# Integrity of Compartmentation in Buildings During a Fire

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# Background

- Review of Approved Document B

  Use of structural fire engineering

  New forms of construction – slim floor systems, longer spans

  New design methods – BRE fire engineering design method for lightly reinforced composite floor slabs (SCI-P288)

  Full scale fire tests – large displacements well in excess of the deflection limits associated with standard fire tests

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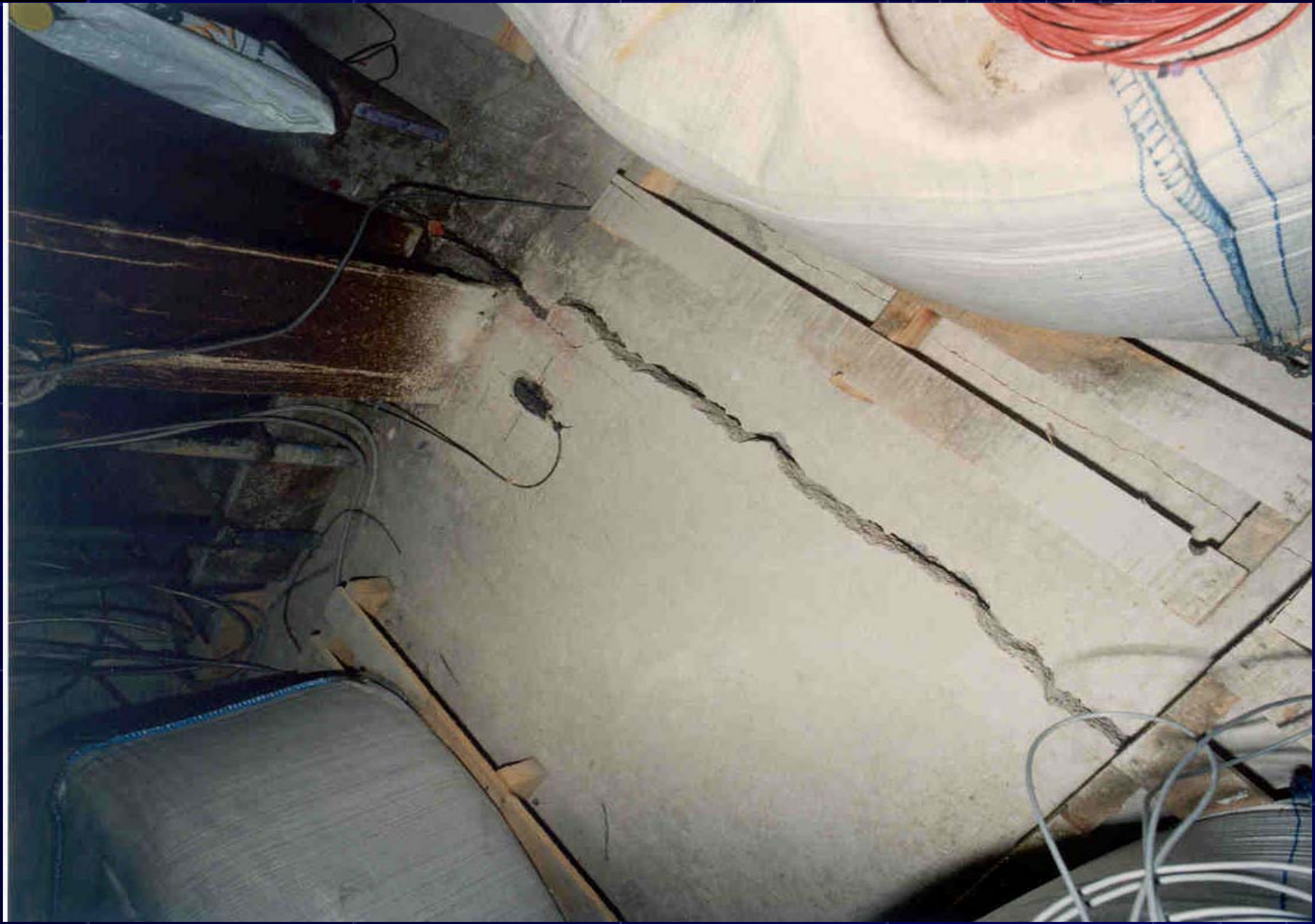

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# Project Objective

- To investigate measures to ensure the integrity of compartmentation in buildings during a fire and, **where appropriate**, to provide recommendations for guidance in support of Approved Document B

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# Scope of project

- To investigate the influence of different forms of construction (principally steel and concrete frames)
- Different flooring systems (flat slab, precast, composite)
- To look at the influence of the location of lines of compartmentation
- To consider different levels of fire protection
- To consider different periods of fire resistance

