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Fire Safety Design of Residential Buildings
Current Practice and Future Trends

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- Approved Document B 2006 (UK)
- BS 5588 Part 1 1997

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Applications of FSE

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Current Prescriptive Guidance 1
Dwellings (TGD-B Approach)

General Provisions

- Escape windows to all bedrooms
- Grade D Type LD2 to three storeys
- Grade D Type LD1 4+ stories and “large houses”
- Inner habitable rooms to have escape windows (<4.5m)
- Stairway in non fire rated storey height construction (<4.5m)
- Design flexibility for open plan arrangements under specified conditions
- Specific requirements for loft conversions
- Protected stair / FD20 doorsets (<7.5m) unless alternative escape provided
- Alternative escape from floors above 7.5m
Current Prescriptive Guidance 2
Dwellings (UK AD-B Approach)

General Provisions

Similar to those in TGD-B subject to the following variations

- Where escape is reliant on an internal stair, same should be constructed as a protected stairway
- No requirements for alternative escape where domestic sprinkler system to BS 9251: 2005 provided
- No requirement for self closers on fire doors within flats
- Grade B Type LD2 for “large houses” of two stories having any floor exceeding 200m²
- Grade A Type LD2 for “large houses” of three or more stories having any floor exceeding 200m²
Current Prescriptive Guidance 3
Flats & Maisonettes (BS 5588 Pt 1)

Internal Planning of Apartments

- No inner habitable rooms for flats (escape windows if H < 4.5m)
- Protected entrance halls (<9m) for apartments >4.5m above ground or access level

Alternative exit potential facilitated at same floor level
Current Prescriptive Guidance 4
Flats & Maisonettes (BS 5588 Part 1)

Internal Planning of Apartments

- Flats with restricted travel (any floor level)
- Similar philosophy adopted for flats entered from below or above the main accommodation level
- Flexibility allowed for flats with galleries
  - TD <7.5m on gallery
  - Internal stair to discharge within 3.0m of flat entrance door or door to protected entrance hall
  - Cooking facilities to be remote
Current Prescriptive Guidance 5
Flats & Maisonettes (BS 5588 Part 1)

Internal Planning of Maisonettes

- Maisonettes <4.5m – similar to dwelling
- Maisonettes with one or more stories above 4.5m above ground or access level
  - At least one alternative exit provided and all rooms accessed from a protected entrance hall
  - Alternative exit from each room (unlikely solution)
Current Prescriptive Guidance 6
Flats & Maisonettes (BS 5588 Part 1)

Common Escape Routes – Single Stair

Design Principles

- Limited travel within common escape routes (max 7.5m)
- AOV / OV to stairs
- AOV to common corridors (may be omitted in small single stair buildings <11m in height where TD<4.5m in common escape route)

Omission of common lobby in small single stair buildings (as below)
Current Prescriptive Guidance 7
Flats & Maisonettes (BS 5588 Part 1)

Common Escape Routes – Multi Stair

Design Principles

Without Dead End
- Max travel 30m
- OV to corridor and stairs

With Dead End
- Limited travel within dead end escape routes (max 7.5m)
- AOV to dead end corridors
- AOV / OV to stairs
- Max travel 30m (alternative escape)
A Time for Change?

**WHY?** - Increased commercial demand for more innovative designs
- Current guidance (BS 5588 Part 1) out of date

Arguments for same include

- AD-B no longer includes the requirement for self closing fire doors in flats.
- Provision of enhanced detection and alarm - potential benefit??
- Provision of Sprinklers or other suppression systems (Water Mist).
- Enhanced level of ventilation (common areas)
- International experience (NFPA 101: permits 23m TD in unsprinklered apartments increasing to 38m TD in a sprinkler protected apartment)
A Time for Change?

