Research Fund for Coal & Steel

Fire Behaviour of Steel and Composite Floor Systems

Review of Real Fires

Content of presentation

- **Cardington fire tests**
  - **Beam test with burners**
  - **Frame test with burners**
  - **Corner tests with wood cribs**
  - **Demonstration tests with real office furniture**

- **Evidence from accidental fire in real buildings**
  - **Accidental fire**

Cardington fire tests

Cardington fire tests

Evidence from accidental fire

- **Eight storey steel framed building**

Beam to beam joint

Beam to column joint

Cardington fire tests

- **Main parameters of the building**
  - **Length: 45 m in 5 spans of 9 m**
  - **Width: 21 m in 3 spans of 6 m, 9 m and 6 m**
  - **Height of storey: 4.2 m**
  - **Steel members: UB for beams and UC for columns**
  - **Composite slab: lightweight concrete with a total depth of 130 mm and a trapezoidal steel deck**
  - **Steel mesh: 142 mm²**
  - **Steel joints: fin-plates for beam-beam joints and flexible end plates for beam-column joints**
  - **Applied load: sand bags (the load will depend on the test)**

Cardington fire tests

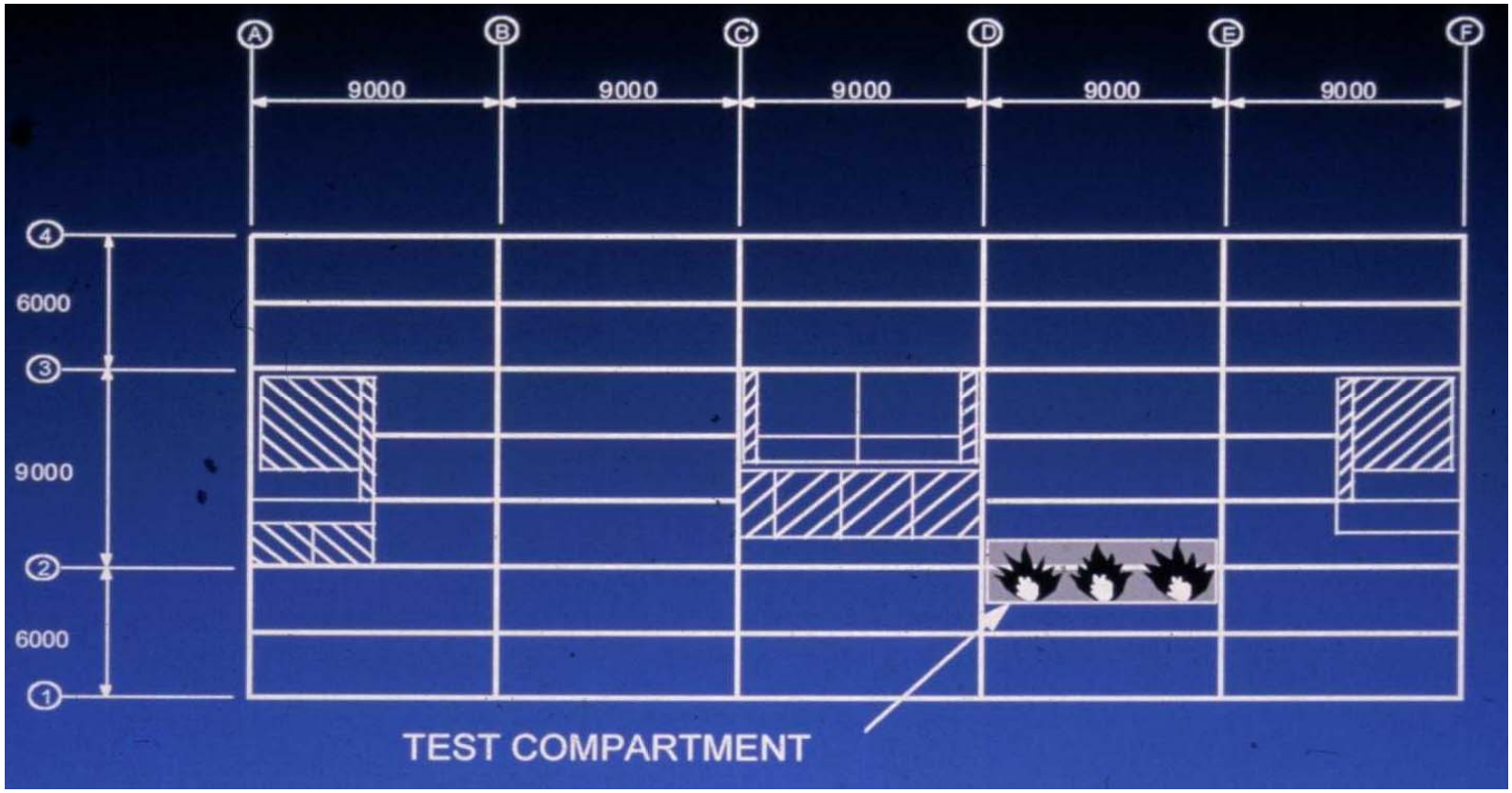
- **Video of Frantisek Wald**
  - **Too long, must be shortened and then will be sent**