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# Methodology

- Review of existing information

  standard test data/full-scale test data/manufacturer's data/guidance documents
- Consultation with industry
- Numerical modelling

  thermal (THELMA) and structural (VULCAN) models

  validation of models against existing and new experimental data

  parametric study to consider variation in key parameters

# Review of existing information

- Standard test data

  concrete floors

  protected beams

  masonry walls

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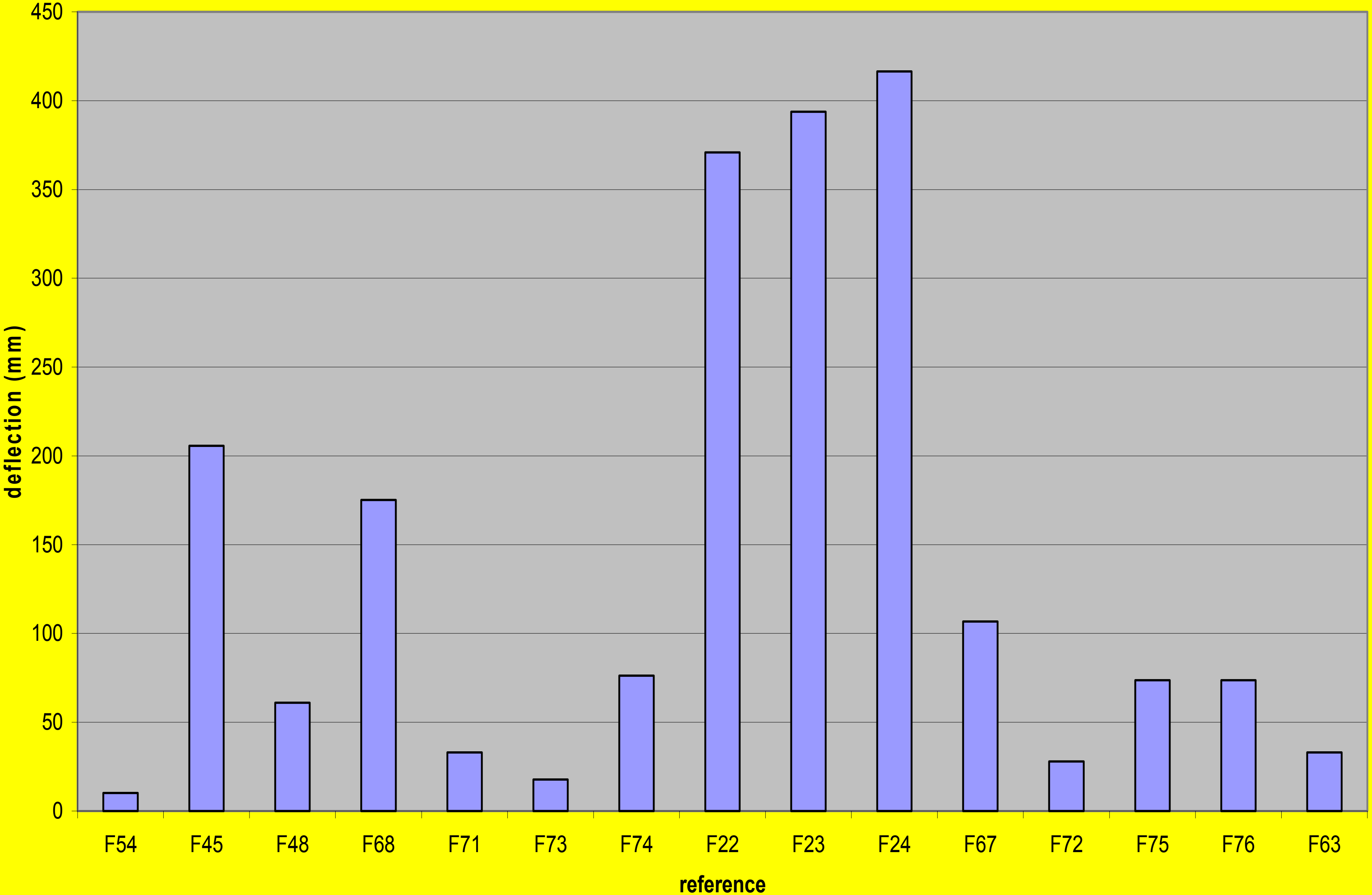
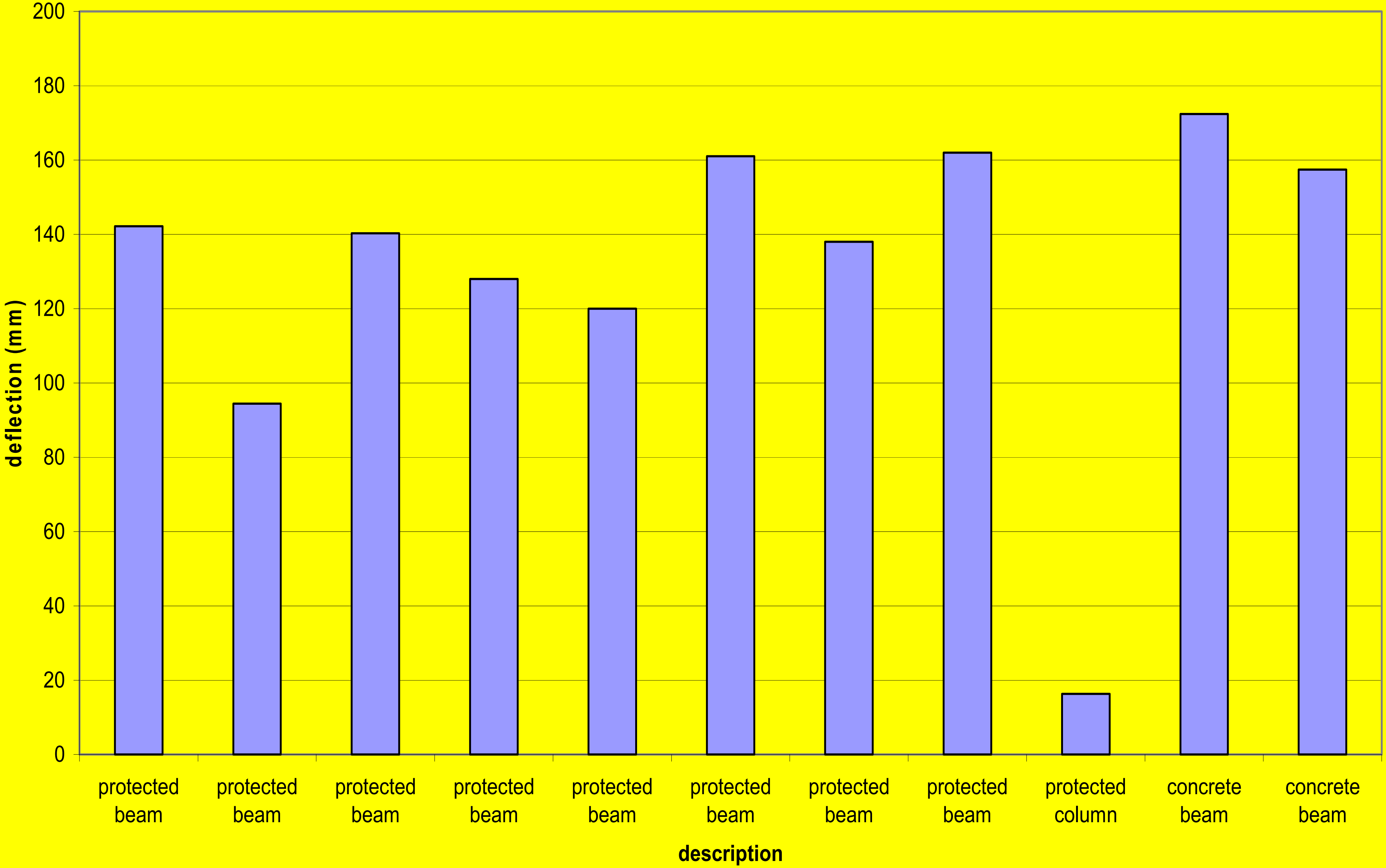
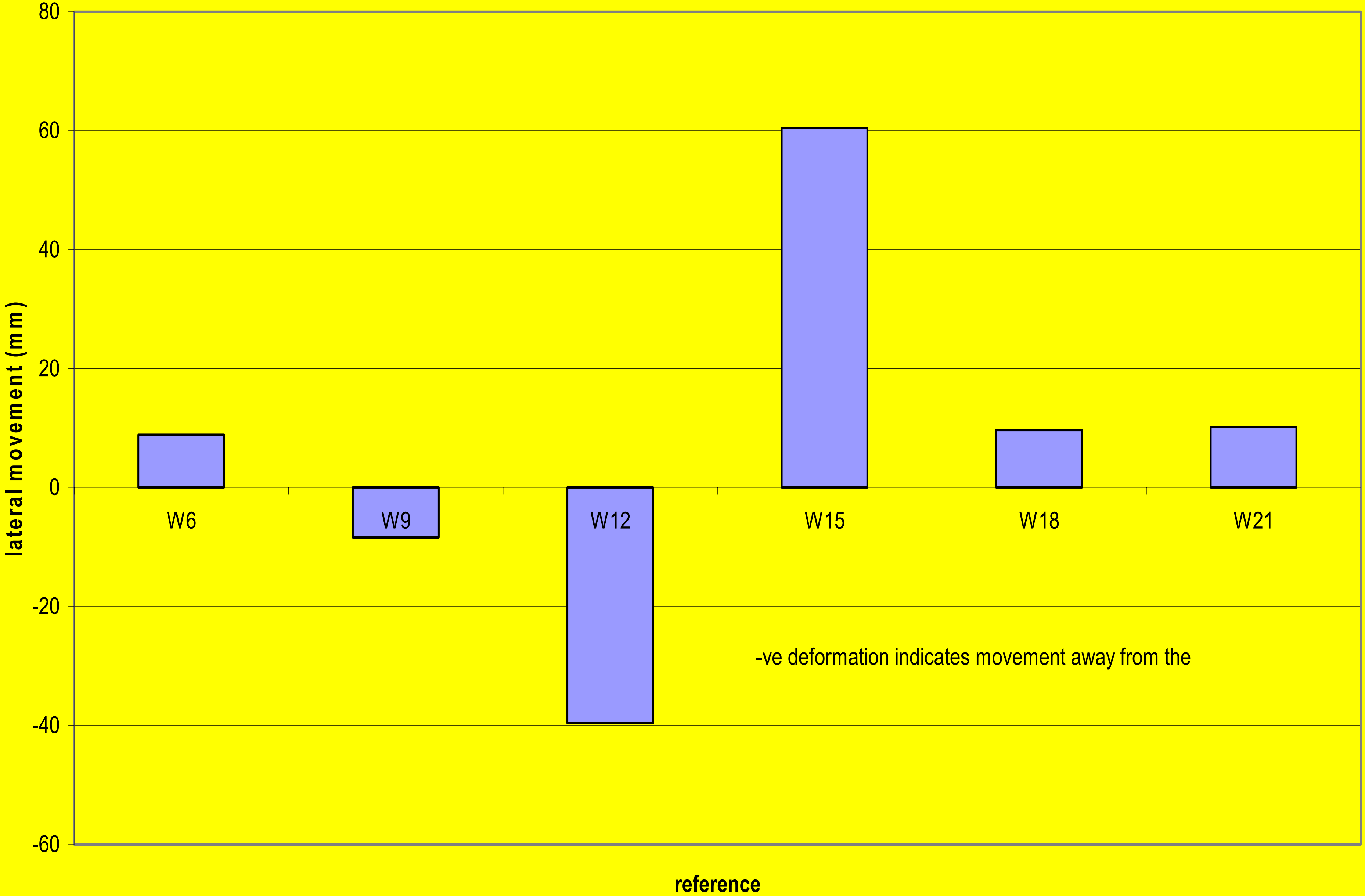
# deflection of reinforced concrete floors in standard fire tests



