
Class 2B Buildings

Offices, hotels, and residential buildings greater than 4 storeys but less than 15 storeys.

Hospitals not exceeding 3 storeys

Class 3 Buildings

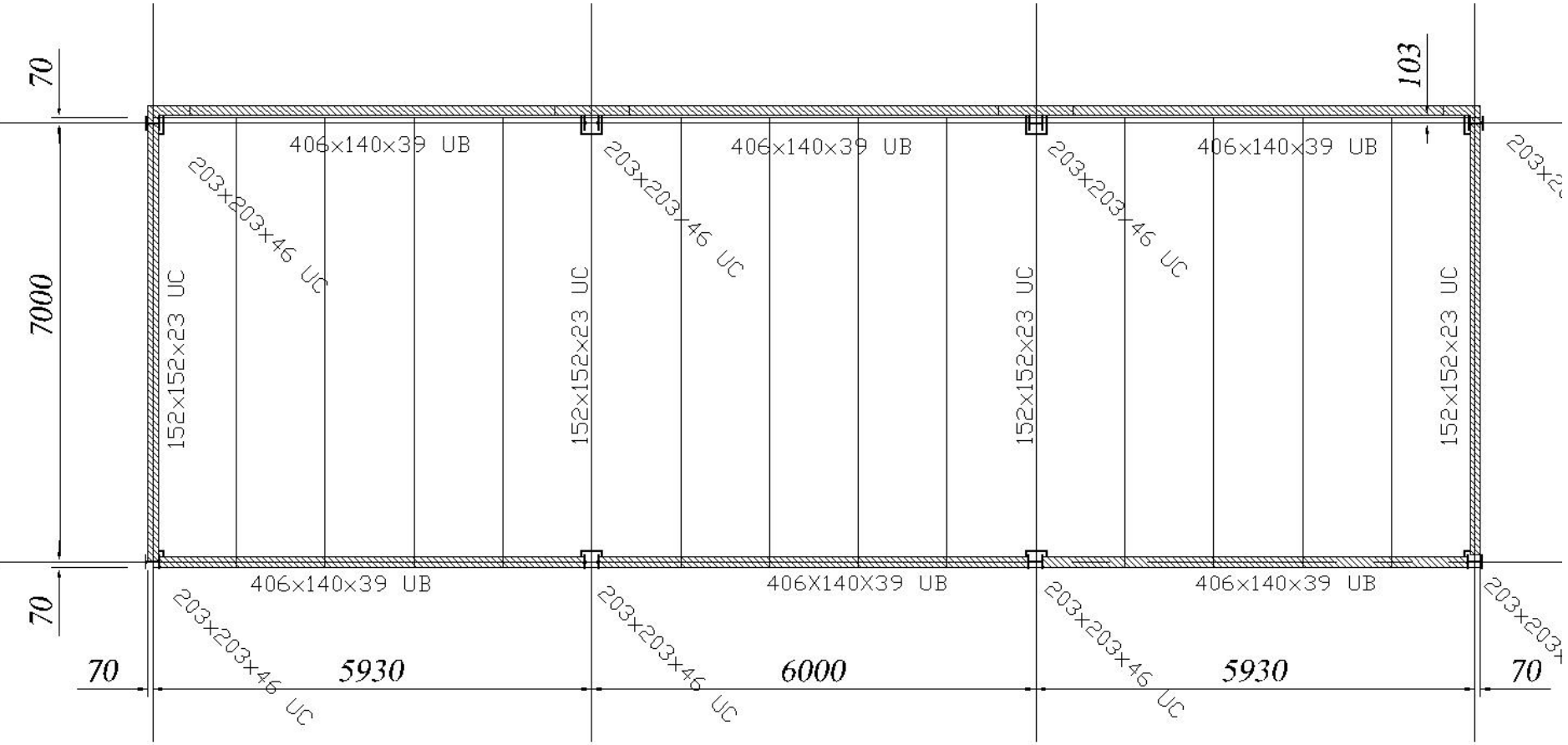
Buildings not defined as Class 2A or 2B



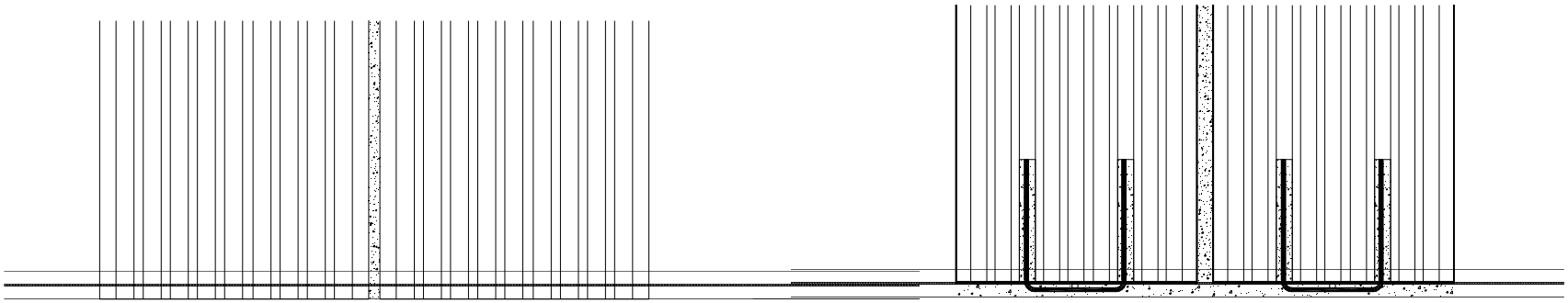
Thermal expansion of units is restrained provided the columns are tied and the tie beams do not expand more than the units.

Test Structure: 7.02m×17.76m (internal plan dimensions) ×3.6m height

15 units 1.2m wide×200mm deep



Different end restraints (Test 1 & Test 2)



Test 1

No additional ‘fixity’

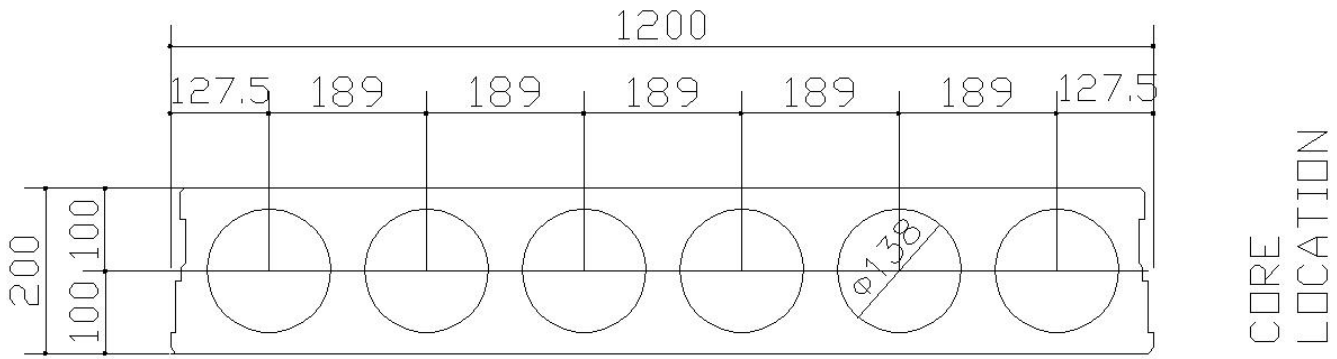
Class 2A

(Generally under 4 stories)

Test 2

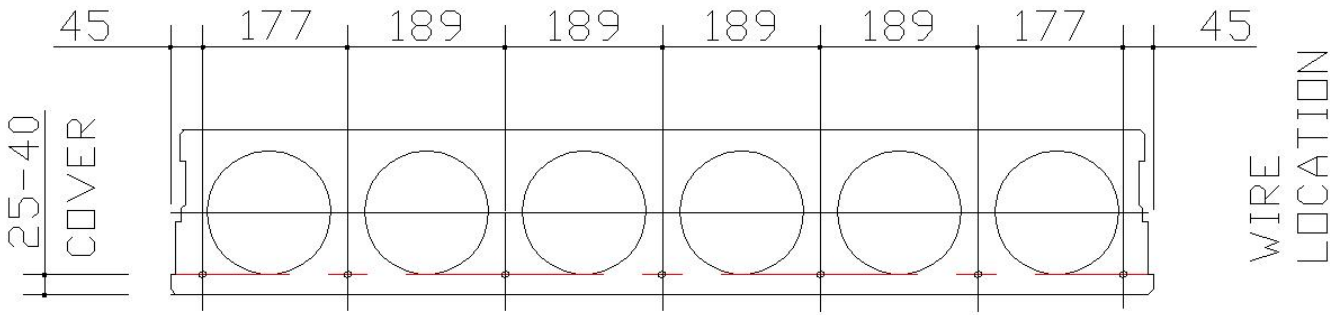
T12 u-bars per unit were placed around 19mm dia stud.