Cardington fire tests

Evidence from accidental fire

Cardington fire tests

- **Restrained beam test : span = 9.0 m**



Cardington fire tests

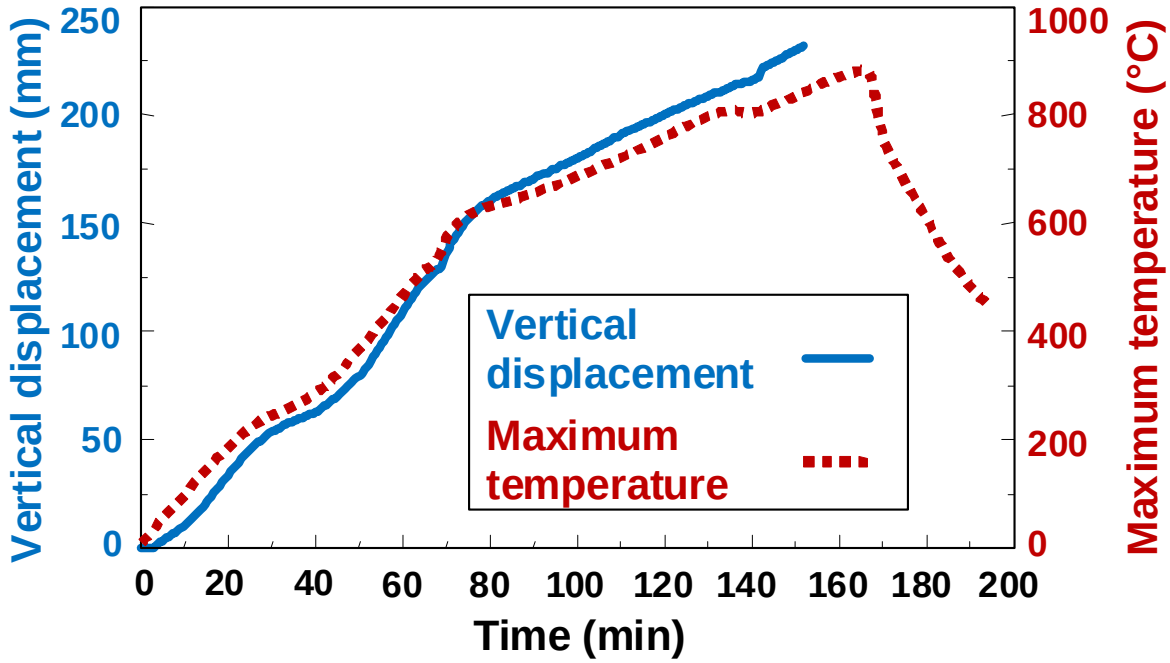
Evidence from accidental fire

Cardington fire tests

Cardington fire tests

Evidence from accidental fire

- **Restrained beam test : experimental results**



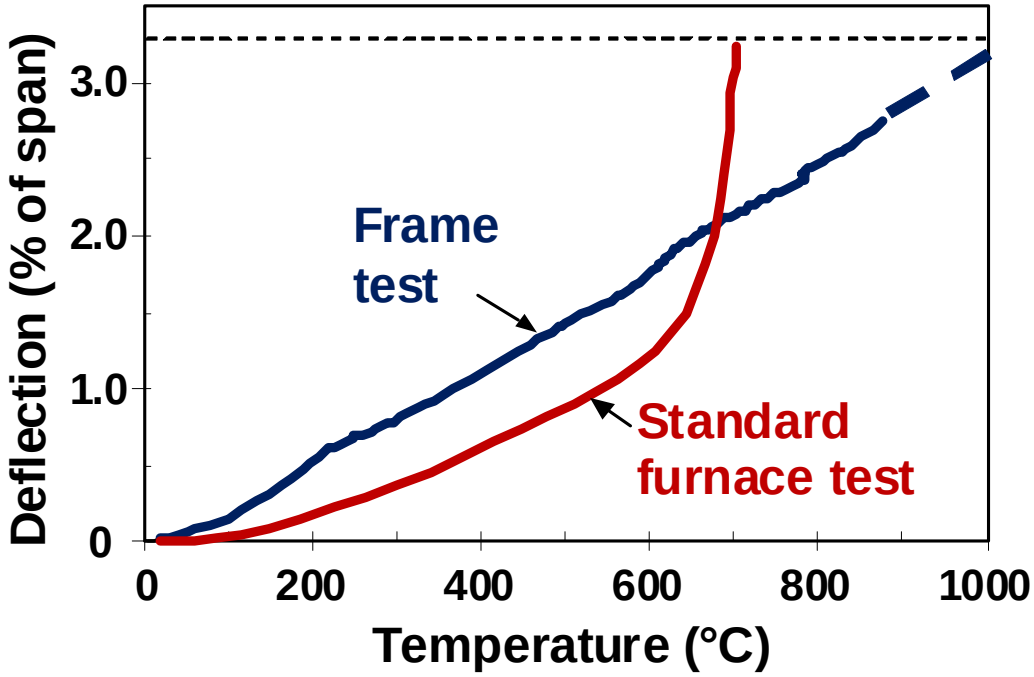
- **Observation**
  - **Maximum heating ≈ 900 °C**
  - **Deflection of the beam: < 250 mm**