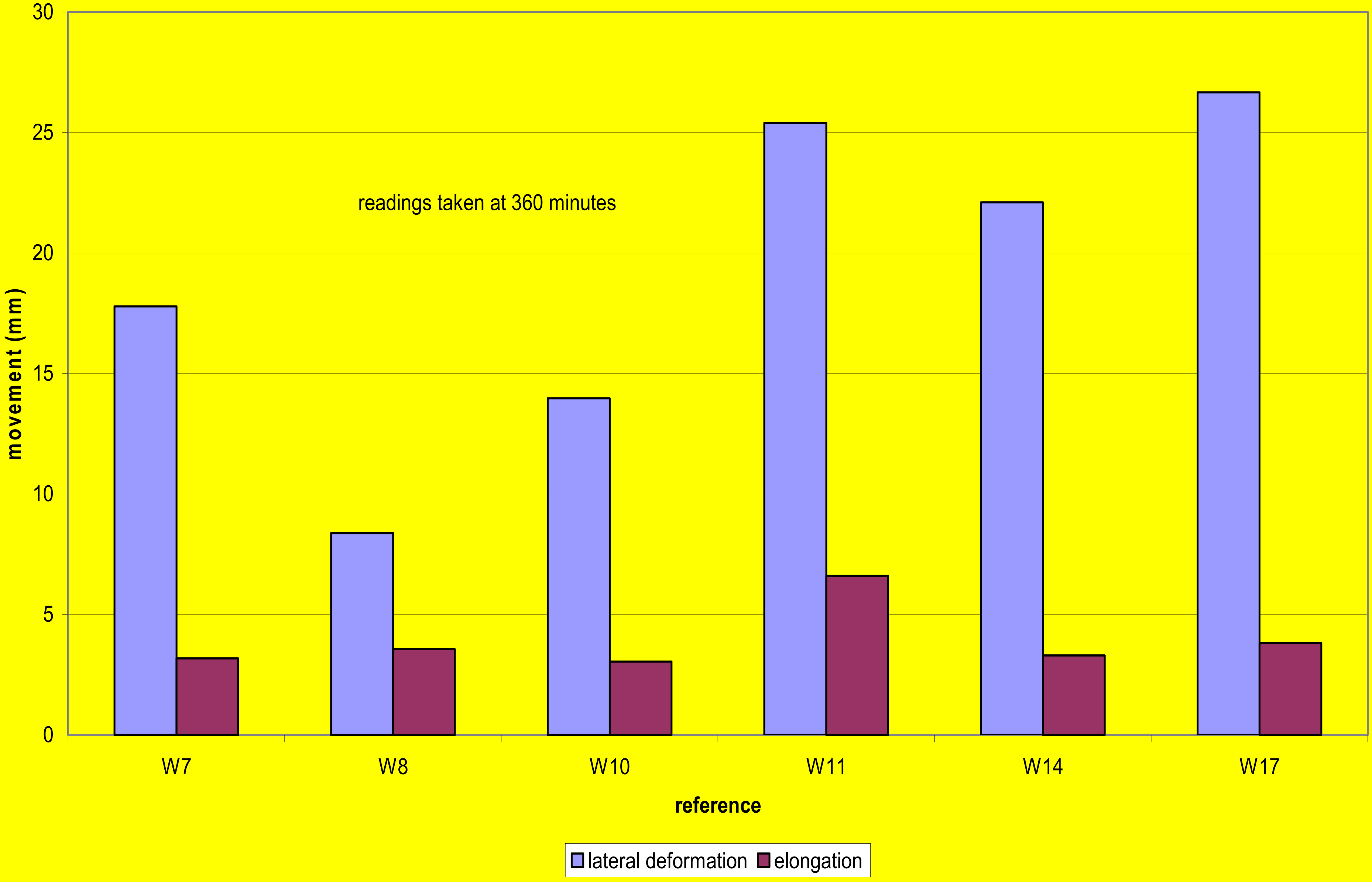
## deflection of protected beams



lateral deflection of non-loadbearing brick walls



# Lateral and vertical movement of loadbearing brick walls subject to a standard fire test



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# Review of existing full-scale data

- Steel framed building with composite floors
- Steel frame with precast concrete floors
- In-situ concrete framed building

