Dr. E. Guillaume, General Manager, Efectis France

Modelling façade fire
What are the latest developments?
Context - External thermal insulation
CONTEXT - EXTERNAL THERMAL INSULATION OF BUILDINGS

Building sector represents 40% of the total energy used in European Union

- Reduction of energy needs in buildings
  - European directive 2010/31/EC on energy savings in building
  - National regulations, i.e. French Thermal regulation RT2012

- Slow renewal of housing/building stock

- Need to improve thermal performances of existing buildings
CONTEXT - EXTERNAL THERMAL INSULATION OF BUILDINGS

There is a need to increase thermal performances of new and existing building

- One of the solutions is a better insulation
- Several technical solutions
  - Internal insulation
  - Double walls
  - Ventilated façades
  - ETICS, External Thermal Insulation Composite Systems
CONTEXT - ARCHITECTURE

Architects develop more and more complex systems:

- Curtain façades, glazed façades
- Nonplanar façades
- Decorative panels, e.g. on balconies
- Biosourced insulants
- Tall wood buildings
- etc
AND AGAINST FIRE?

- What are the consequences of a thermal insulator against fire?
  - Increase insulant thickness
  - Firefighting action and tactics modified
  - Modification of fire scenarios

- What is a facade in terms of fire safety?
  - Assembly of materials (insulant, cladding, etc.)
  - Construction product?
  - Constructive system?
  - Part of a building?

- Other threats?
  - New materials
  - New constructive systems

Mounting and fixing facade in laboratory
FACADE FIRE SCENARIOS

1) Fire from external building
2) Fire behind the building
3) Fire propagating on the facade
4) Fire inside the facade
Modelling facade fire at design phase - When? How?
REGULATION QUESTIONS

Construction product

Constructive system

Facade of a building

Test results

Visa / assessment
PLACE OF MODELLING IN ASSESSMENT

- Historical data
- Intermediate scale tests
- Modelling

Understanding what happens

Direct and extended applications

Large-scale test method

Assessment protocol and responsibilities

On-site expertise

Compliance
C+D according to Hasemi? Effect of balconies, loggias, etc
EXAMPLE - LUSAIL TOWERS (DUBAI) - ARCHITECTURAL THORNS
EXAMPLE - LUSAIL TOWERS (DUBAI) - ARCHITECTURAL THORNS

- Design of the facade test to reproduce flame deflection
EXAMPLE - LUSAIL TOWERS (DUBAI) - ARCHITECTURAL THORNS

Flame and temperature pattern

Then test performed on a 3-storeys mock-up

Modelling facade fires

www.efectis.com 2020
WOOD CLADDING AT DESIGN PHASE

- Wood cladding, 18 mm. Cavity barrier at 2 m.
- Calibration of model versus ISO 13785-1 test.
- Validation of the model to extrapolate:
  - Different cavity barriers
  - Wood cladding thickness variation
WOOD CLADDINGS AT DESIGN PHASE

- Wood cladding, 18 mm. Cavity barrier at 2 m.
- Calibration of model versus ISO 13785-1 test.
- Validation of the model to extrapolate:
  - Different cavity barriers
  - Wood cladding thickness variation
WOOD CLADDINGS AT DESIGN PHASE

- Wood cladding, 18 mm. Cavity barrier at 2 m.
- Calibration of model versus ISO 13785-1 test.
- Validation of the model to extrapolate:
  - Different cavity barriers
  - Wood cladding thickness variation

590 s

650 s
EFFECT OF PERFORATED SHEET METAL ON FACADE OF A CAR PARK

1. Experimental validation of the model
2. Calculation at the building level
3. Evaluation of smoke re-entrance through facade

Modelling facade fires
www.efectis.com
September 2020
USING MODEL TO UNDERSTAND TEST BEHAVIOUR

- Case of LEPIR2 (French test) -
- Example of heat flux pattern at the surface as function of insulation thickness

200 mm thick ETICS

300 mm thick ETICS
USING MODEL TO UNDERSTAND TEST BEHAVIOUR

- Case of LEPIR2 (French test) -

  Temperature inside cavity, for 2 cavity thicknesses:

  Left: 40 mm cavity

  Right: 80 mm cavity
USING MODEL TO UNDERSTAND TEST BEHAVIOUR

Case of LEPIR2 (French test) -

Temperature patterns in the axis of windows for 2 configurations of window frames

Temperature slices inside cavity for different deflector designs
CONCLUSION - AT DESIGN PHASE

- Modelling is a part of the fire safety engineer toolbox:
  - As the large scale test, the historical data, the intermediate-scale tests
  - To understand what he is doing!