Cardington fire tests

Cardington fire tests

Evidence from accidental fire

- **Comparison with standard furnace fire test**



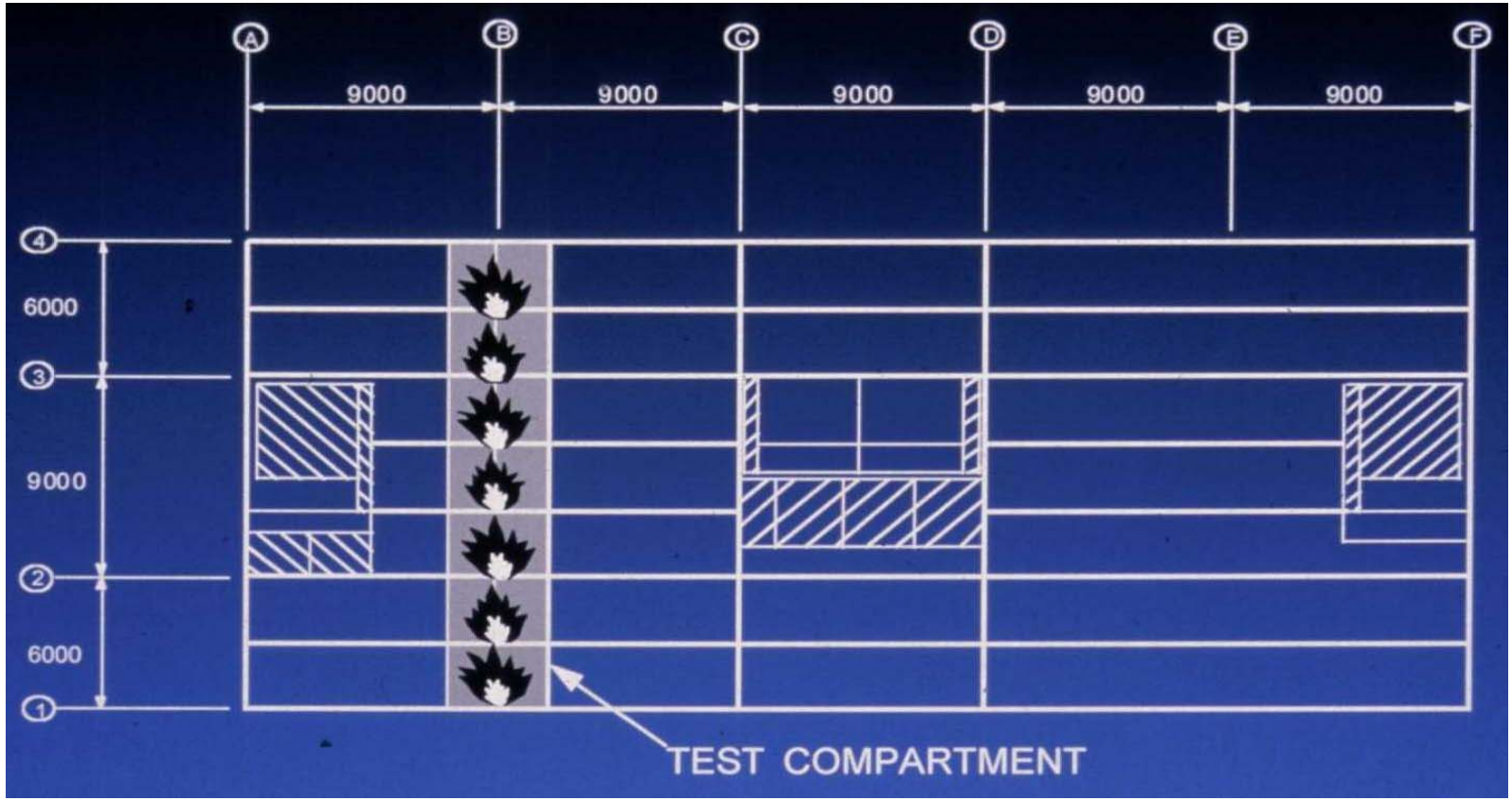
- **Conclusion**
  - **No sign of failure in global composite floor system**
  - **Collapse at $\theta \approx 650$ °C <u>if simply supported</u>**