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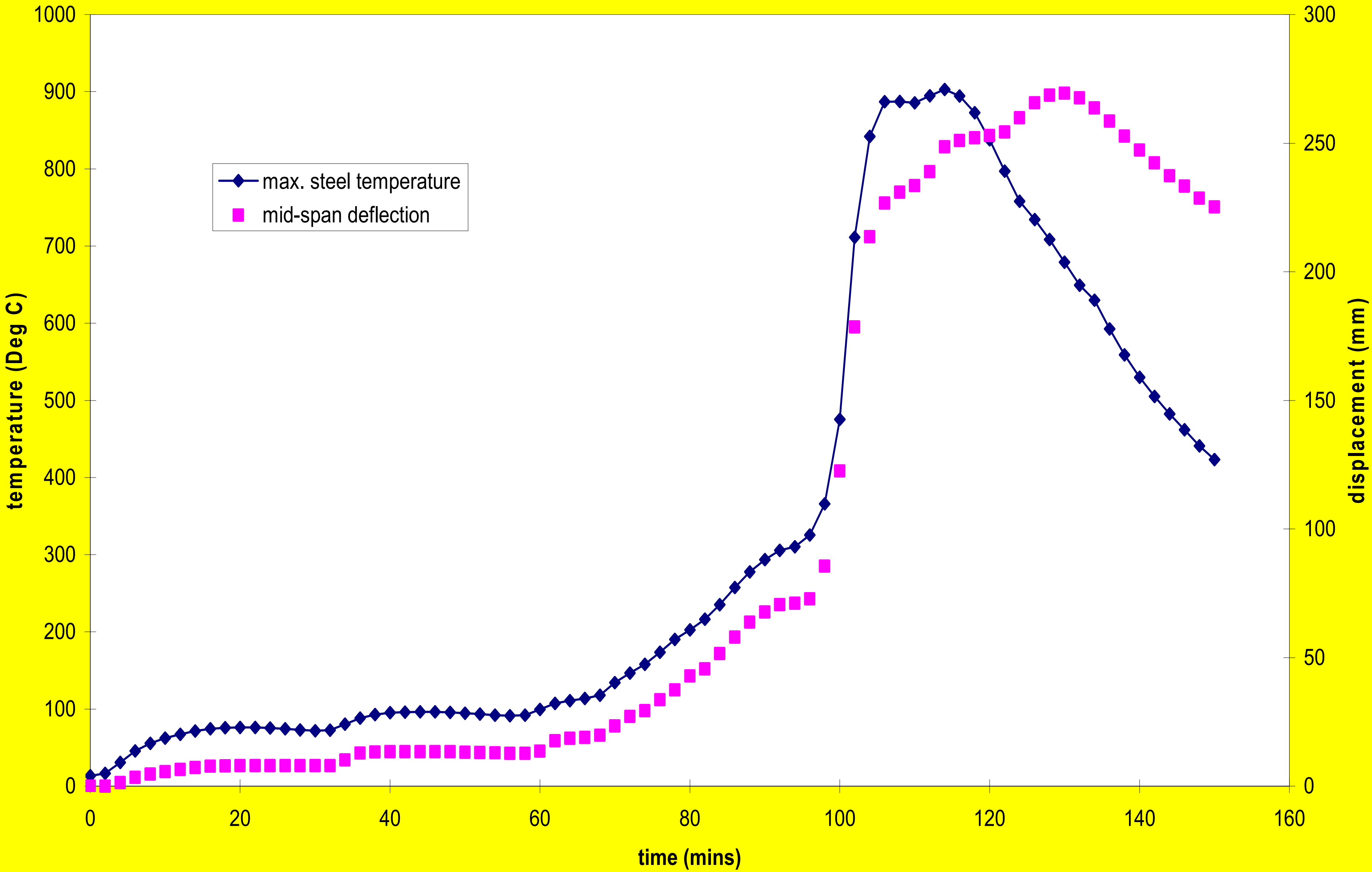
| Test reference | Test description | Type of construction | Maximum vertical displacement (mm) | Maximum horizontal displacement (mm) |
|---|---|---|---|---|
| 1 | British Steel Restrained beam test | Steel framed building – composite floor slab | 230 | 3 |
| 2 | British Steel plane frame test | Steel framed building – composite floor slab | 445 | 20 |
| 3 | BRE corner test | Steel framed building – composite floor slab | 270 | |
| 4 | British Steel corner test | Steel framed building – composite floor slab | 425 | 26 |
| 5 | BRE large compartment test | Steel framed building – composite floor slab | 557 | |
| 6 | British Steel Demonstration test | Steel framed building – composite floor slab | 610 | |
| 7 | European connection test | Steel framed building – composite floor slab | 919 | 58 |
| 8 | Slimdek fire test | Steel framed structure deep deck composite floor slab | 387 | |
| 9 | Hollow core fire test 1&2 | Steel framed structure precast floor units | 100/15 | 7/10 |
| 10 | Concrete building fire test | Concrete framed structure | 78 (residual) | 67 (residual) |