**Difficulty resolving the merits of design argument to-date as statements almost always qualitative in nature.**

**Facility for change -** Advance in modelling techniques / quantitative analysis to support design including

- Engineered mechanical extract systems for common escape routes (AD-B compliant)
- Advanced fire modelling techniques (FDS etc) to assess tenability criteria in flats and common escape routes
- Codified standards
A Time for Change?  
Codes and Guidance Documents

Overview

Recent and ongoing changes to guidance, and research and developments include;

- UK AD-B 2006
- Scottish Technical Standards (2010 Ed)
- Domestic Fire Safety (Wales) Measures 2011
- BS 5588 Part 1 currently under review (to be published as BS 9991)
- UK NHBC Foundation “Open Plan Flat Layouts: Assessing life safety in the event of fire” 2009
- Research on cost benefit and effectiveness of sprinkler / fire alarm
A Time for Change
UK AD-B

- No current plant to extend mandatory provision of sprinklers beyond that of AD-B 2006 (CLG Report “Future changes to the Building Regulations – next steps” Dec 2010)

- Wider variety of options for smoke control in multi-storey apartment buildings (implemented in AD-B 2006)
  - Natural ventilation (common vertical smoke shaft)
    - Being closed at the base
    - minimum CSA of 1.5m² with min dimension of 0.85m
    - Extending >0.5m above the highest structure within 2m
    - Extending 2.5m above the ceiling of the highest level served by the shaft
A Time for Change
UK AD-B

- Mechanical ventilation (extended corridor protection)
  - Dedicated air inlet
  - Mechanical extract (typically 0.6m² shaft)
  - Increased efficiency compared to AOV’s
  - Unaffected by wind pressures

- Mechanically, using pressure differentials, in accordance with BS EN 12101-6: 2005.

- Omission of self closers to doors within flats (Implemented in AD-B 2006)
A Time for Change
Scottish Technical Standards
Section 2 Fire

- Extends scope of 2005 Ed to include mandatory sprinklers in schools. Sprinklers now mandatory in
  - an enclosed shopping centre;
  - a residential care building;
  - a high rise domestic building (>18m);
  - building which forms the whole or part of a sheltered housing complex;
  - a school building.

- Permits open plan flats above 4.5m on basis of sprinkler protection and Grade D LD1 detection and alarm
A Time for Change
Scottish Technical Standards
Section 2 Fire

- Similar scope to AD-B re ventilation of common escape routes
- Domestic fire detection and alarm in dwellings to include
  - detection in “every principal habitable room” defined as “a frequently used room by the occupants of a dwelling for general daytime living purposes”
  - Grade C specification for sheltered housing
A Time for Change

The Domestic Fire Safety (Wales) Measure

- Approved by Welsh Assembly 16 Feb 2011
- Requires mandatory sprinklers in all new homes
- Enforcement date yet to be confirmed (suggested 2015)
A Time for Change
BS 5588 Part 1 Review

- Review of BS 5588 Pt 1 commenced late 2009
- Currently at committee stage (slightly behind schedule)
- DD 9991 due Sept 2011 (estimated)
- BS 9991 due late 2011 / Jan 2012 (worst case)
- Matters currently being considered by committee include
  - mechanical vent solutions (extended corridor)
  - effectiveness of sprinklers (NHBC Report)
  - Increased scope re sheltered housing
  - Include “extra care” facilities
NHBC Foundation / BRE
Open Plan Flat Layouts:
Assessing Life Safety In the Event of Fire

Overview

- Research conducted in association with BRE
- Objective to ensure a more coherent approach to the design of “open plan” flats and highlight potentially unacceptable risks
- Methodology
  - evaluation of risk level for open plan and equivalent AD-B compliant design
  - max size of apartment 12m x 16m
  - effectiveness of suppressions systems and increased alarm considered
  - BRE risk assessment model CRISP used to assess life safety risk
Factors considered

- thermal properties of the walls
- range of fire scenarios considered (fire location in flat, time of day/night, type of burning item, fire spread beyond item first ignited etc)
- ventilation (probability of doors or windows being open or shut, probability and extent of window breakage when exposed to heat, etc)
- active fire protection systems (characteristics of smoke detectors, heat detectors, and sprinklers)
- characteristics of human population (numbers of adults, elderly people and children, sleeping patterns, arousal thresholds, other characteristics)
- behavioural ‘rules’ for different people types.
NHBC Foundation / BRE
Open Plan Flat Layouts:
Assessing Life Safety In the Event of Fire