Class 2B



Cover to strands = 25mm to obtain 60 mins FR

7No. 12.5 mm strand per unit



Limestone aggregate

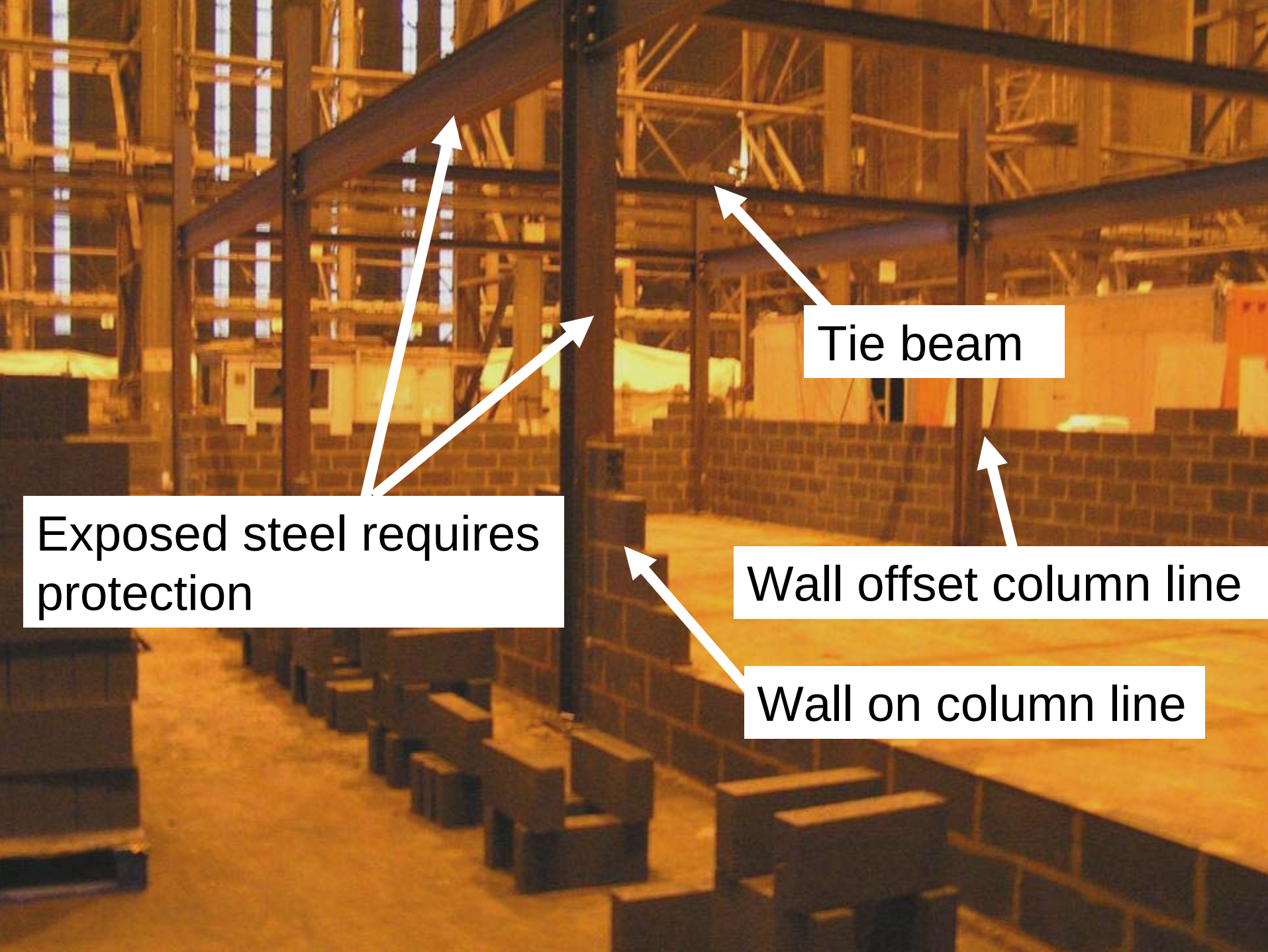
M/C = 2.8% by weight

18 12:41

Test 1: Units sit directly on steel beams and grout placed between units and around columns

Test 1

Grout placed between units and around column


Tie beam
Exposed steel requires protection
Wall offset column line
Wall on column line

Fire Protection:

15mm Lafarge fire board

60mins FR in standard test.

Fire Load:

Aim: to try and follow standard fire curve upto 60 mins.

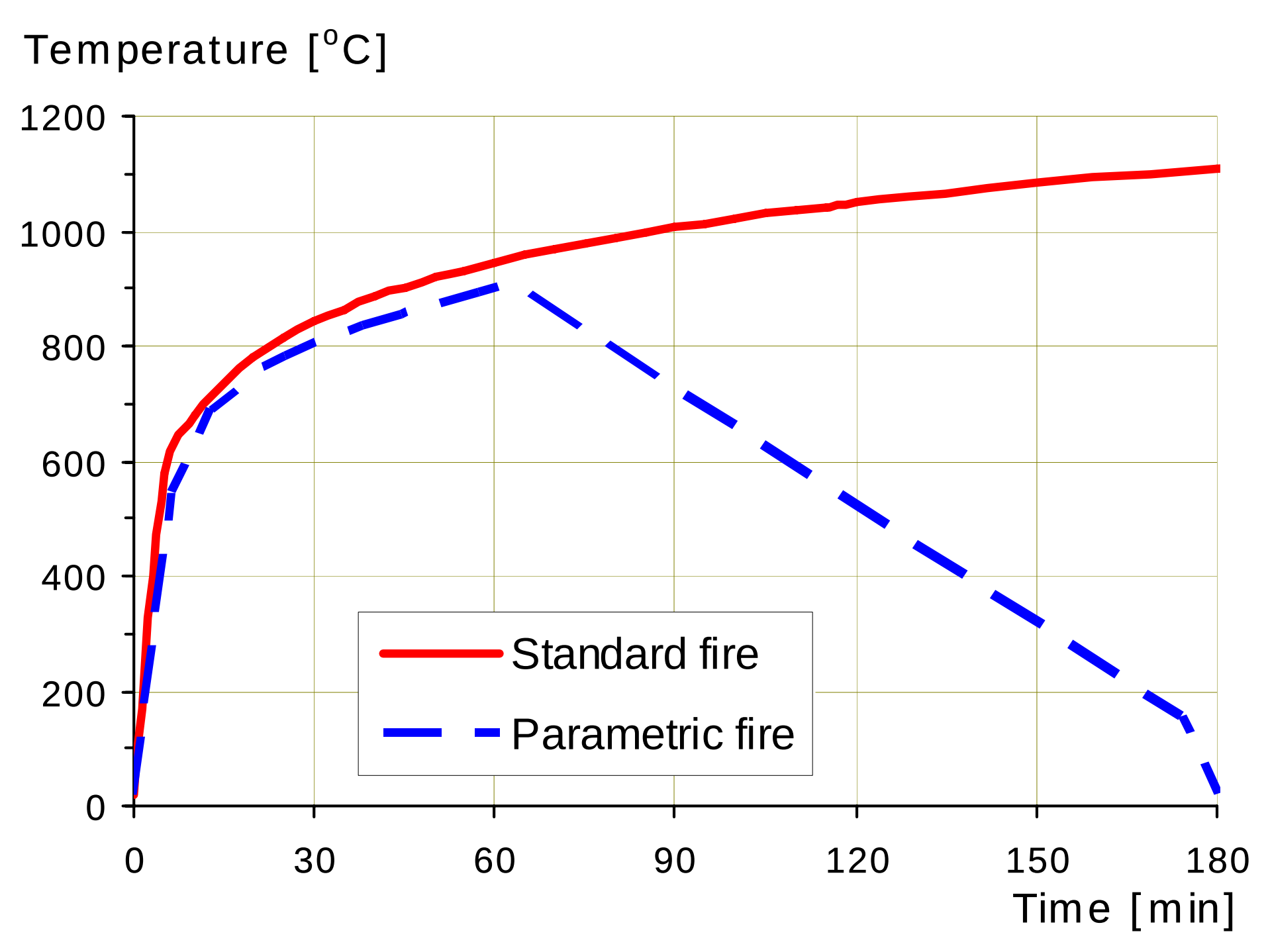
Used Annex A from BSEN1991-1-2

Office fire load = 511MJ/m^2

UK NA Office load = 570MJ/m^2

$\therefore$ 32.5kg wood/m^2 used.

570MJ/m2
(32.5kg wood/m2)

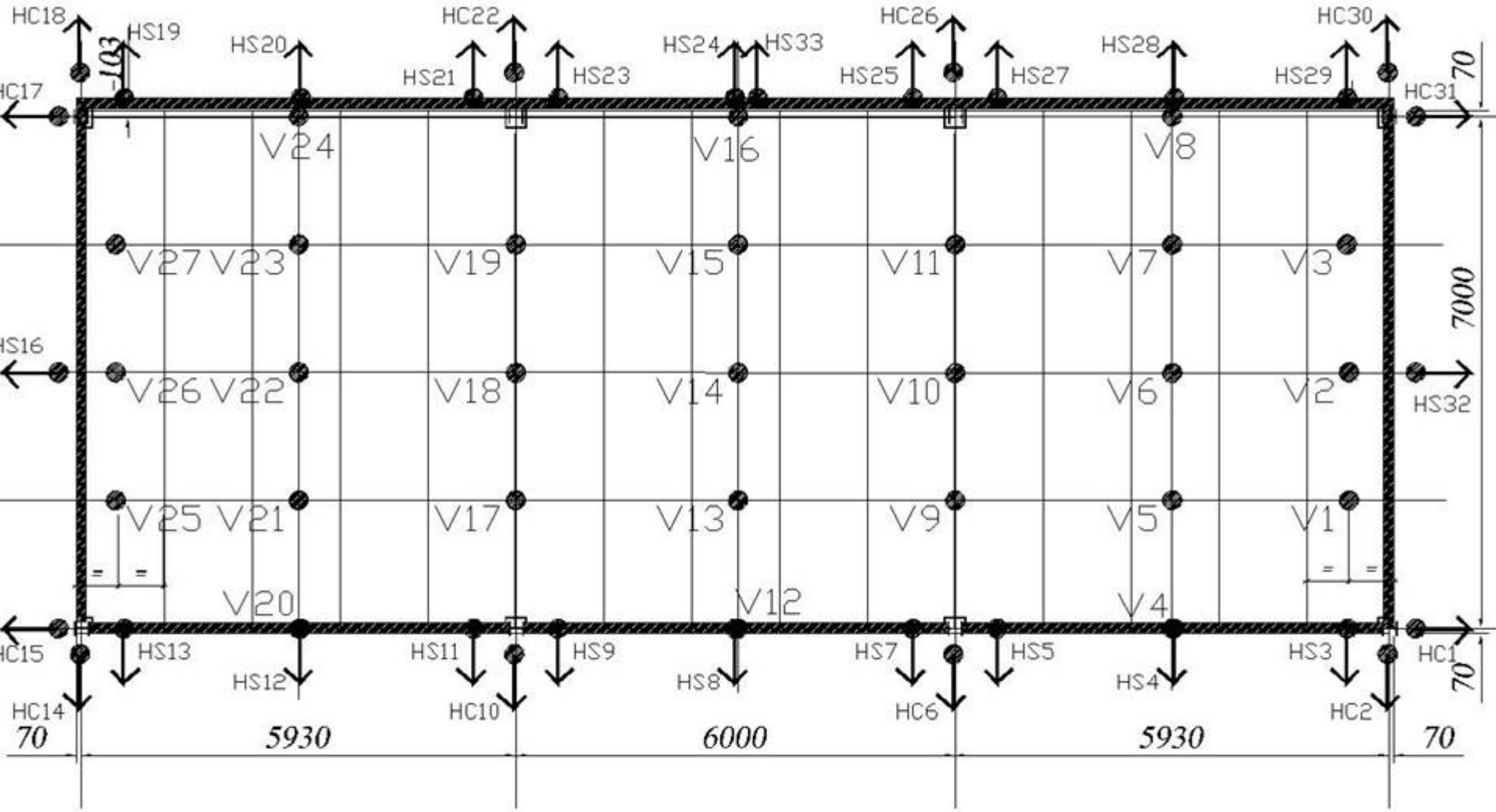

Temperature [°C]
1200
1000
800
600
400
200
0
0
30
60
90
120
150
180
Time [min]
Standard fire
Parametric fire

3 openings 2.2m×16m high

Increase in ventilation will increase temp & decrease duration

Total load = 7.67 kN/m^2 (Applied = 4.71kN/m^2)

Load Ratios: 0.34 bending; 0.26 shear.