# Time/Temperature/Displacement for Mid-Span Beam



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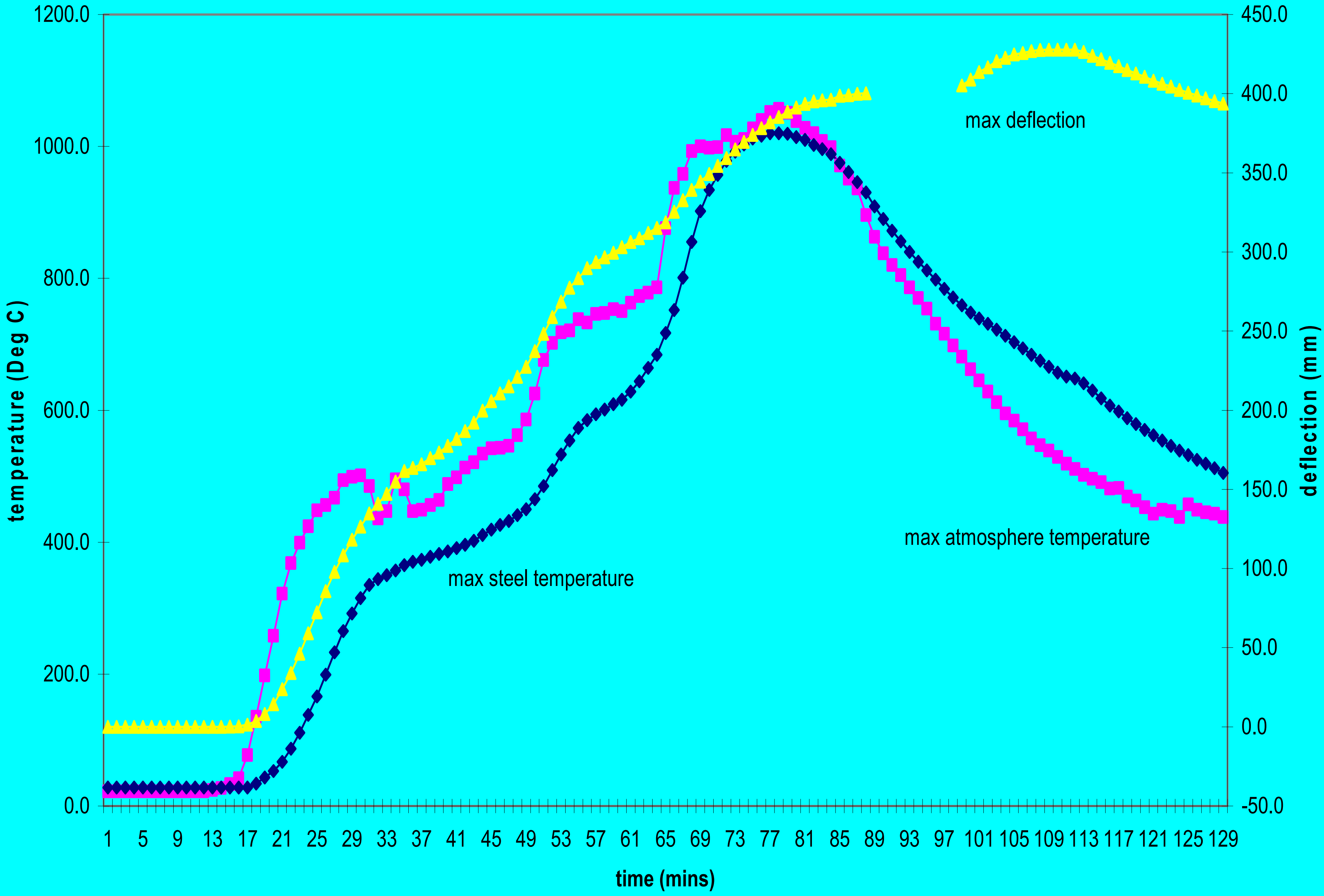
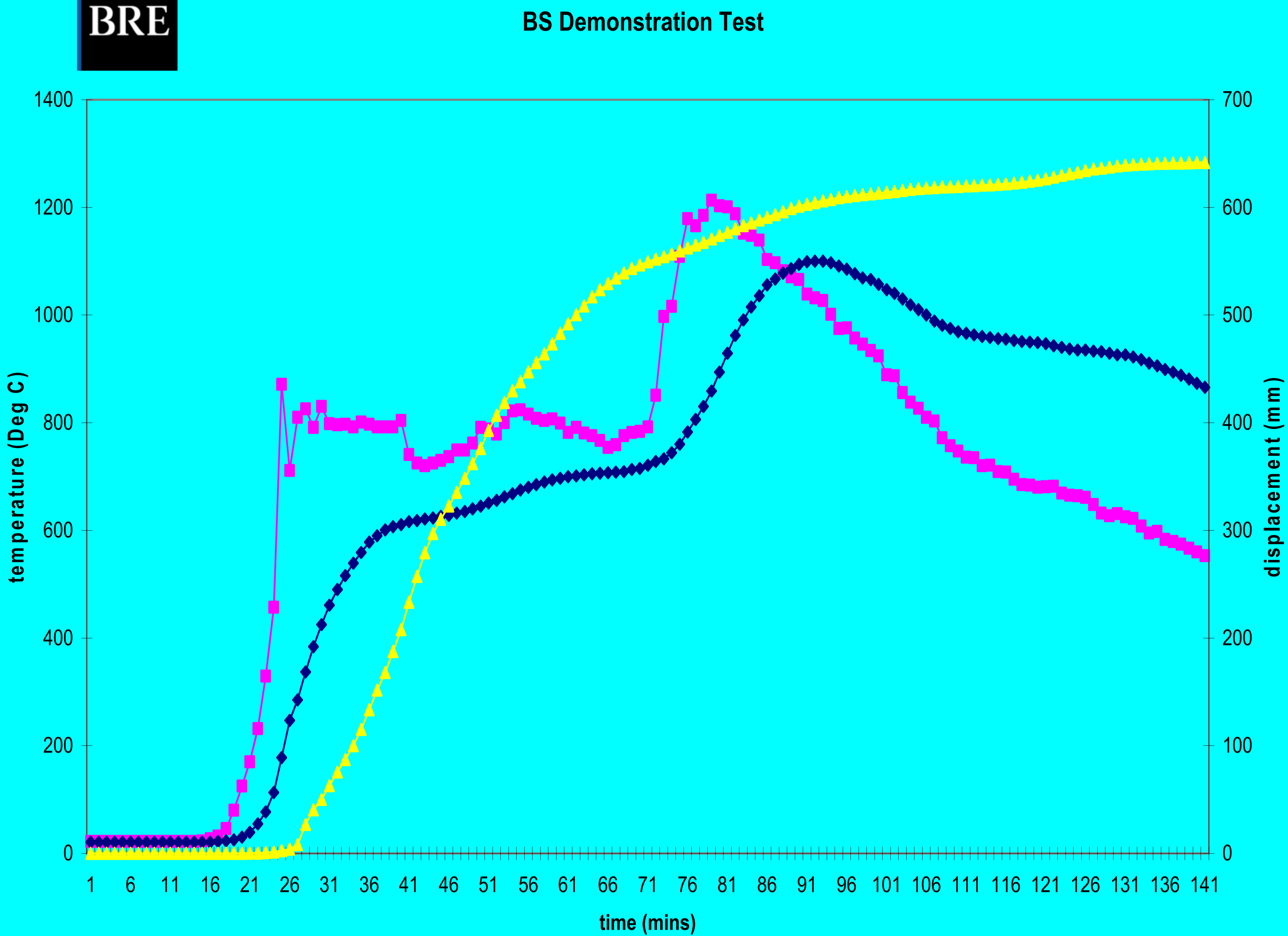
# BS Corner Test