Cardington fire tests

Cardington fire tests

Evidence from accidental fire

- **Plane frame beam test**

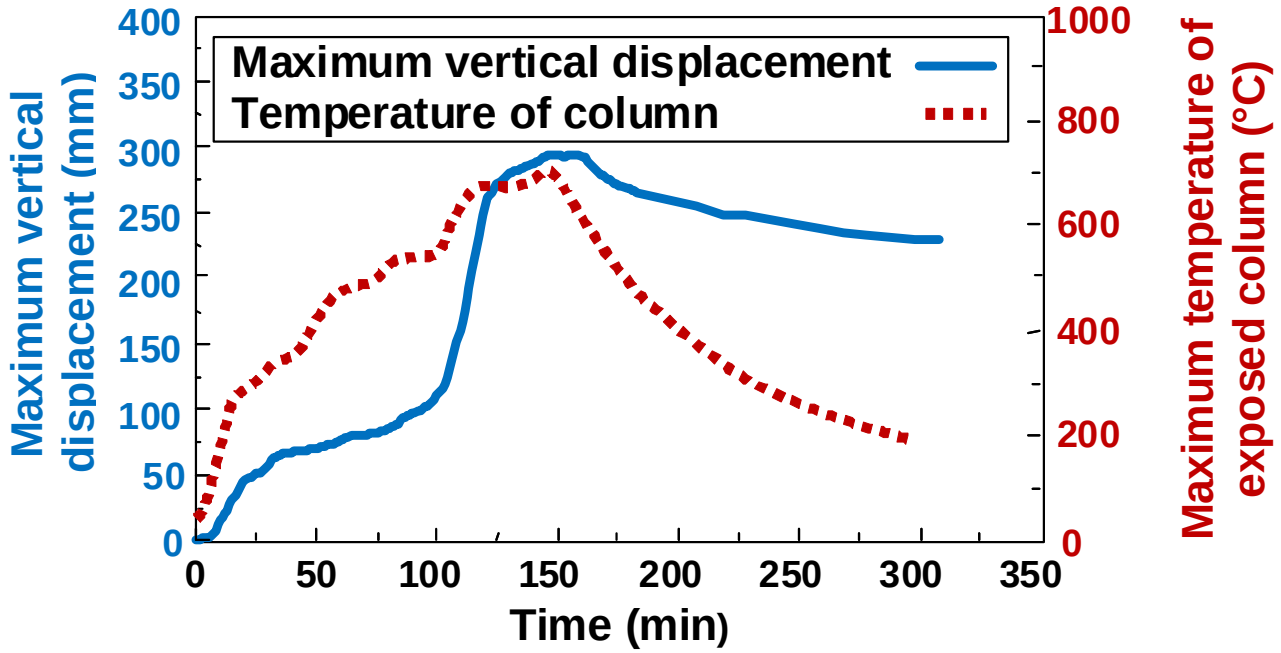


Cardington fire tests

Cardington fire tests

Evidence from accidental fire

- **Plane frame test : experimental results**



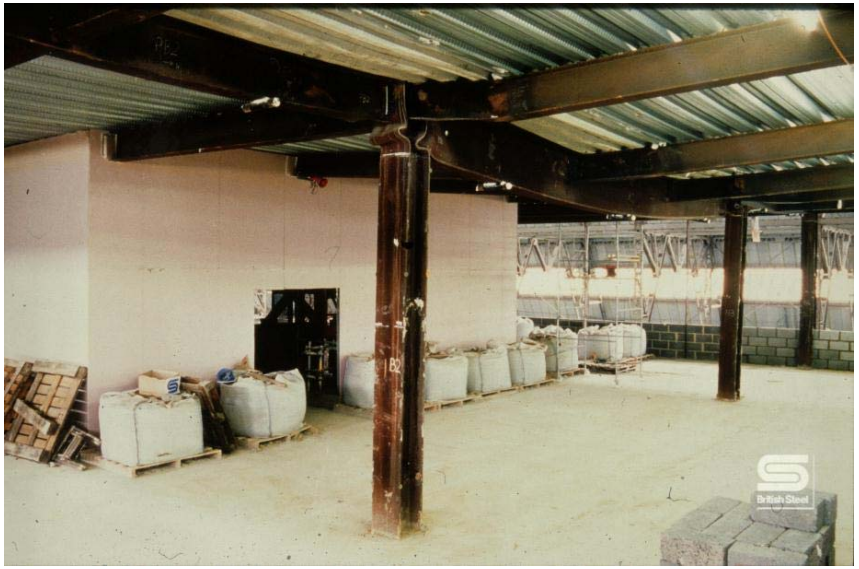
- **Observation**
  - **Maximum heating ≈ 750 °C**
  - **Deflection of the beam ≈ 300 mm**