Horizontal movement measured at 33 locations

Vertical displacement measured at 27 locations

Reference frame

BUILDING

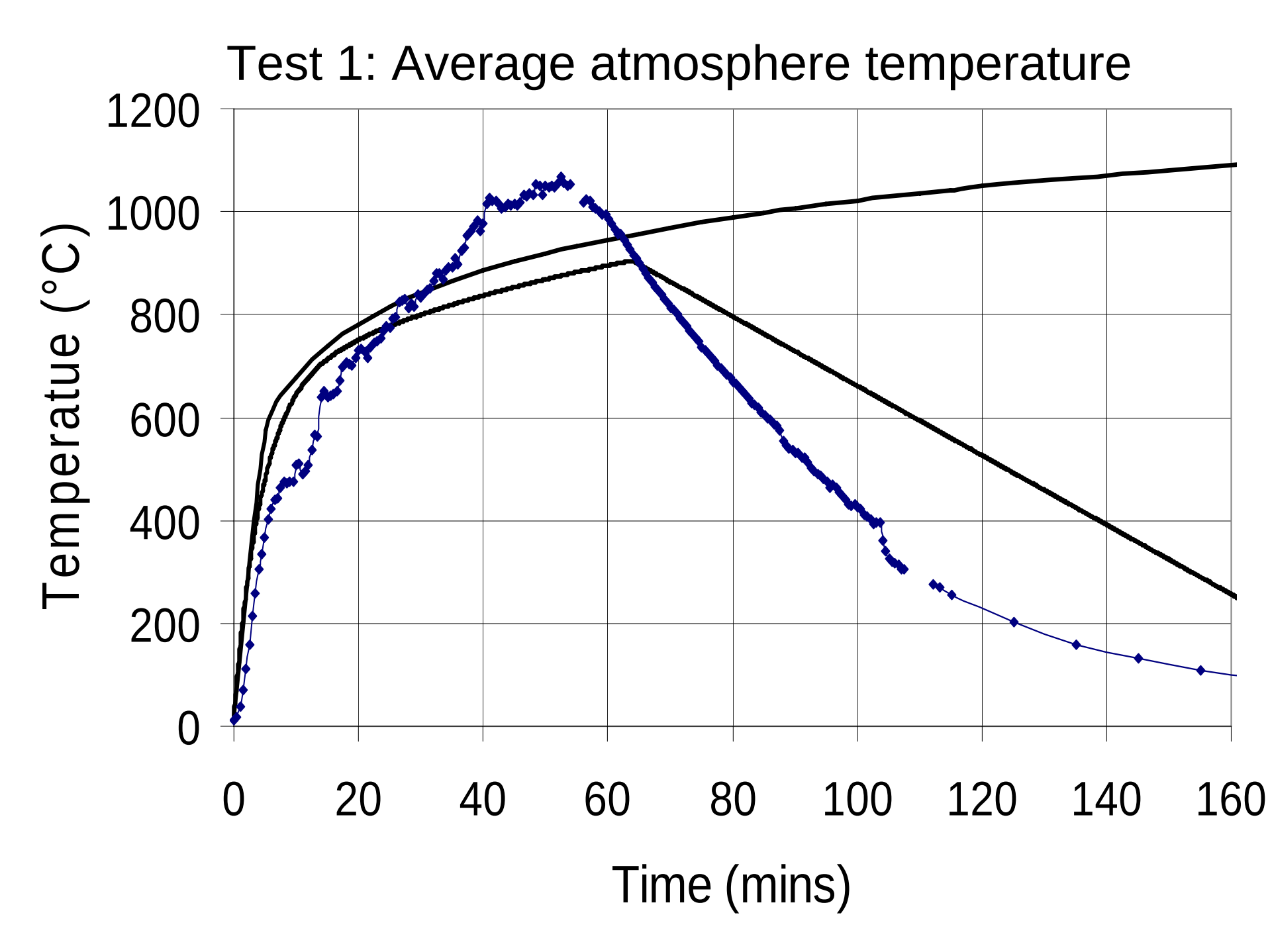
Temperature measurements: per test

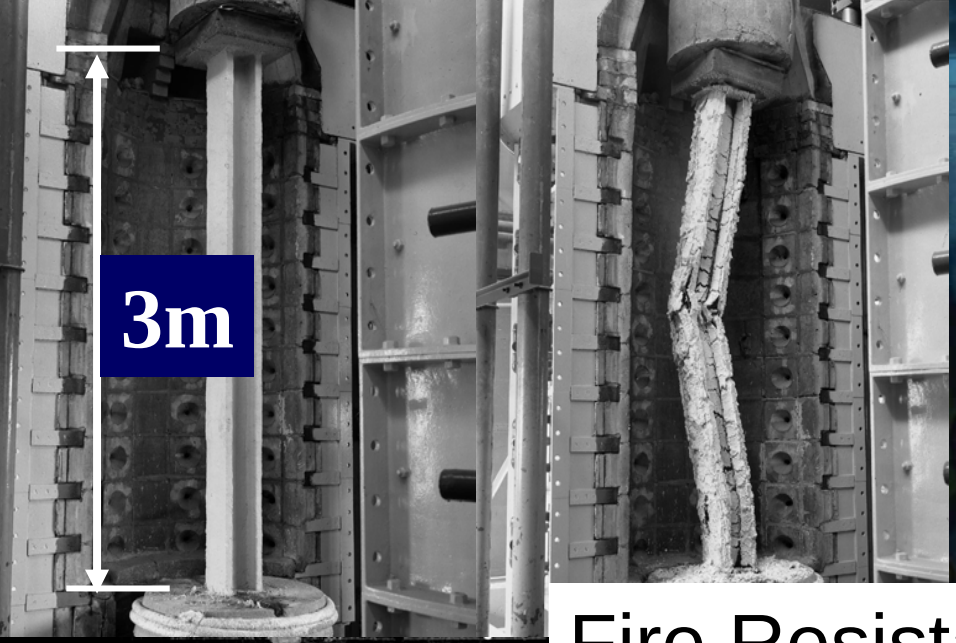
24 atmosphere temperature measurements

90 beam temperature measurements

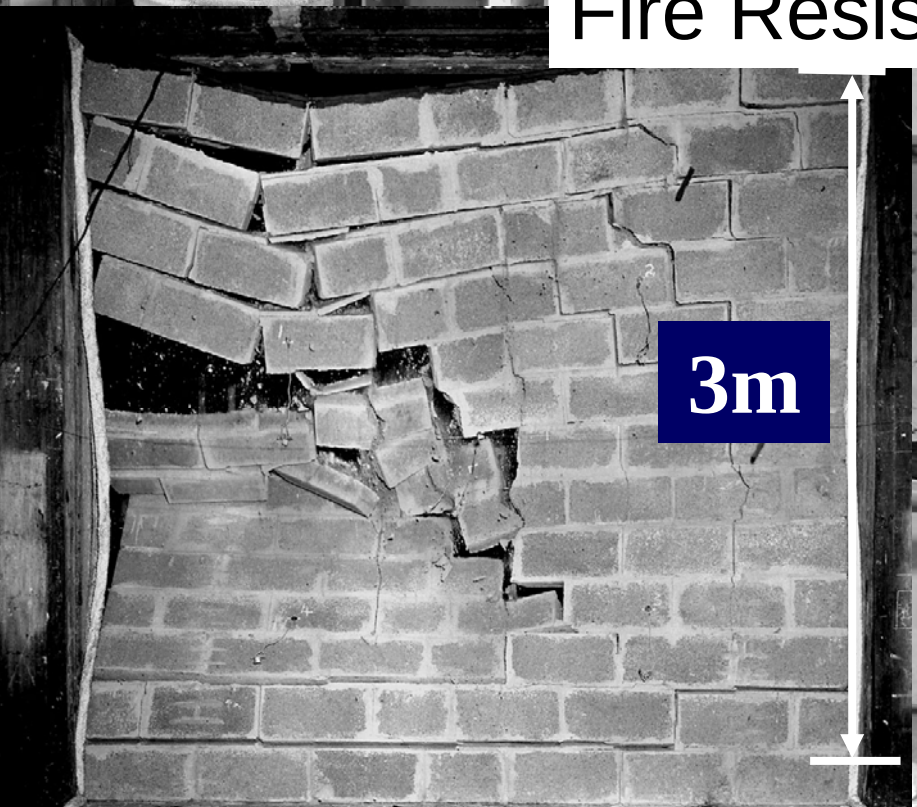
140 slab temperature measurements

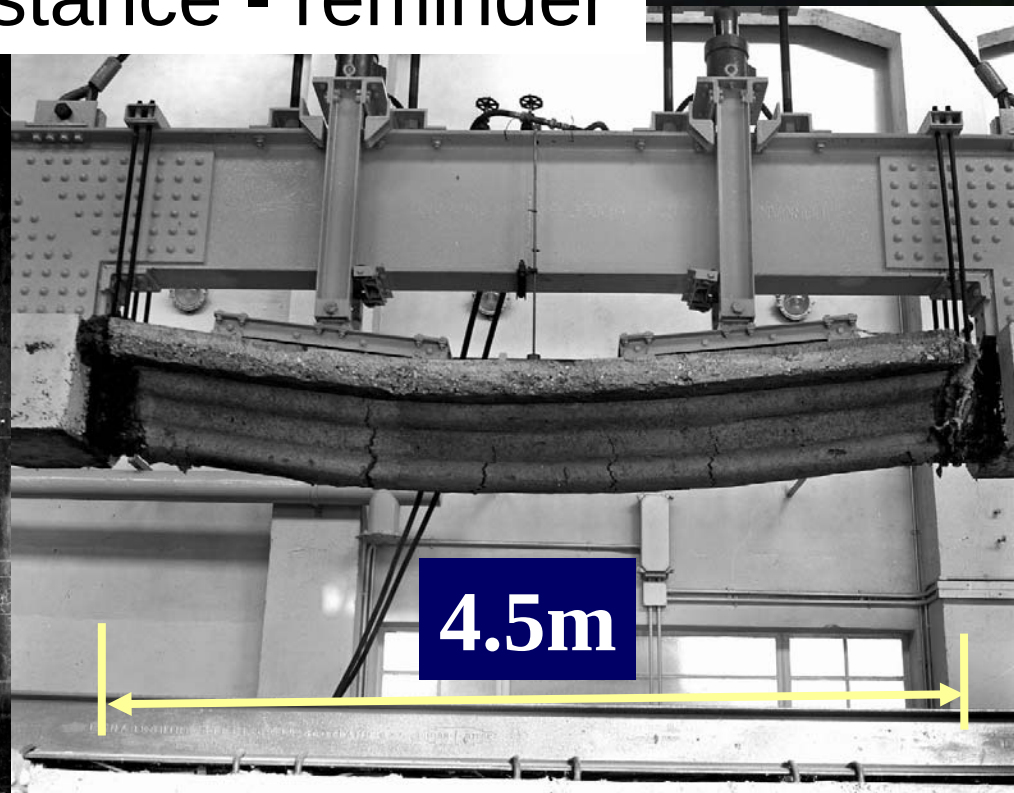
A total of 628 data points were measured