BS Demonstration Test
1400
1200
1000
800
600
400
200
0
700
600
500
400
300
200
100
0
temperature (Deg C)
displacement (mm)
1 6 11 16 21 26 31 36 41 46 51 56 61 66 71 76 81 86 91 96 101 106 111 116 121 126 131 136 141
time (mins)

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# Review of existing guidance

- SCI-P288 – “compartment walls should, whenever possible, be located beneath and in line with beams”

  where beams pass over a compartment wall they should either be protected to the appropriate requirement or sufficient allowance for movement should be provided. “It is recommended that a deflection allowance of span/30 should be provided in walls crossing the middle half of an unprotected beam. For walls crossing the end quarters of the beam, this allowance may be reduced linearly to zero at the supports”

# Review of existing guidance

- BS 5950 Part 8 2003

  Where a fire resisting wall is liable to be subjected to significant additional vertical load due to the increased vertical deflection of a steel beam in a fire either:

  a) provision should be made to accommodate the vertical movement of the beam; or

  b) the wall should be designed to resist the additional vertical load in fire conditions

The anticipated vertical movement at midspan of a vertically loaded steel beam in a fire should be taken as 1/100 of its span, unless a smaller value can be justified by an analytical assessment

# Conclusions from review of existing information

- No correlation between displacement allowance in standard fire tests and measures to allow for deformation (deflection heads)
- Light composite floor systems the most onerous case in terms of displacement
- Numerical models for thermal and structural response are capable of accurately predicting behaviour under realistic conditions

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# Parametric study

| Analysis | Floor construction | Grid size (m) | Imposed load (KN/m²) | Fire exposure | Beam protection | Compartmentation |
|---|---|---|---|---|---|---|
| 1A | Composite | 9x9 | 4+1 | 60 mins | All | 0 |
| 1B | Composite | 9x9 | 4+1 | 60 mins | All | 0 |
| 2 | Composite | 9x9 | 4+1 | 60 mins | All | 1 |
| 3 | Composite | 9x9 | 4+1 | 60 mins | All | 2 |
| 4 | Composite | 9x9 | 4+1 | 60 mins | All | 3 |
| 5 | Composite | 9x9 | 4+1 | 60 mins | All | 4 |
| 6 | Composite | 9x9 | 4+1 | 60 mins | Partial | 0 |
| 7 | Composite | 9x9 | 4+1 | 120 mins | All | 0 |
| 8 | Composite | 9x9 | 4+1 | Natural | All | 0 |
| 9 | Composite | 9x9 | 2.5+1 | 60 mins | All | 0 |
| 10 | Composite | 9x9 | 7.5+1 | 60 mins | All | 0 |
| 11 | Composite | 9x6 | 4+1 | 60 mins | All | 0 |
| 12 | Composite | 9x7.5 | 4+1 | 60 mins | All | 0 |