- It is not a way of compliance but helps at:
  - Designing tests adapted to specific projects
  - Understanding detains and selecting « worst cases »
  - Understanding physics of facade fires
  - Allowing extendes applications be based

- Models shall be validated for the application case

- Limitations of modelling tools shall be known and documented
Modelling facade fire as a tool for fire reconstruction
MODELLING AT RECONSTRUCTION PHASE

- Modelling tools are very useful to help understanding what happened at reconstruction phase of major disasters, including facade fires.
  - Time frame is not the same
  - Consequences are not the same
  - Finances are less limiting
  - State-of-the art can be applied
  - Starting from observations

Step-by-step analysis possible
METHODOLOGY - EXAMPLE FOLLOWED FOR GRENFELL RECONSTRUCTION

**Step 1:**
- Implementation of the simple façade numerical model
- Validation based on ISO 13785-1 test results

**Validation of:**
- Thermal properties
- Combustion properties
- Aeraulic phenomenon
- Numerical hypothesis

**Step 2:**
- Implementation of a larger façade numerical model
- Validation based on BS 8414-1 test results

**Validation of:**
- Mesh resolution transition
- Upscaling effects

**Step 3:**
- Implementation of the larger façade numerical model on the full scale Grenfell Tower
- Validation based on real fire observations

**Validation of:**
- Apartments contribution
- Fire propagation

**Step 4:**
- Implementation of the full scale Grenfell Tower to investigate particular phenomenon
- Validation based on real fire observations

**Assessment / investigation of:**
- Apartments contribution
- Fire propagation
- Tenability conditions
- Modifications in the façade system details
RESULTS FOR FLAME PROPAGATION

Modelling facade fires
RESULTS FOR FLAME PROPAGATION

5 min

6 min

7 min

8 min

Modelling facade fires
RESULTS - HEAT RELEASE RATE

- Without burner contribution (100 kW)
- Maximum value:
  - 5 MW during test (10% uncertainty)
  - 5.3 MW in simulation (17% uncertainty)
- Global HRR
  - The numerical model doesn’t reproduce the small contribution at early time
  - It predicts longer contribution after the mean peak
  - Globally within experimental uncertainty

Following ISO 16730-1:2015 method for validation of calculation:

<table>
<thead>
<tr>
<th>Method</th>
<th>Relative difference</th>
<th>cosine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euclidian</td>
<td>10.86%</td>
<td>0.982</td>
</tr>
<tr>
<td>Hellinger</td>
<td>5.94%</td>
<td>0.946</td>
</tr>
<tr>
<td>Secant</td>
<td>4.65%</td>
<td>0.979</td>
</tr>
<tr>
<td>Hybrid</td>
<td>8.33%</td>
<td>0.980</td>
</tr>
</tbody>
</table>
RESULTS - FLAME PROPAGATION AT BS8414 STEP

- Visualisation at 120 s and every 60s
RESULTS - VIEW OF THE CLADDING BURNT

- At wood extinguishment (400 s in simulation)
PROPAGATION OF THE FIRE FROM THE FAÇADE TO AN APARTMENT

- External fire solicitation
  - Example: Flat 26

[Diagram showing parts of a building and temperature at different times]
PROPAGATION OF THE FIRE FROM THE FAÇADE TO AN APARTMENT

- Thermomechanical analysis of windows failure
- Tilted window
  - Strong deformation of the frame between 3 and 5 minutes of exposure
  - The window is expected to be partially ruined during this time

Deformation at 316 s: failure of the outer exposed part

Deformation at 650 s: failure of the inner part (fails inside the apartment)
PROPAGATION OF THE FIRE TO THE FULL EAST FAÇADE

- Horizontal propagation - numerical prediction

PROPAGATION OF THE FIRE TO THE FULL NORTH FAÇADE

- Horizontal propagation - numerical prediction
  - Report of the fire boundary condition (BC) to the partial East façade after 01:29 am

  The flame seems to be extinguished at the centre of the façade (local extinction) and are close to the columns.

Barbara Lane report vol 5. Figure 5.15. – North façade
EXAMPLE OF RESULT COMPARED TO OBSERVATIONS

- Comparison of numerical and observed horizontal propagation at crown level
EXAMPLE OF RESULT FROM THE MODEL - TENABILITY ASSESSMENT

- FED evaluated numerically at 1.5 m high in the centre of the kitchen of flat 26 following ISO 13571 Standard, for a given ventilation scenario.
General conclusion
Modelling façade fire - What are the latest developments?

- Modelling tools are nowadays a very powerful tool...

- ...But it is only a tool! And it needs case-by-case validation.

- This mean it helps engineer to understand physics, but it doesn’t replace his brain!

- Facades are complex and assessed at several levels: products, systems, buildings. Pass/fail is not enough.

- Modelling is also very powerful tool at reconstruction phase for major disasters
THANK YOU FOR YOUR ATTENTION

Dr. Eric GUILLAUME
Eric.guillaume@efectis.com