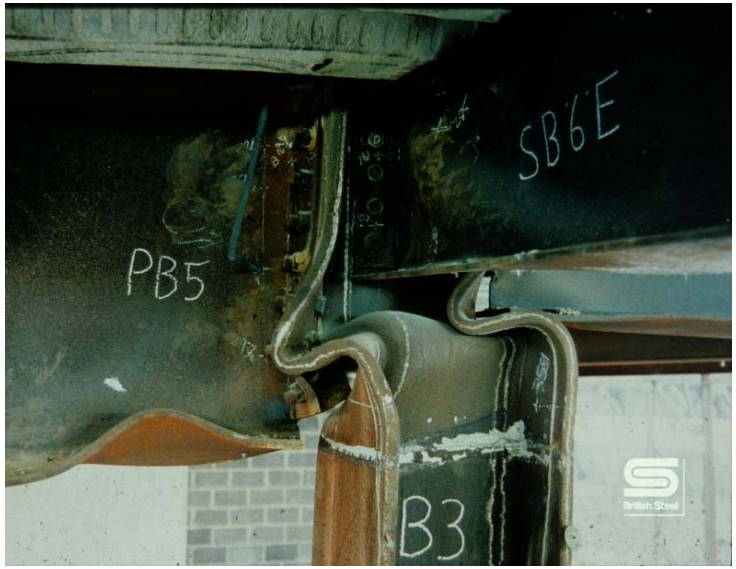
Cardington fire tests

Cardington fire tests

Evidence from accidental fire

- **Deformed state of heated part of the floor**

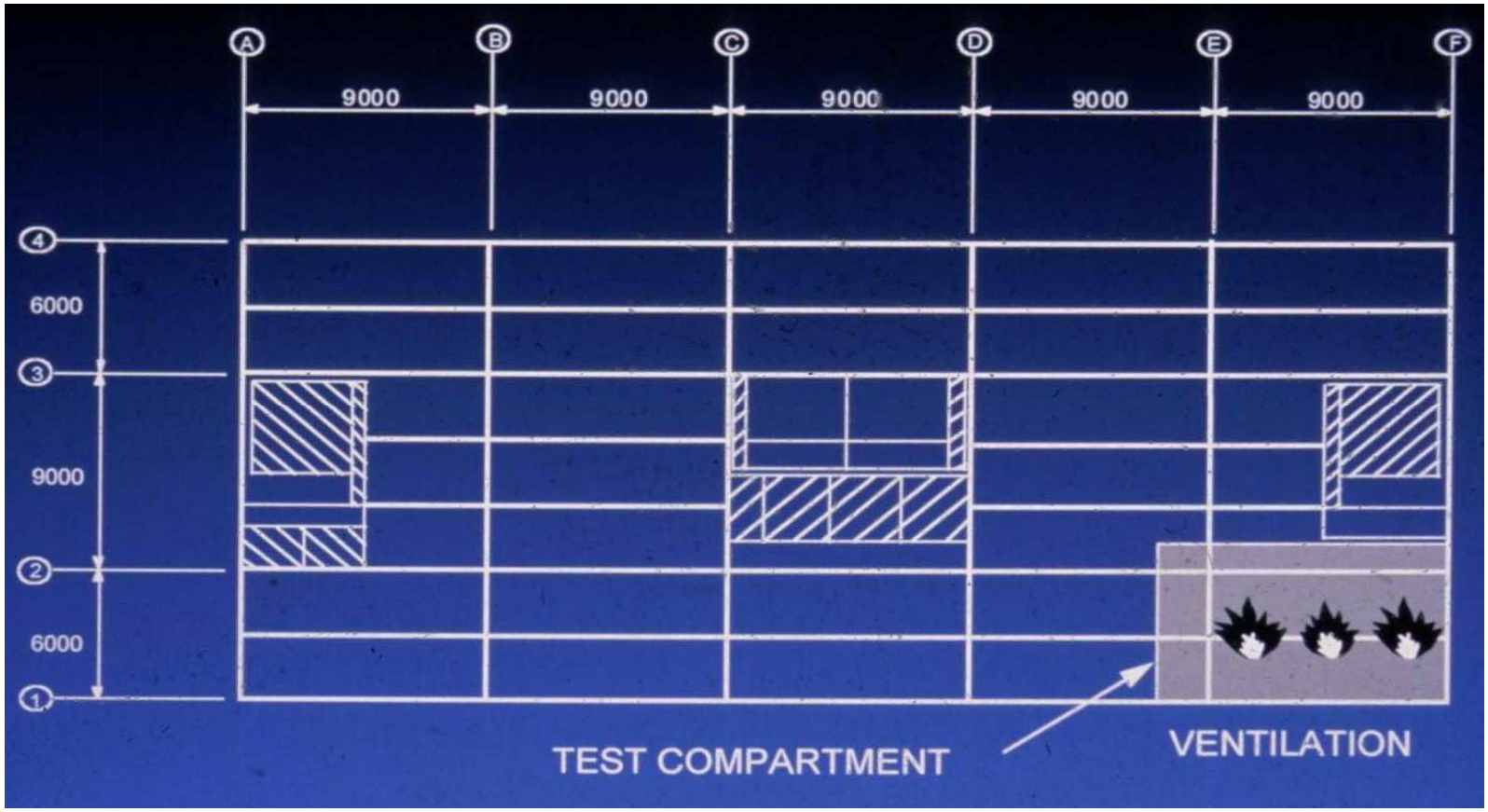




- **Conclusion**
  - **Squashing of unprotected part of column**
  - **No further collapse <u>despite above local failure</u>**