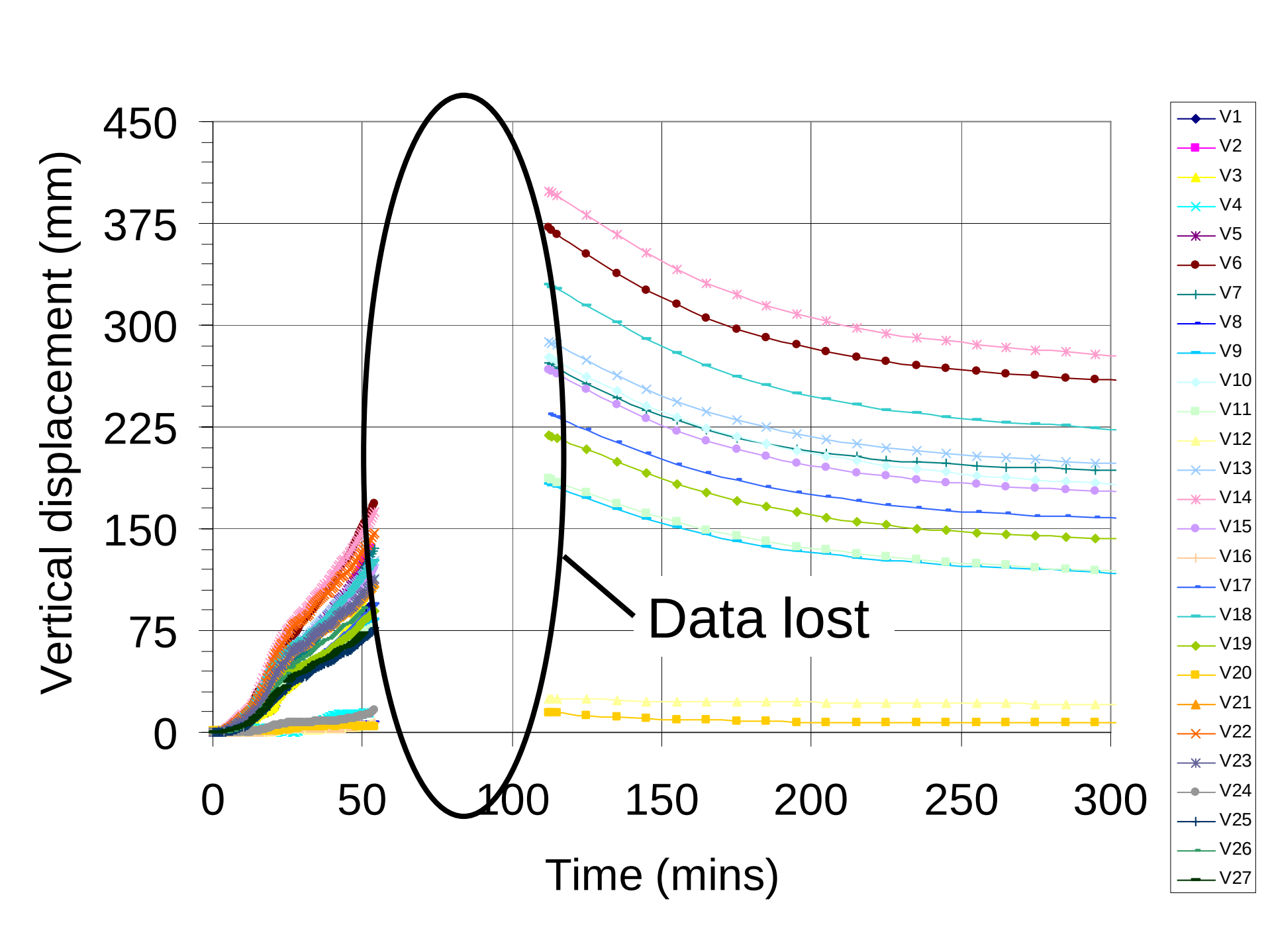

Test 1: Average atmosphere temperature
Temperatue (°C)
1200
1000
800
600
400
200
0
0
20
40
60
80
100
120
140
160
Time (mins)