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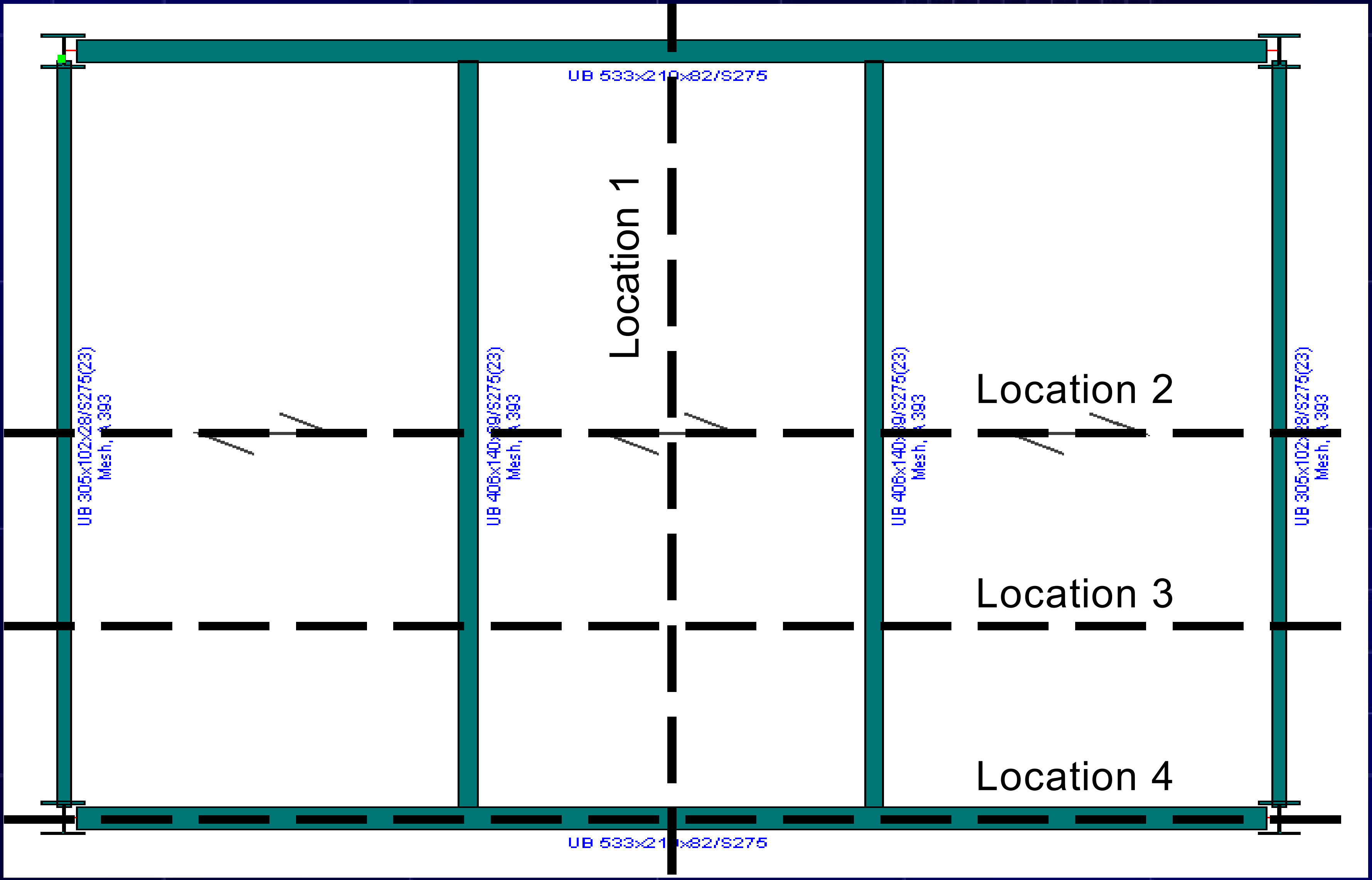
# Parametric study – location of compartmentation



# Results from parametric study

| Analysis | Maximum deflection (mm) | Maximum deflection on compartment line (mm) |
|---|---|---|
| 1-Base case | 185 (span/49) | N/A |
| 2-Compartment 1 | 175 (span/51) | 85 (span/106) |
| 3-Compartment 2 | 205 (span/44) | 40 (span/225) |
| 4-Compartment 3 | 175 (span/51) | 55 (span/164) |
| 5-Compartment 4 | 200 (span/45) | 15 (span/600) |
| 6-Partial protection | 350 (span/26) | N/A |
| 7-Natural fire | 56 (span/160) | N/A |
| 8-120 Minute fire | 161 (span/56) | N/A |
| 9-2.5+1 $KN/m^2$ | 186 (span/49) | N/A |
| 10-7.5+1 $KN/m^2$ | 146 (span/61) | N/A |
| 11-9mx6m | 115 (span/52) | N/A |
| 12-9mx7.5m | 150 (span/50) | N/A |

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# Conclusions

- Available computer models are capable of predicting global structural behaviour under realistic conditions
- Deflections are a function of the form of construction
- BS476 tests based on span/20 or span/30
- Unprotected steel beams deflections of span/10 may occur
- Concrete slabs typically span/60
- Standard deflection heads should be designed to accommodate anticipated deflection or be capable of supporting additional load