Research Engineering Development
Façade Consultants Limited
Advanced Laboratory for Fire and Curtain Wall Testing

Topic:
Standard Fire Tests in Hong Kong

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Agenda

Section 1: Code of Practice for Fire Safety in Buildings 2011 (Part E)

Section 2: BS 476 : Part 20 series and BS EN 1363 series

Section 3: BS EN 1634-1 and BS EN 1634-3 test methods

Section 4: Q & A Section
Section 1

Fire Test Requirement in HK

- Code of Practice for Fire Safety in Buildings, 2011 issued by Building Departments (Fire Safety Code)

- Part E – Fire Properties of Building Elements and Components
  - Reaction to Fire Properties
    - Surface lining within a room or MOE
  - Resistance to Fire Properties
    - Fire separation construction elements
Expression of FRR

• The expression that used in HK Fire Safety Code:
  – Fire Resistance rating (FRR)

  – Form of presentation: X/Y/Z
    • X is Stability fire resistance rating (mins)
    • Y is Integrity fire resistance rating (mins)
    • Z is Insulation fire resistance rating (mins)
    • E.g. 120/60/30 means Loadbearing capacity up to 120 minutes, integrity up to 60 minutes and insulation up to 30 minutes
Fire Test Standard adopted in Fire Safety Code

• Before 2011 (CoP for Fire Resistance 1996)
  – BS 476: Part 20 series:
    • BS 476: Part 20 – General Principles
    • BS 476: Part 21 – Loadbearing elements
    • BS 476: Part 22 – Non-loadbearing elements
    • BS 476: Part 23 – Contribution of components to the fire resistance of a structure
    • BS 476: Part 24 – Duct works
Fire Test Standard adopted in Fire Safety Code

- Fire Safety Code 2011 adopts the following test standards
  - BS 476: Part 20 series still applicable (until obsolete)
  - BS EN 1363 series
    - More specific and product basis
Fire Test Standard adopted in Fire Safety Code

– BS EN 1363 series
  • More specific and product basis
  • BS EN 1365 – X: Loadbearing series
  • BS EN 1364 – X: nonloadbearing series
  • BS EN 1634 – X: Doorset series
  • BS EN 1366 – X: Services Installation series
### Performance Evaluation

#### Separation function or loadbearing?

<table>
<thead>
<tr>
<th>Building Elements</th>
<th>Loadbearing Capacity</th>
<th>Integrity</th>
<th>Insulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load-bearing wall</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Floor / Ceiling</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Beam</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Column</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Partition</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Door</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Glazing wall</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Section 2

What is BS 476?
What is BS EN 1363?
What is Fire Rated Product?

• In case of fire, the fire rated element will be used to separate fire spread between compartments

• Fire Rated Elements
  – Vertical: Walls, Loadbearing?
  – Horizontal: Floor slap or ceiling, Loadbearing?

• Openings in Fire Rated Wall or Ceiling
  – Doors
  – Assess panels
  – Duct works
  – Windows, etc.
How to Define Fire Rating

• Standardized test with repeatable testing condition (heating curve, pressure, etc.)

• Standardized pass/fail criteria to compare performance of varies similar products

• Applicable to all fire rated products
Heating Curve

• Real Compartment Fire

• How long the Growth Period and the Fully Development Phase last for?
Heating Curve (Cont.)

- Heating Curve
  - Expression:
    \[ T = 345 \log_{10}(8t + 1) + 20 \]
    - \( T \) is the average temperature in furnace (°C)
    - \( t \) is the time, in minute
  - Same for BS 476 and BS EN 1363
Fire Test Furnace
Furnace Thermocouples

BS 476: Part 20

Heat resisting steel support tube

Stainless steel sheathed thermocouple

Porcelain insulators
single bore 6 to 10 diameter

Direct heat the hot junction

Heat up the whole plate first to heat up the hot junction

BS EN 1363-1
Difference in Heating Between BS 476: Part 20 and BS EN 1363-1?

Insulated system or uninsulated system? The heating regime may be different
Furnace Pressure

• Pressure gradient along specimen height
  – 8.5 Pa per meter
  – Neutral pressure at
    • 500 mm from floor (BS EN 1363-1)
    • 1000 mm from floor (BS 476: Part 20)
  – Max. 20 Pa at the head of specimen
  – Therefore negative pressure at the base of the specimen

• Pressure condition for horizontal elements
  – 20 Pa 100 mm below the under surface of the specimen
Furnace Pressure (Cont.)