Cardington fire tests

- **Corner compartment test**



Cardington fire tests

Evidence from accidental fire

Cardington fire tests

Cardington fire tests

Evidence from accidental fire

- **Corner compartment test : set-up**

Fire load with wood cribs equals to 45 kg/m²

Walls of the compartment with hollow breeze-blocks

Cardington fire tests

- **Corner compartment test : experimental results**

Cardington fire tests

Evidence from accidental fire

Fire during the test

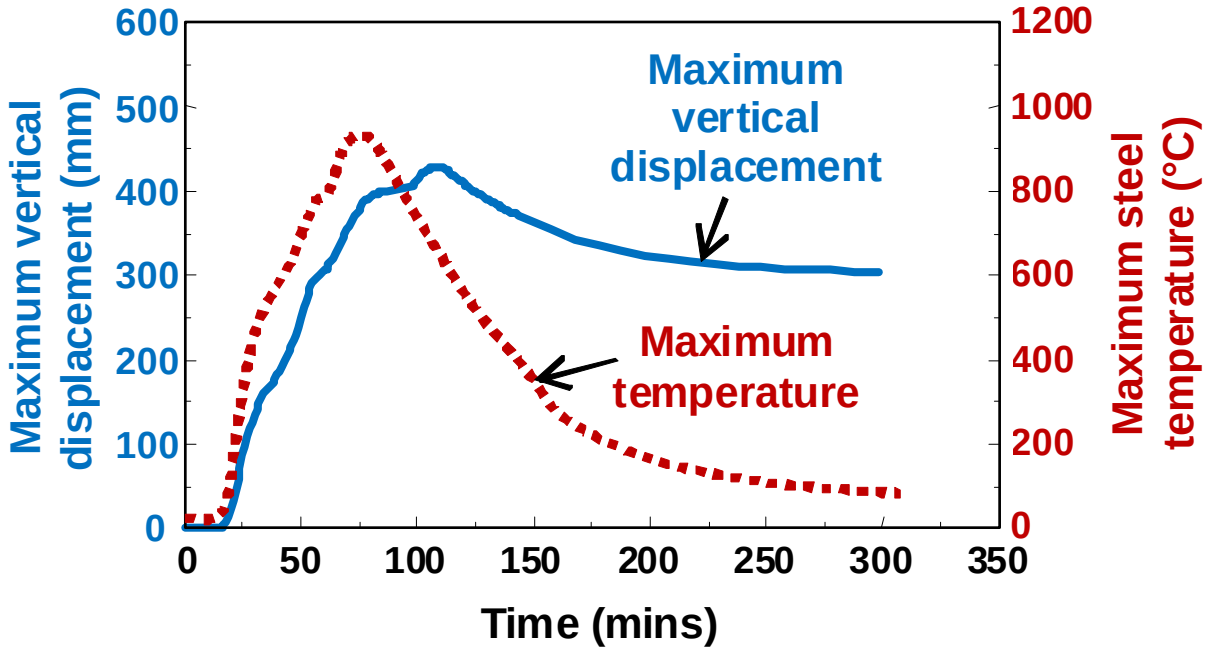
Deformed floor after the test

Cardington fire tests

Cardington fire tests

Evidence from accidental fire

- **Corner compartment test : experimental results**



- **Observation**
  - **Maximum heating of steel ≈ 1014 °C**
  - **Maximum deflection of the floor ≈ 428 mm**