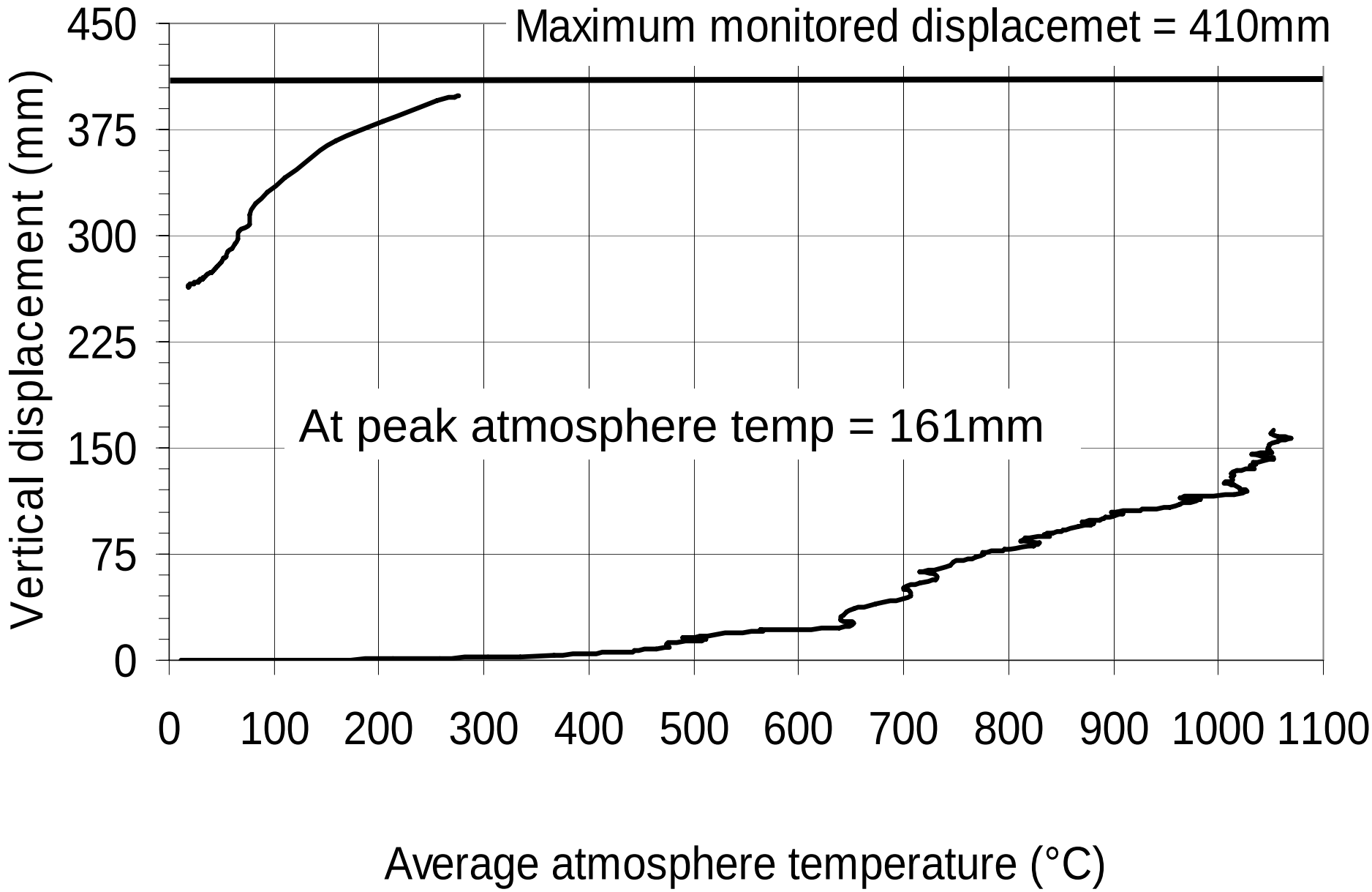
Fire Resistance - reminder



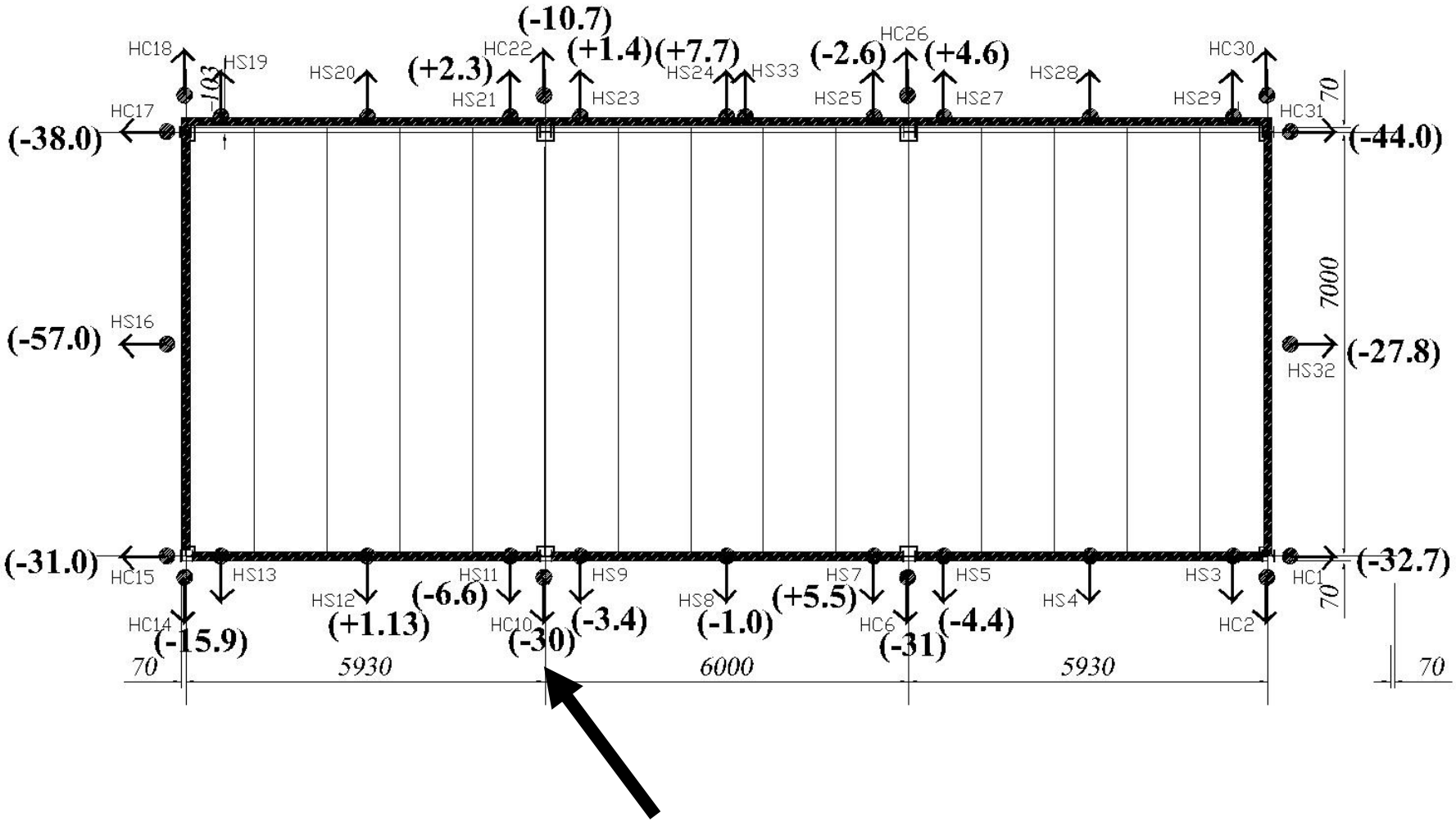



Vertical displacement (mm)
450
375
300
225
150
75
0
0
50
100
150
200
250
300
Time (mins)
Data lost
V1
V2
V3
V4
V5
V6
V7
V8
V9
V10
V11
V12
V13
V14
V15
V16
V17
V18
V19
V20
V21
V22
V23
V24
V25
V26
V27

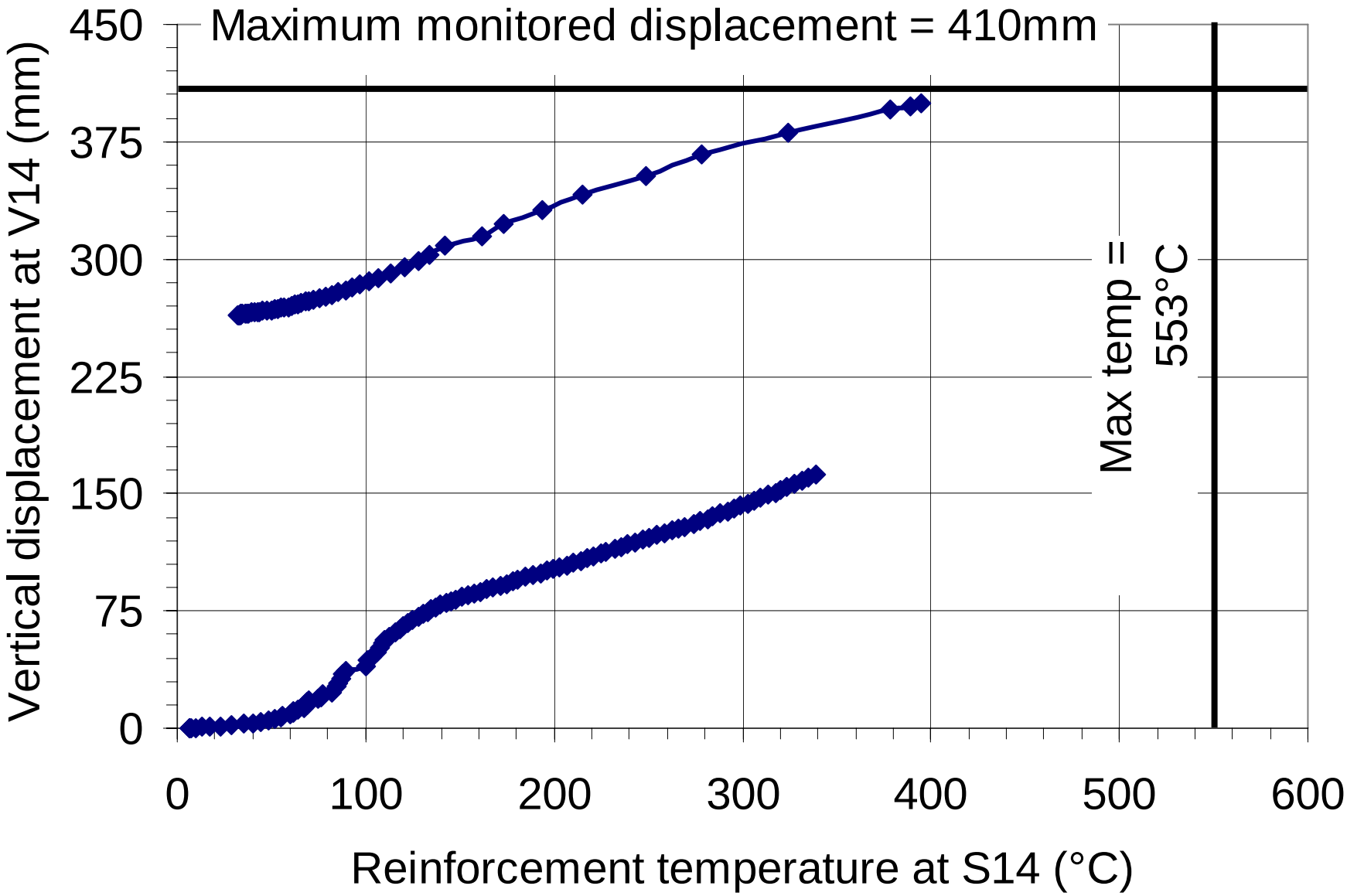
MKM
BUILDING SUPPLIES


Maximum monitored displacemet = 410mm
At peak atmosphere temp = 161mm
Vertical displacement (mm)
450
375
300
225
150
75
0
0
100
200
300
400
500
600
700
800
900
1000
1100
Average atmosphere temperature (°C)

Horizontal displacements at 54 mins (1053ºC atmosphere temp)



Column moved out 23mm more than the unit

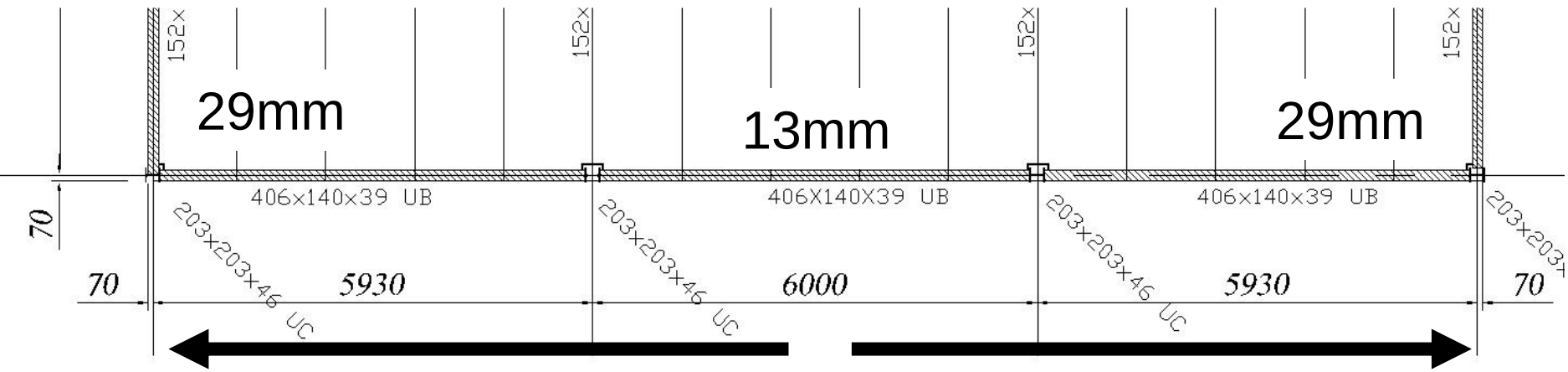

Maximum monitored displacement = 410mm
Max temp = 553°C
Vertical displacement at V14 (mm)
450
375
300
225
150
75
0
0
100
200
300
400
500
600
Reinforcement temperature at S14 (°C)