Height

-ve Pressure 0 Pa +ve Pressure

1,000 mm
500 mm

BS 476: Part 20
BS EN 1363-1

Higher pressure
Performance Criteria

• Integrity performance
  – The ability of the specimen to prevent the passage through it of flames and hot gases and to prevent the occurrence of flame on the unexposed side

• Insulation performance
  – The ability of a specimen to restrict the temperature rise of the unexposed face to below specific level

• Loadbearing capacity
  – The ability of a specimen intended to bear external loading to support its load, without exceeding specified criteria with respect to both the extent of, and rate of deflection
Integrity performance

- Integrity performance
  - Evaluated by the test by cotton wool pads, gap gauges and visual monitoring of sustained flaming

- Cotton wool pad test:
  - use a cotton wool to check suspected hot spot, the possibility of igniting a cotton pad even though, there are cracks smaller than that can be assessed by gap gauges

- Gap gauges test:
  - 6 mm gap gauge penetrating through the specimen and move a distance of 150 mm
  - 25 mm gap gauge penetrating through the specimen
  - Check the formation of large cracks

- Monitoring of continuous flaming sustained for 10 seconds or more
Cotton Wool Pad Test
Gap Gauges
Sustained flaming

- Visual observation
Insulation performance

- Insulation performance
  - Use of Type K T/Cs attached to the surface of unexposed side
  - Use of Type K roving T/C to assess for hot spot area

- Performance criteria
  - Average temperature rise on unexposed face
    - Not exceed 140 °C rise in temperature
  - Maximum temperature rise on unexposed face
    - Not exceed 180 °C rise in temperature
**T/Cs locations**

**BS EN 1634-1**

- T/Cs for assessing insulation against average temperature criteria
- T/Cs for assessing insulation (BS 476: Part 22 or BS EN 1634-1 ($I_2$)) against maximum temperature criteria

**BS 476: Part 22**

- T/Cs for assessing insulation ($I_1$) against maximum temperature criteria

**Diagram Notes**

- Blue dots: T/Cs for assessing insulation against average temperature criteria
- Red dots: T/Cs for assessing insulation (BS 476: Part 22 or BS EN 1634-1 ($I_2$)) against maximum temperature criteria
- Green dots: T/Cs for assessing insulation ($I_1$) against maximum temperature criteria
Doorsets with vision panel

- BS 476: Part 22 may have uninsulated doorset, partially insulated doorset and fully insulated doorset

- BS 476: Part 22 allow uninsulated on the door leaf, provided that the area is smaller than 25% of the area of door leaf

- BS EN 1634-1 have not defined the type of insulated doorset, but it represent as the doorset with discrete area of insulation
Discrete area of insulation

• Glazed panel is discrete area of insulation?

• With different insulation performance?

• Cotton pad test had to be applied on those uninsulated area as well

• Ignition of beading for uninsulated glass?
Deflection measurement

• Measurement of deflection is not compulsory in the test of non-loadbearing element

• Measurement will still be taken as secondary evaluation of the integrity and insulation performance

• Large deflection lead to risk in integrity or insulation failure
Building Elements Require Fire Separation Function Only

- Door with integrity failure occurred

- Insulation performance is deemed to be not satisfy as the integrity failed

- Flame can’t be maintain within the compartment
Insulation performance
Fire test: Doorset
## Expression of Results

<table>
<thead>
<tr>
<th></th>
<th>BS EN 1634-1</th>
<th>BS 476-22 Partially insulated / uninsulated</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Integrity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cotton pad:</td>
<td>23 minutes*</td>
<td></td>
</tr>
<tr>
<td>Gap gauge:</td>
<td>120 minutes</td>
<td>120 minutes</td>
</tr>
<tr>
<td>Sustained flaming:</td>
<td>120 minutes</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Insulation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Door leave ($I_1$):</td>
<td>23 minutes#</td>
<td>120 minutes</td>
</tr>
<tr>
<td>Discrete area:</td>
<td>9 minutes</td>
<td>120 minutes</td>
</tr>
</tbody>
</table>

* Cotton pad test applied to glazed panel and failure occurred

# Insulation failure deemed to be occurred as integrity failed
What is BS EN 1634-1

• Adopting the general principle BS EN 1363-1

• Determining the possibility of failure of a doorset when subject to the standard heating curve and pressure

• Find out what is the failure mode and when the failure occurs

• Results may be used for
  – complying with code requirements, or
  – for fire engineering approach
What is BS EN 1634-1 (Cont.)

• Assessing the performance of the doorset itself to separate fire from one side to the other side

• Assessing the performance of the doorset as the fire barrier of the opening in supporting construction
  – What type of supporting construction is used
  – How the interface affected
What is BS EN 1634-1 (Cont.)