Typical Layouts (1 bed)
- 4m x 8m bedsit
- Case 1a: AD-B compliant studio
- Case 1b: Open plan with inner bedroom + increased detection
- Case 1c: Open plan with inner bedrooms + increase detection + sprinkler protection
NHBC Foundation / BRE
Open Plan Flat Layouts:
Assessing Life Safety In the Event of Fire

Typical Layouts (3 bed)
- 12m x 16m
- Case 3a: AD-B compliant
- Case 3b: Open plan with inner bedrooms + increased detection
- Case 3c: Open plan with inner bedrooms + increase detection + sprinkler protection
NHBC Foundation / BRE
Open Plan Flat Layouts:
Assessing Life Safety In the Event of Fire

CRISP ANALYSIS

- Risk considered on basis of exposure to toxic smoke - fractional effective dose (FED)
- FED of 100% the person is defined as ‘dead’.
- Risk (averaged over a sufficiently large Monte Carlo sample) expressed in terms of
  - the fraction of people originally present who become ‘dead’ or
  - average number of fatalities per fire.
NHBC Foundation / BRE
Open Plan Flat Layouts:
Assessing Life Safety In the Event of Fire

ADVANTAGES OF CRISP ANALYSIS

- It is a system model of ‘everything’, not just smoke movement from a pre-determined fire growth rate.
- Model considers a wide range of different fire scenarios. fire safety strategies, including differences in human behaviour.
- Based on engineering from first principles (with simplifying approximations where appropriate).
- Validated for use in domestic occupancies using experimental data, and real fire incident data for human behaviour.
NHBC Foundation / BRE
Open Plan Flat Layouts:
Assessing Life Safety In the Event of Fire

Results –
FED Analysis
NHBC Foundation / BRE
Open Plan Flat Layouts:
Assessing Life Safety In the Event of Fire

Results – Visibility
Conclusions

- Flat size/travel distance does not seem to be a significant factor.
- The open plan designs with enhanced detection have risks of death and injury similar to those for AD B compliant flats. At present it is not possible to reach a robust conclusion that enhanced detection can offer equivalent or better levels of safety compared with AD B compliant flats.
- The open plan flats with a sprinkler system (in accordance with BS 9251 or BS EN 12845 as appropriate) and an enhanced detection system (LD1 system in accordance with BS 5839 Pt 6) can provide a level of safety that is at least as good as that of a similar AD B compliant design.
Sprinklers in Residential Buildings
Supporting Research

Effectiveness of sprinklers in residential buildings

- No cases on record worldwide of multiple fire deaths in sprinklered buildings “with working systems”
- NFPA Report “Experience with sprinklers and other automatic fire extinguishing equipment” January 2009 concluded
  - The death rate per fire is lower by an estimated 76 per cent
  - The cost of direct property damage is 63 per cent lower
  - 96 per cent of reported structure fires have flame damage confined to the room of origin (all types of sprinklers) compared to 76 per cent when no automatic extinguishing system is present.
Sprinklers in Residential Buildings
Supporting Research

Effectiveness of sprinklers in residential buildings

- Vancouver – No of deaths / 100,000 in 1972-74 was 7
  - No of deaths / 100,000 in 1992-98 was 0.6
    (post mandatory sprinkler)

- Scottsdale – Ordinance for mandatory sprinklers as of 1 Jan 1986
  - Most comprehensive study to date (10 year study)
    (Saving Lives, Saving Money Automatic Fire Sprinklers A 10 Year Study, Scottsdale, Arizona, 1997)
Sprinklers in Residential Buildings
Supporting Research

Cost Benefit Analysis of Sprinklers in Residential Buildings

- NIST Report “Benefit-Cost Analysis of Residential Fire Sprinkler System” September 2007 concludes that sprinklers in single family residential units make very good economic sense

- US (NIST and NFPA) more positive about the cost/benefit arguments for residential sprinklers than UK (ODPM and BRE)