Design to BSEN1992-1-2

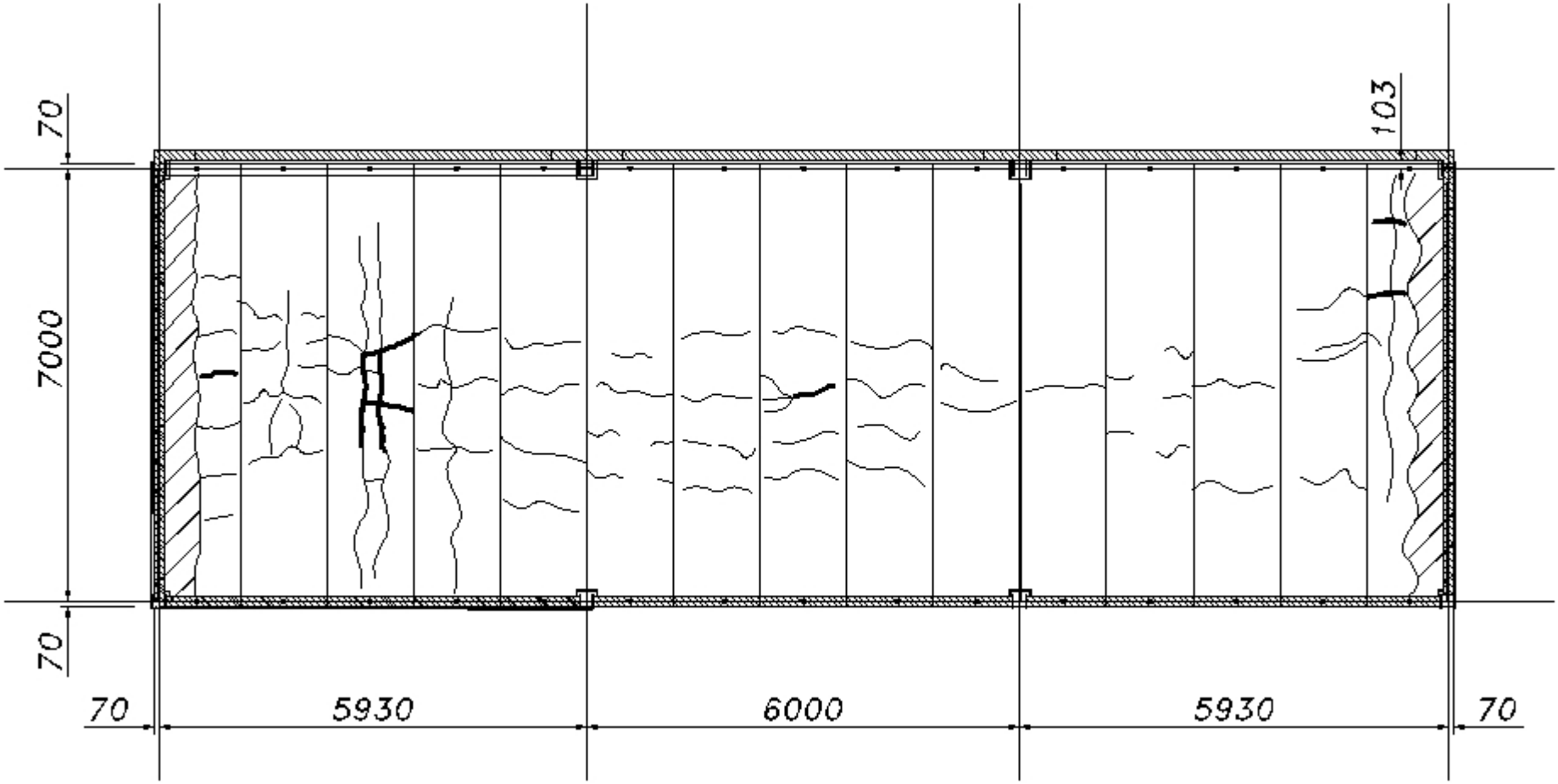
Maximum strand temp = 553ºC

Flexural capacity = 39.7kNm

Applied load = 54.8kNm

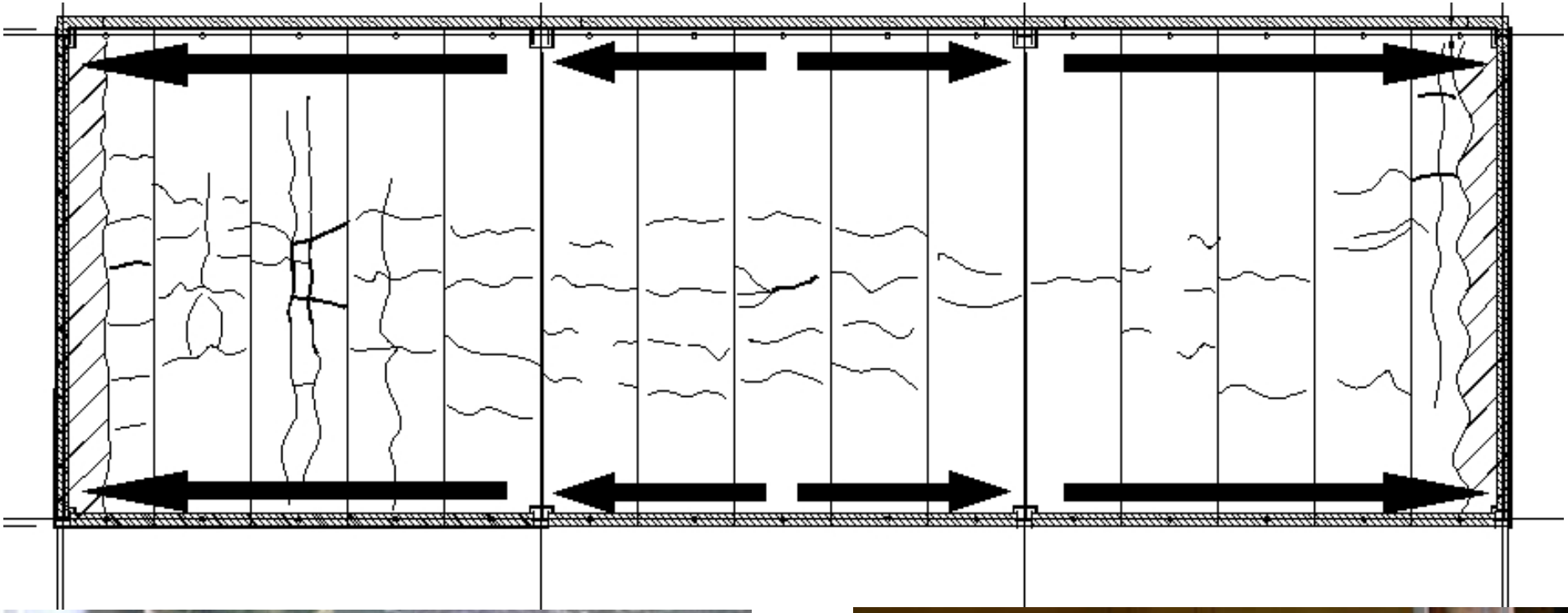


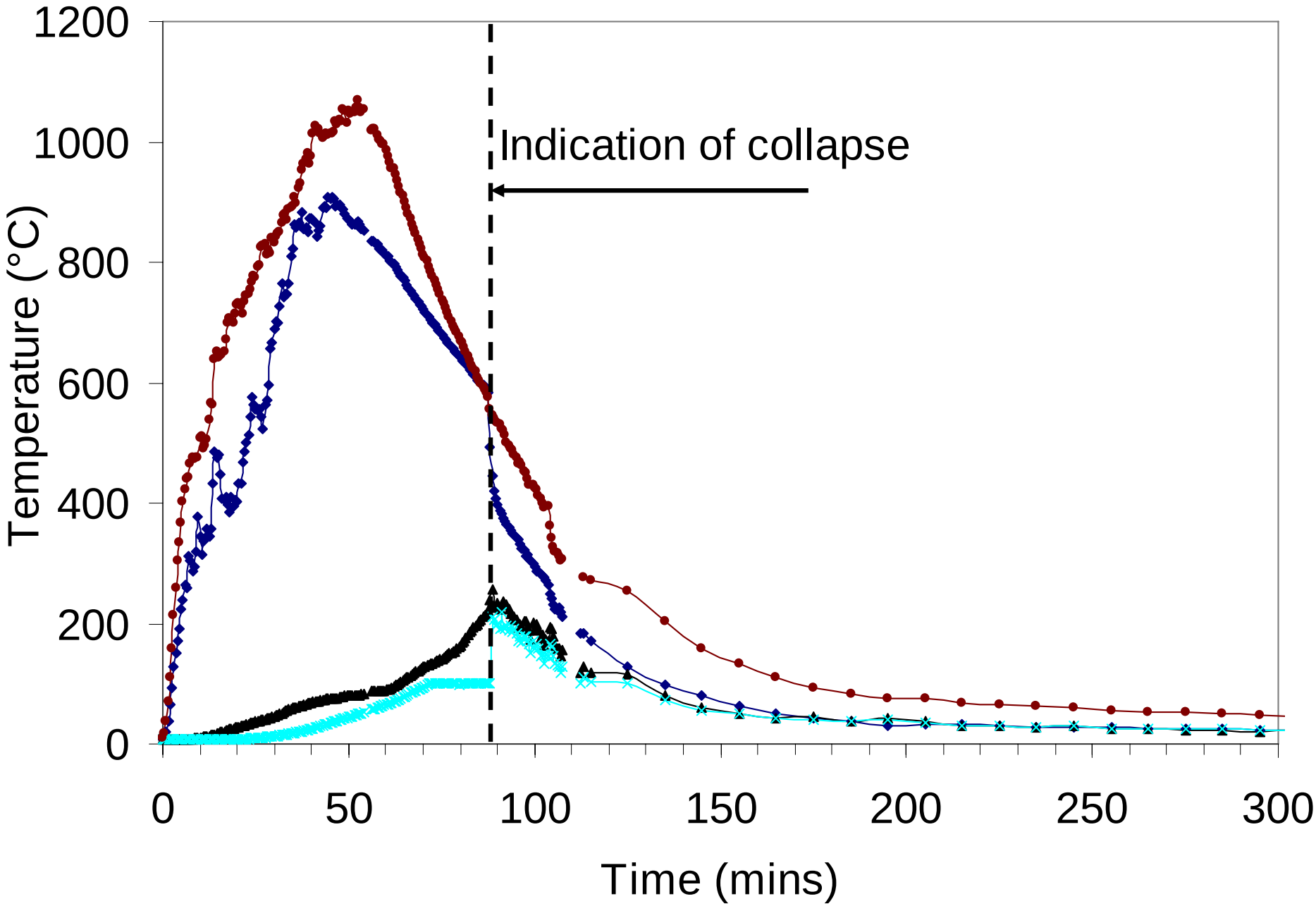
Residual slippage increased towards ends