- Installation of doorset
  - The doorset shall be constructed same as practice
  - Same supporting construction
  - Fixing method
  - Sealing method between the supporting and the frame
  - Leaf-configuration
  - Door leaf action
  - Dimensions
  - Opening direction
  - The use of ironmongery
  - Incorporation of vision panel
  - The present of smoke seals (acoustic seals)
What is BS EN 1634-1 (Cont.)

- **Unexposed face T/Cs for insulation criteria**
  - T/Cs for average temp. assessment
    - Total of 5 nos.: one at centre and at the centre of each quarter
  - T/Cs for max. temp. assessment
    - $I_1$ (supplement procedure)
      - Absolute temperature rise of 180 °C for all T/Cs
    - $I_2$ (normal procedure)
      - Temperature rise of 180 °C for all T/Cs except those on the door frame that are assessed against 360 °C
What is BS EN 1634-1 (Cont.)

- **T/Cs locations**
  - **T/Cs for max. temp. assessment (door frame)**
    - Mid-height of door frame
    - Mid-width of door frame or perimeter frame not closer than 100 mm from the visible edge
    - At the corner of the door frame, 50 mm in from the visible edge
  
  - **T/Cs for max. temp. assessment (door leaf)**
    - Mid-height, 100 mm in from the visible edge
    - Mid-width, 100 mm in from the visible edge
    - At the upper corners 100 mm in from visible edges
T/Cs locations

For BS 476: Part 22 test, all T/Cs near the edges, will not be fixed T/Cs.

The application of roving T/Cs will be at least 50 mm away from the discontinuity.
Fire Test

- 60 mins, 945 °C
- 120 mins, 1049 °C

Intumescent material expands

Hot spot developed
Fire Test

60 mins 945 °C

120 mins 1049 °C

Temp

Charring of timber occur

Hot spot developed

T/C for BS EN 1634-1 (I₁ insulation)

Roving T/Cs to be applied as BS 476-22

T/C for BS EN 1634-1 (I₂ insulation)
Discrete area of insulation

• Glazed panel is discrete area of insulation?
• With different insulation performance?
• Cotton pad test had to be applied on those uninsulated area as well
• Ignition of beading for uninsulated glass?
Interpretation of Results

The results from BS EN 1634-1 may be expressed as below:

- **Integrity:**
  - Cotton pad test: 15 minutes
  - Gap gauges test: 102 minutes
  - Sustained flaming: 68 minutes

- **Insulation ($I_1$):**
  - Insulation (discrete area): 9 minutes

* Failure simultaneous as cotton pad test failed

The form in BS EN 13501-2: 2007 + A1: 2009 may be E30, E60, EI30
Section 3

BS EN 1634-3 Smoke Leakage Test
What is BS EN 1634-3

• Smoke Control Test on doors or openable windows
  – Ambient temperature test
  – Medium temperature test
  – Each temperature condition subject to pressure difference 10 Pa, 25 Pa and 50 Pa
  – Measure leakage rate of ambient air and warm air through the door
BS EN 1634-3 test

Air in = leakage out at constant pressure

Air out from clearance
Air out from supporting

Air out from supporting
BS EN 1634-3 test condition
BS EN 1634-3 test procedure

Air in = leakage out at constant pressure

Pressure developed

Seal the clearance to measure the leakage rate from supporting \( Q_{\text{app+sup}} \)

Air out from supporting

Air out from supporting
BS EN 1634-3 test procedure

Air in = leakage out at constant pressure

Remove the seal to measure the leakage of all $Q_{total}$

Air out from supporting

Air out from clearance

Air out from clearance

Air out from supporting
What is BS EN 1634-3

• The leakage rate of door will be
  \[ Q_{\text{total}} - Q_{\text{app+sup}} \]

• The measurement shall be done for each temperature condition at each pressure point

• The \( Q_{\text{total}} \) measurement just after 30 minutes of heating period shall be done within 10 minutes

• To take the measurement, the pressure shall be hold for 2 minutes
BS EN 1634-3 test procedure

Wiper type/flipper type

In between

Compression type

Drop type
BS EN 1634-3 test procedure

Door is latched, unlatched?
Passive leaf is bolted or unbolted?
BS EN 1634-3 test procedure

Door is latched, unlatched?
Passive leaf is bolted or unbolted?
BS EN 1634-3 test procedure

Under Pressure
Door leaf movement under heat

Under Heat
Performance criteria

• BS EN 1634-3 standard only tell the test method, no performance criteria were given.

• However, it has mentioned that $S_a$ and $S_m$ classification which shall be referred to BS EN 13501-2: 2007 + A1: 2009.

• $S_a$ classification, the linear leakage rate shall be smaller than $3 \text{ m}^3/\text{h}$ per linear meter of gaps up to 25 Pa (linear rate normalized to the total length of gap excluding the threshold).