Cardington fire tests

Cardington fire tests

Evidence from accidental fire

- **Corner compartment test : structure after test**

Deformed state of the heated part of the composite floor

Deformed state of steel members around protected steel column

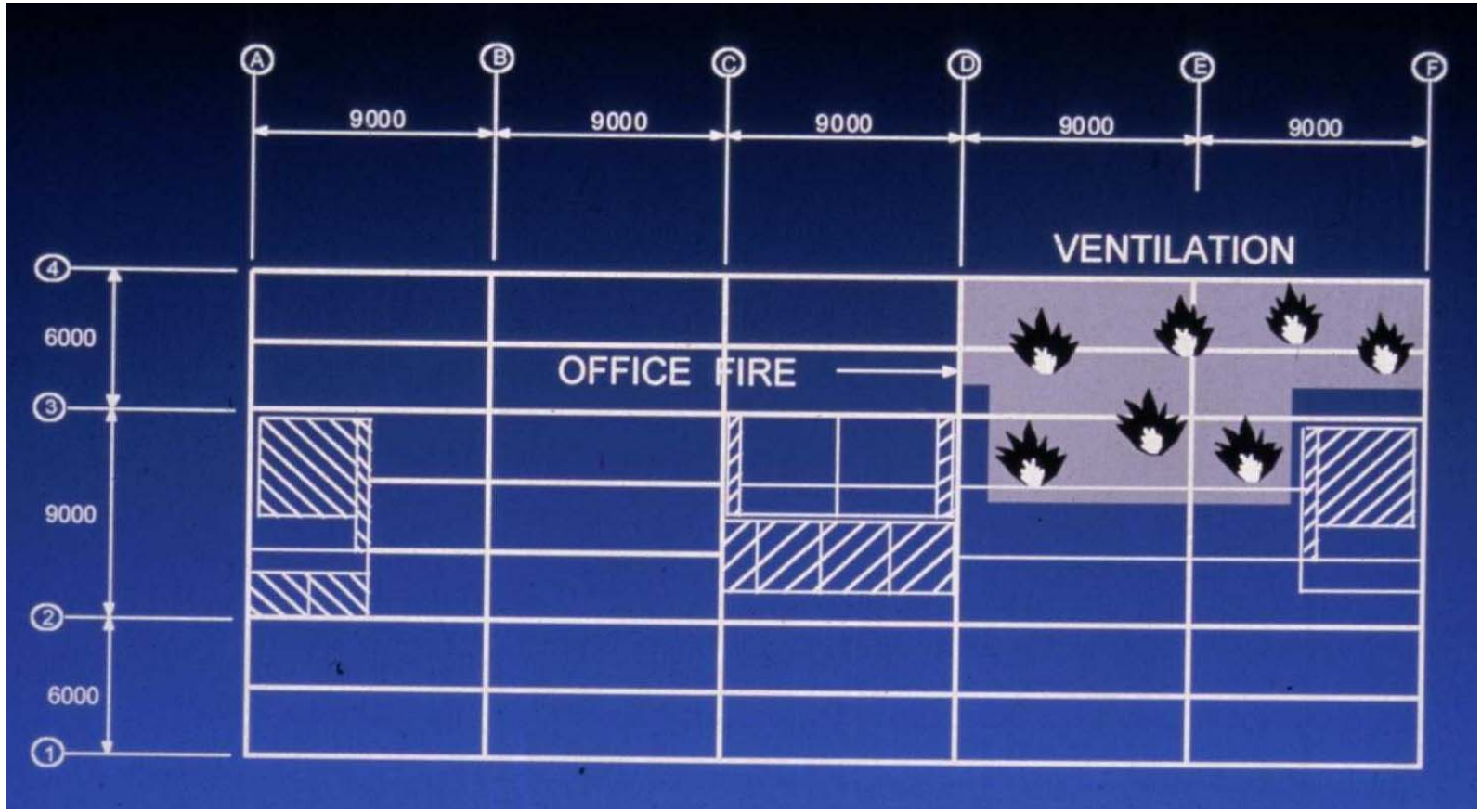
- **Conclusion**
  - **No sign of global failure of the floor as well as limited deflection of the floor <u>despite important heating of steel</u>**

Cardington fire tests

Cardington fire tests

Evidence from accidental fire

- **Demonstration test** (an area of more than 130 m²)