70
7000
70
103
70
5930
6000
5930
70

Test 1

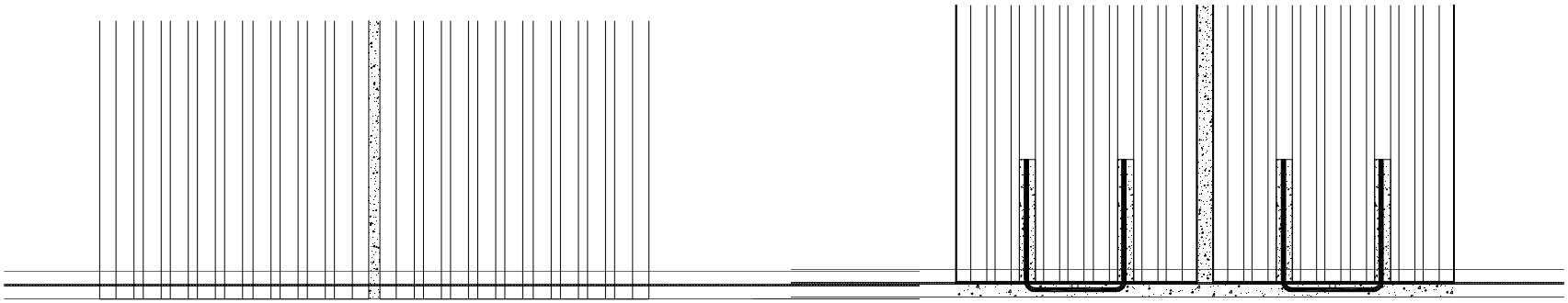
No significant spalling




1200
1000
800
600
400
200
0
Temperature (°C)
Indication of collapse
0
50
100
150
200
250
300
Time (mins)

Test 2: Different end conditions

Different end restraints (Test 1 & Test 2)



Test 1

No additional ‘fixity’

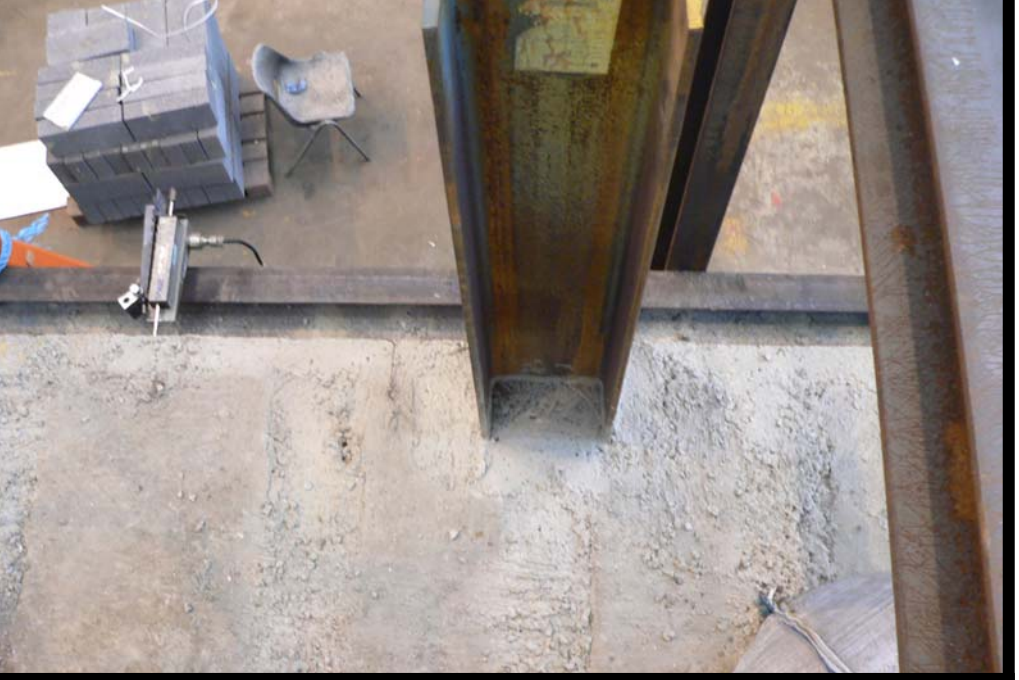
Class 2A

(Generally under 4 stories)

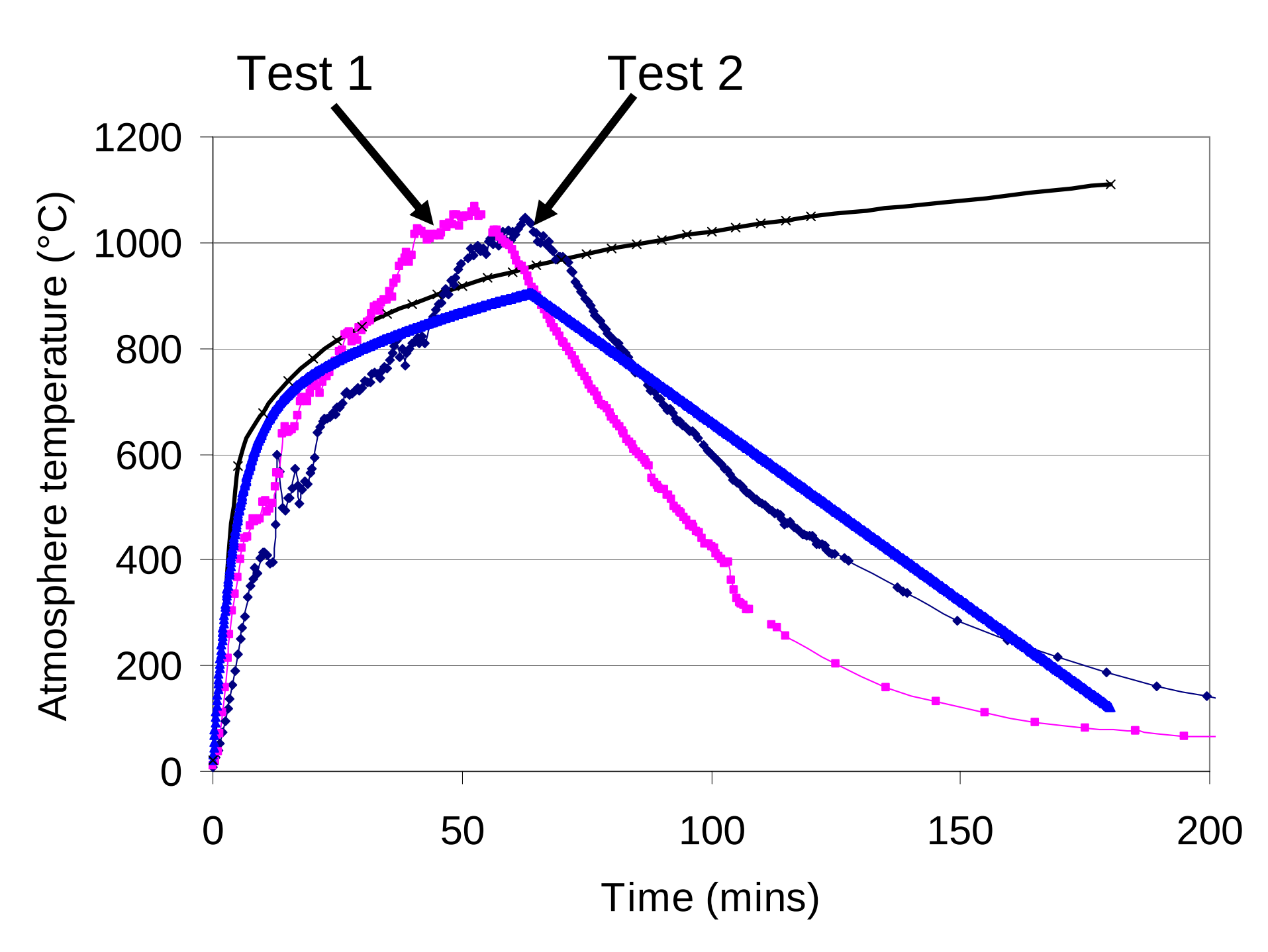
Test 2

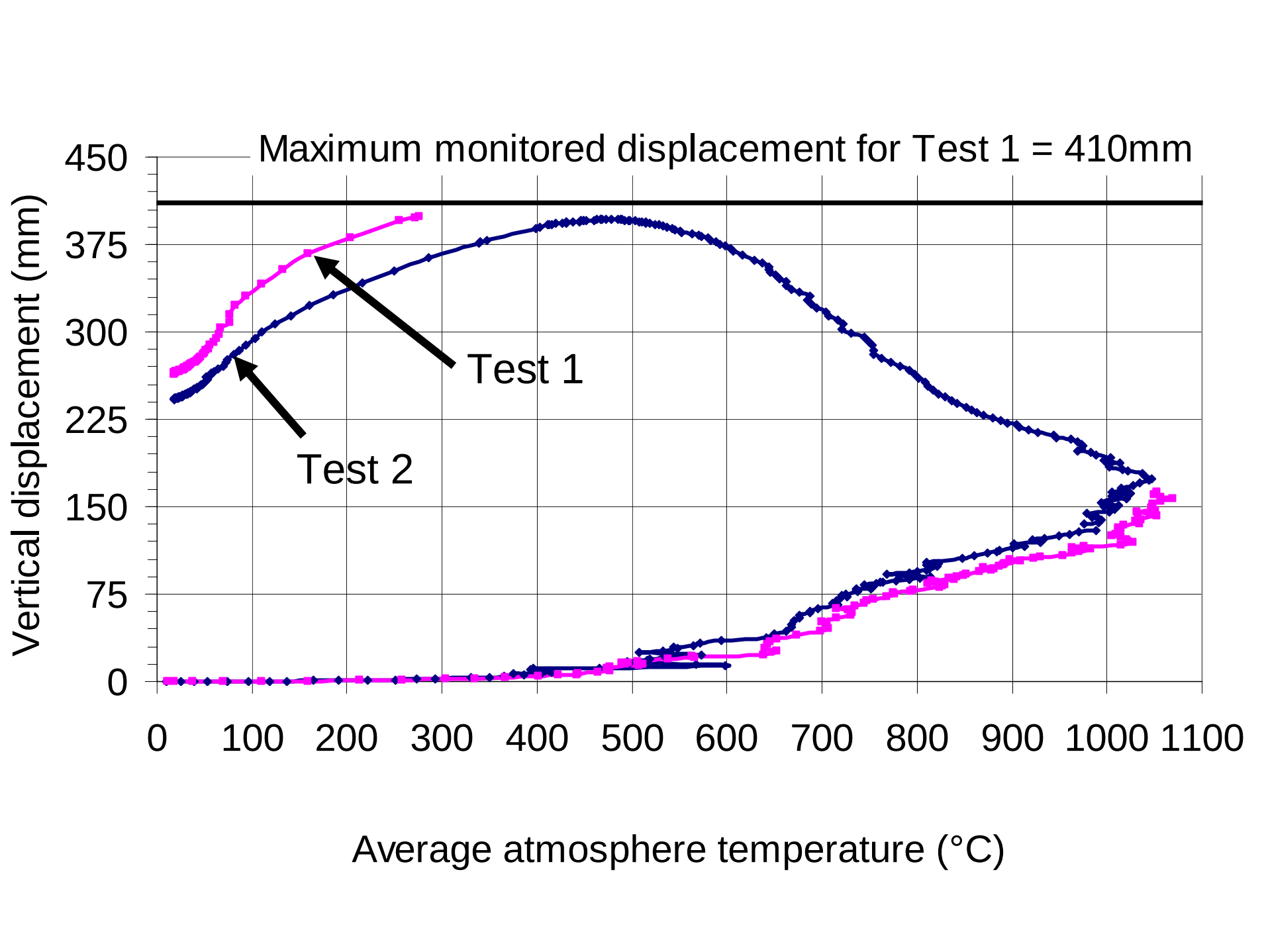
T12 u-bars per unit were placed arround 19mm dia stud.