• $S_m$ classification, the leakage rate of the specimens shall be
  - $\leq 30 \text{ m}^3/\text{h}$ for double-leaf doorset up to 50 Pa
  - $\leq 20 \text{ m}^3/\text{h}$ for single-leaf doorset up to 50 Pa.
Interpretation of the results

- Linear leakage rate of 3 m³/h/m:
  - For typical single-leaf door, 900 mm wide by 2,200 mm high, the leakage rate will be 18.6 m³/h
  
  - For a room which is 5 m (w) x 5 m (w) x 2.8 m (h), it will take approximately 1.07 hours to fill the upper part of the room and the smoke layer drops to 2 m clear height
Fire Test?

Smoke Test?

- Fire Resistance Test and Smoke Control Test are two different tests.
- The test are conducted separately with the use of different equipments.
- Tests are conducted under different test conditions:
  - Under fire test, the door is subjected to over 1,000 °C and 20 Pa.
  - Under smoke test, the door is subjected to 200 °C and up to 50 Pa.
- The door with the same fire and smoke seal protection subject to the fire resistant test and smoke control test separately.
In case of fire, the door can’t resist fire and at the same time prevent the smoke pass through.
Fire Test?  
Smoke Test?

• The expression of results:

<table>
<thead>
<tr>
<th>Fire Resistance Performance</th>
<th>Smoke Control Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Integrity</strong></td>
<td></td>
</tr>
<tr>
<td>Cotton Pad</td>
<td>Ambient, Side A</td>
</tr>
<tr>
<td>55 mins</td>
<td>15.6 m³/h</td>
</tr>
<tr>
<td>Sustain Flaming</td>
<td>Ambient, Side B</td>
</tr>
<tr>
<td>61 mins</td>
<td>13.7 m³/h</td>
</tr>
<tr>
<td>Gap Gauge</td>
<td>Medium, Side A</td>
</tr>
<tr>
<td>66 mins</td>
<td>10.1 m³/h</td>
</tr>
<tr>
<td>Insulation</td>
<td>Medium, Side B</td>
</tr>
<tr>
<td>55 mins*</td>
<td>10.2 m³/h</td>
</tr>
</tbody>
</table>

*Gap Gauge
Design of Smoke Seals Application

- The door is latched or unlatched?
- Will the door use panic device?
- The present of meeting edge for double-leaf door?
- The profile of meeting edge: Plain or rebated?
- Fire test evidence for the use of smoke seals?
Force act on the door leaf

- The maximum pressure act on the doorset 50 Pa = 50 N/m²

- Typical doorset of sizes 1,00 mm wide by 2,200 mm high

- Force = Pressure x Area
  50 N/m² x 2.2 m² = 110 N to push open the door
Thank you for your attention
Fire Test Standard adopted in Fire Safety Code

- **Reaction to Fire Properties**
  - **BS 476 series**
    - BS 476: Part 4 – Non-combustibility
    - BS 476: Part 6 – Fire Propagation
    - BS 476: Part 7 – Surface Flame Spread
    - BS 476: Part 12 – Ignitability of products

- **BS EN 13501-1** – Classification for products (Class A1, A2, B, C, D, E, F) associated with CE marking
  - ISO 1182 – Non-combustibility
  - ISO 1716 – Determination of heat of combustion
  - BS EN 13823 – Single burning item (SBI)
  - ISO 11925-2 – Ignitability of products
## Fire Test Standard adopted in Fire Safety Code

<table>
<thead>
<tr>
<th>Reaction to Fire Properties</th>
<th>BS EN 13501-1 classification</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-combustible</td>
<td>BS 476: Part 4 – Non-combustibility</td>
<td>Class A1</td>
</tr>
</tbody>
</table>
|                             | ISO 1182 – Non-combustibility  
ISO 1716 – Determination of heat of combustion                                                    |       |
| Limited Combustibility      | BS 476: Part 11 – Limited combustibility                                                         | Class A2 |
|                             | ISO 1716 – Determination of heat of combustion  
BS EN 13823 – Single burning item (SBI)                                                           |       |
| Class 0 to Class 4          | BS 476: Part 6 – Fire Propagation  
BS 476: Part 7 – Surface Flame Spread                                                             | Class B to Class D |
|                             | BS EN 13823 – Single burning item (SBI)  
ISO 11925-2 – Ignitability of products                                                              |       |
| Limited ignitibility        | BS 476: Part 12 – Ignitability of products                                                        | Class E  |
Fire Test Standard adopted in Fire Safety Code

- Test on BS 476-7, Surface flame spread properties