- BRE Report 204545 (2005) concluded that the cost benefit arguments for residential sprinklers not supported other than for
  - residential care homes,
  - tall blocks of flats (over 11 storeys high)
  - other properties (case by case basis)
Application of Fire Engineered Solutions

CASE STUDIES:

• IRISH PRISON SERVICE:
  Cell Block Accommodation:

• OLYMPIC VILLAGE LONSDON:
  Open Plan Atrium Apartment Design
Application of Fire Engineered Solutions

IRISH PRISON SERVICE:
Cell Block Accommodation : Fire Engineering Design

- Typically 3-4 storey cell blocks (inclusive of attic plant)
- Balcony approach to cells (2-3 storey atrium)
- Key objective of maintaining tenable conditions for the assisted evacuation of inmates
- Three methods of maintaining tenability;
  - Clear layer height
  - Dilution ventilation
  - Opposed flow ventilation
Application of Fire Engineered Solutions

IRISH PRISON SERVICE:
Cell Block Accommodation : Fire Engineering Design

Design Parameters

- Fire loading within the cells / other areas non fire separated from the atrium / central hub
- Appropriate fire growth constants (time dependent analysis)
- Control of fire growth (manual suppression through the use of inundation points and automatic suppression achieved by the sprinkler system in cell accommodation)
- Operational requirements with respect to response team actions (cell door opening and closing times, IPS staff response times, time required to evacuate a cell)
Application of Fire Engineered Solutions

IRISH PRISON SERVICE:
Cell Block Accommodation : Fire Engineering Design

- Time line of events
  - Fire initiation
  - Time to detection.
  - Time to alarm.
  - Time to suppression action.
  - Duration and effect of suppression action.
  - Response time of Prison Officers
  - Duration and effect of inundation.
  - Various door opening/closing times during prisoner rescue.
Application of Fire Engineered Solutions

IRISH PRISON SERVICE:
Cell Block Accommodation : Fire Engineering Design
Application of Fire Engineered Solutions

IRISH PRISON SERVICE:
Cell Block Accommodation : Fire Engineering Design

DETAILS OF FDS MODELLING TO BE INCLUDED
Application of Fire Engineered Solutions

London Olympic Village (courtesy of LFB Fire Engineering Unit)

- Plot 09 of Olympic Village
- Consists of affordable apartments in a triangular tower and has a fully fire engineered fire protection solution
- Sprinklers also incorporated in open plan market apartments with fire engineered flat layout. Sprinklers required due to being over 30 m in height
Application of Fire Engineered Solutions

London Olympic Village (courtesy of LFB Fire Engineering Unit)

- Plot 09 of Olympic Village
- Single stair
- 13 floors
- Extended dead end (20.5m)
- Sprinklered open plan flats
- Some fire load in atrium base
- Mechanical ventilation
- Olympic mode/Legacy mode
Application of Fire Engineered Solutions

London Olympic Village (courtesy of LFB Fire Engineering Unit)

Methodology

- Deterministic Study
  Performance judged against pre-defined acceptance criteria

- Comparative Study
  Performance judged against code-compliant scenarios to assess the relative standard of safety
Application of Fire
Engineered Solutions

London Olympic Village (courtesy of LFB Fire Engineering Unit)

Deterministic Study

- Sprinklered flat fire
- 1MW instantaneous fire, 3% soot yield.
- No Glazing failure (0.2m² vent to sustain fire)
- Flat door opens for 20s then shuts
- Flat door opens again to simulate fire fighting
- Atrium base – 1MW with 2MW sensitivity

Tenability Criteria

- Visibility (5m on balcony)
- Smoke temp on balcony < 60 degC on balcony
- CO <125ppm
  (Tenability time = 30mins (BS7974-6))

Acceptance Criteria

- Clear layer on balcony of fire origin
- Tenable conditions on fl
SUMMARY

- Significant trends of change in demands of residential living
- International prescriptive approach evolving to meet such demands
- Use of fire engineered solutions becoming more prevalent in meeting functional requirements of prescriptive codes
QUESTIONS?