Class 2B

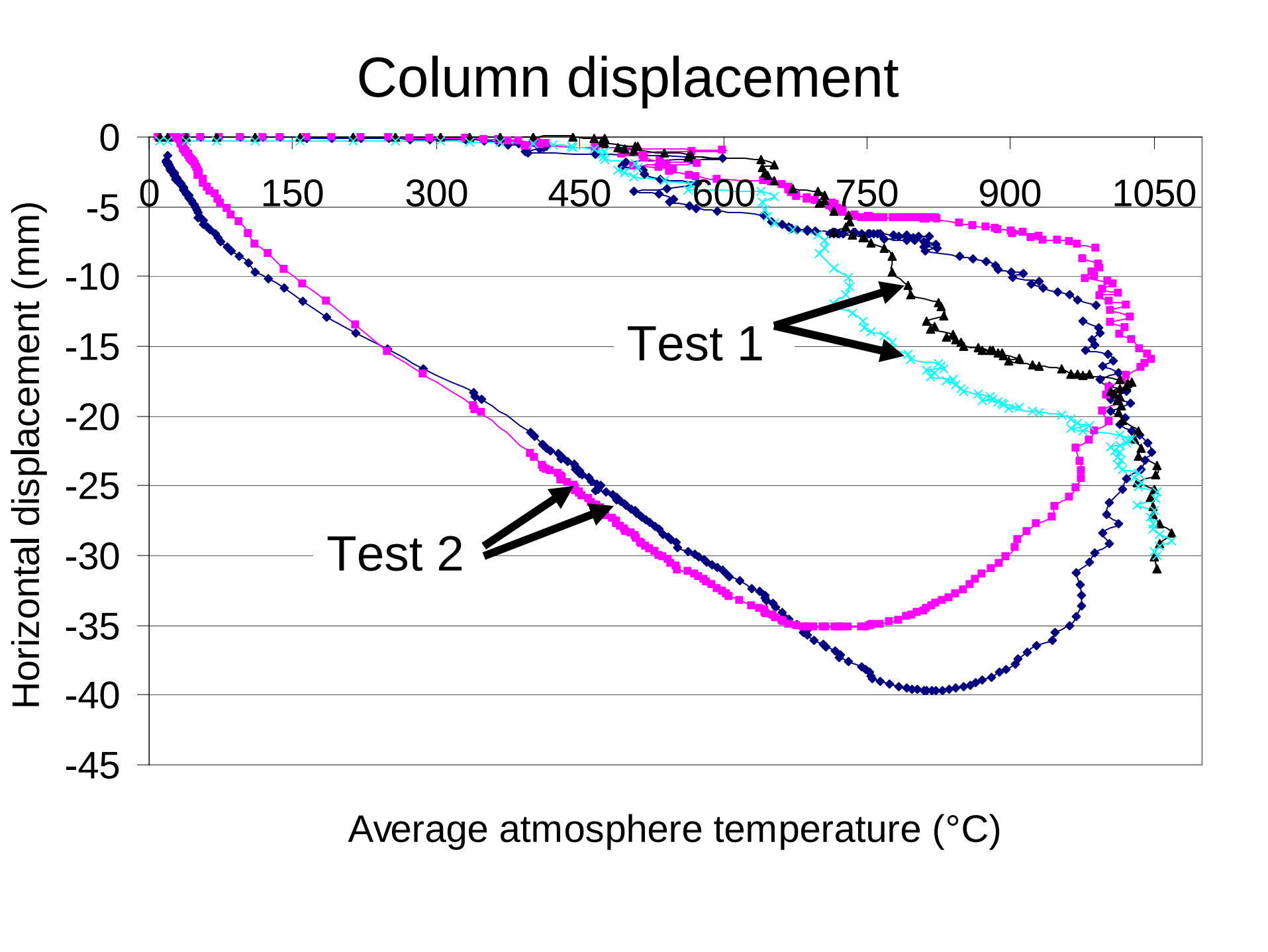


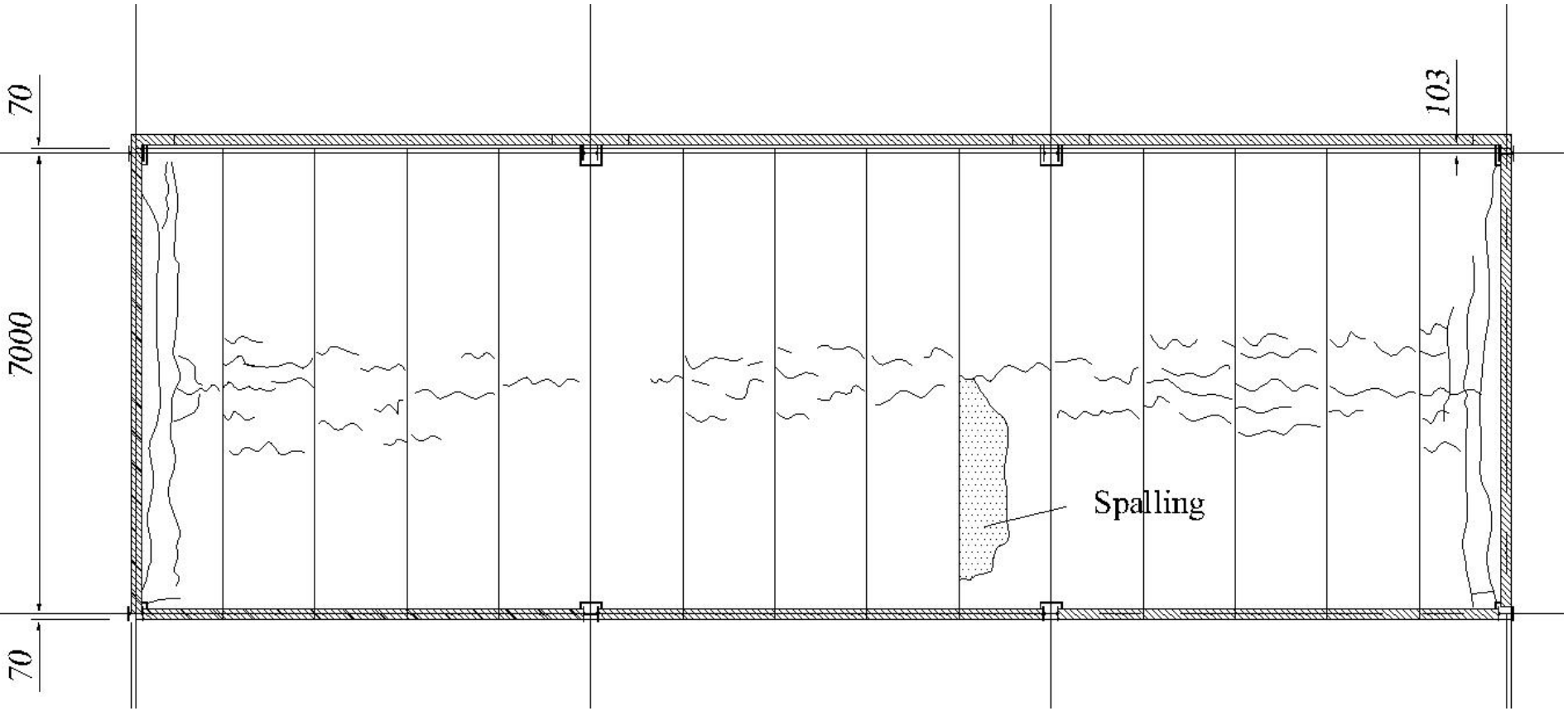
Test 2 : Additional reinforcement


Test 1
Test 2
1200
1000
800
600
400
200
0
Atmosphere temperature (°C)
0
50
100
150
200
Time (mins)


Maximum monitored displacement for Test 1 = 410mm
Test 1
Test 2
Vertical displacement (mm)
450
375
300
225
150
75
0
0
100
200
300
400
500
600
700
800
900
1000
1100
Average atmosphere temperature (°C)

Column pushed out


Column displacement
Horizontal displacement (mm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
0
150
300
450
600
750
900
1050
Test 1
Test 2
Average atmosphere temperature (°C)


70
7000
70
103
Spalling

Additional bars kept unit in place

(Time of fracture can be obtained from data)

Fracture of end units:

Test 1: 87mins (576ºC)
& 103 mins (394 ºC)

Test 2: 76mins (870ºC)
& 95mins (645ºC)

Conclusions (1)

- System performed well during the heating phase, under a very severe (unrealistic ?) fire.
- The system supported the applied load during the cooling phase (even though this was ignored during the design)
- Test 1 and Test 2 had similar performance (except for the end units).
- There was evidence of a lateral compressive strip forming enhancing flexural and shear capacity.

Conclusions (2)

- No significant spalling occurred.
- The parametric curve produced lower temps during the heating phase and should be addressed.
- Although the applied load was higher than the assumed office load the LRs of 0.34 and 0.26 were low. A range of LRs should be considered.

Acknowledgements

Tom Lennon - BRE

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Jeremy Milbank – Mibanck Industries

Norman Brown – British Precast

Thank you