Cardington fire tests

Cardington fire tests

Evidence from accidental fire

- **Demonstration test : set-up**

Fire load with real office furniture

Openings with normal glazed windows

Cardington fire tests

Cardington fire tests

Evidence from accidental fire

- **Demonstration test : experimental results**

Early stage of fire

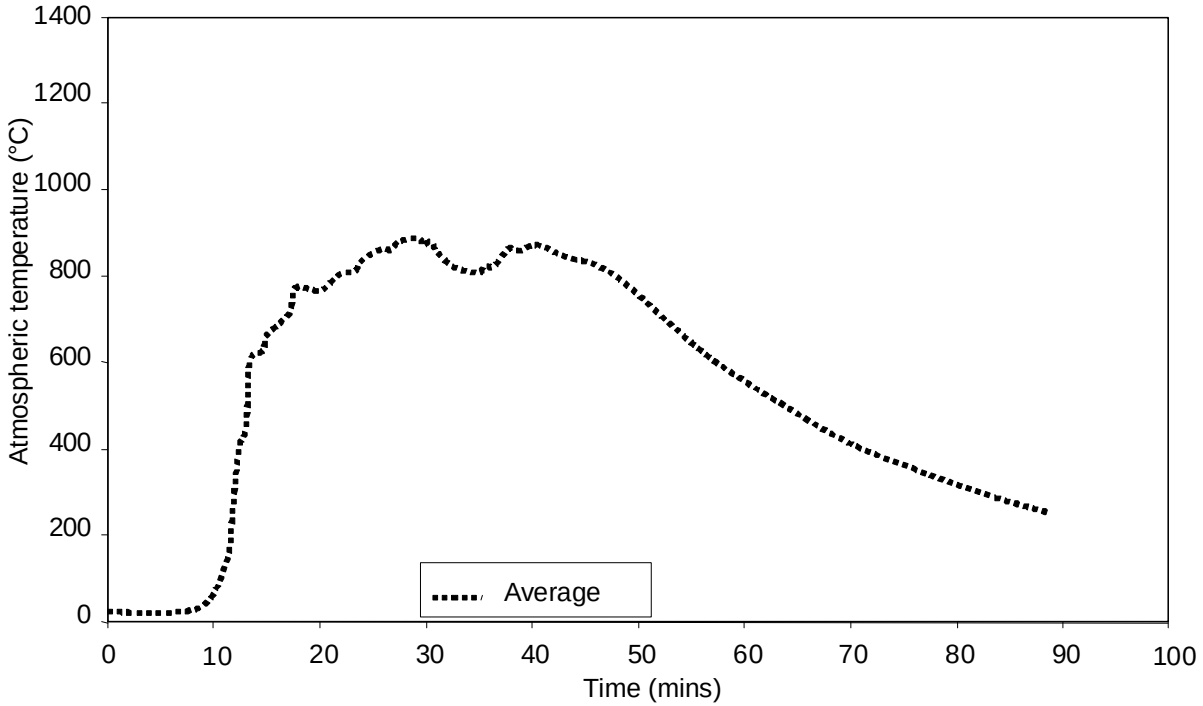
Fully developed fire

Cardington fire tests

Cardington fire tests

Evidence from accidental fire

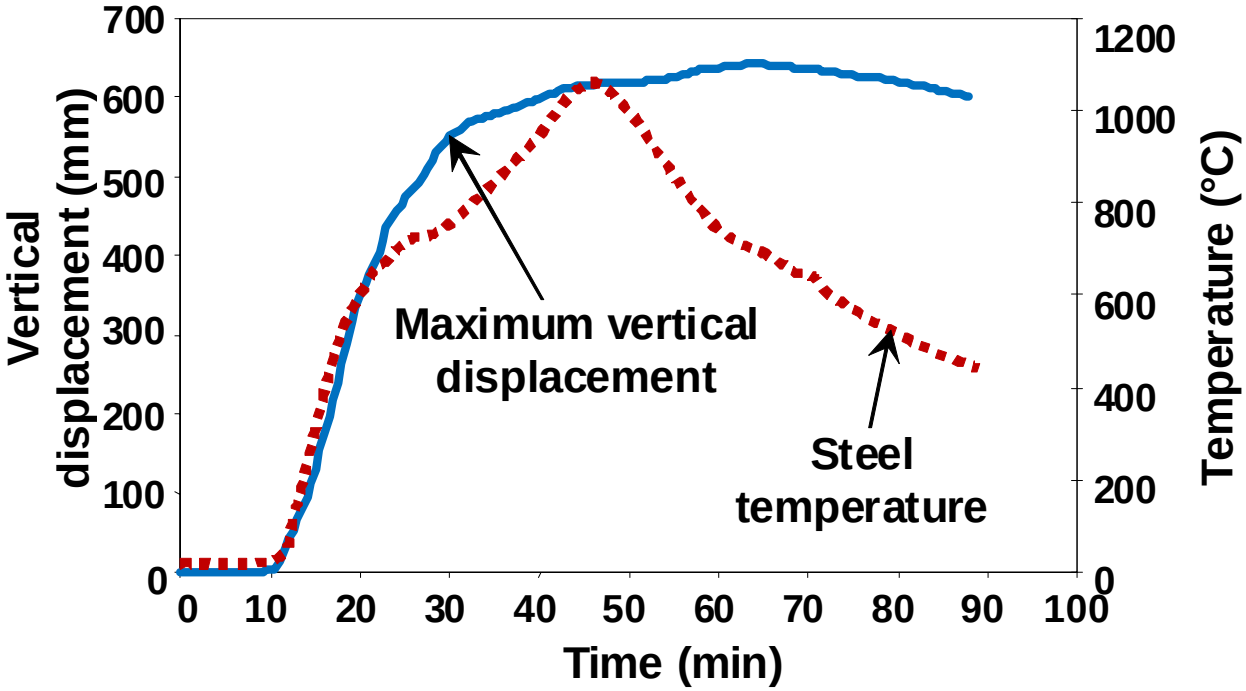
- **Demonstration test : experimental results**



- **Observation**
  - **Maximum gas temperature ≈ 1200 °C**
  - **Maximum heating of steel ≈ 1150 °C**

Cardington fire tests

- **Demonstration test : experimental results**



- **Observation**
  - **Important deflection of the floor ≈ 640 mm**
  - **No collapse of the floor**

Cardington fire tests

Cardington fire tests

Evidence from accidental fire

- **Demonstration test : structure after test**

Deformed state of the heated part of the composite floor

Deformed state of steel members around protected steel column

- **Conclusion**
  - **No sign of global failure of the floor <u>despite important heating of steel and deflection of the floor</u>**

Cardington fire tests

- **Other fire tests**
  - **Second corner test**
  - **Large compartment test**
  - **New corner test**

Cardington fire tests

Cardington fire tests

Evidence from accidental fire

- **General remarks**
  - **Large number of severe fire tests performed in this steel framed building without collapse of the global structure**
  - **Much better fire performance observed with respect to ordinary standard fire tests with isolated steel members**
  - **Excellent global behaviour of composite floor even if steel beams were heated up to more than 1000 °C**
  - **Obvious enhancement of fire resistance of the composite floor owing to induced membrane effect under large deflection**
  - **Good structural robustness of the composite floor system in case of important concrete cracking**

Accidental fires and other fire tests

Cardington fire tests

Evidence from accidental fire

- **Broadgate fire**
  - 14 storey-office building with composite floor system
  - Fire temperature more than 1000 °C
  - Important deflection of the floor (more than 600 mm) but no collapse