Education and Culture DG
Lifelong Learning Programme
LEONARDO DA VINCI

1&4 ANEFORE

FRACOF

Fire Behaviour of Steel and Composite Floor Systems

Review of Real Fires

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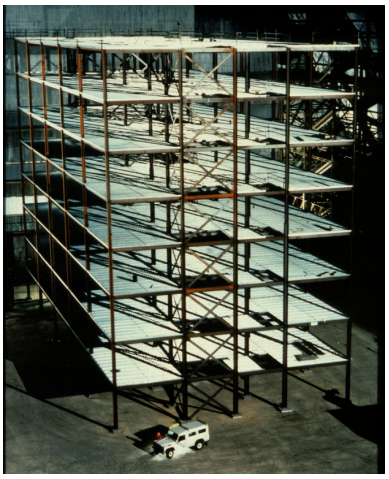
26th of May 2011

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
- **Fire tests of open car parks**
  - Localized car fire tests
- **Evidence from accidental fire in real buildings and other fire tests outside Europe**
  - Accidental fires
  - Other fire tests

Cardington fire tests

- **Eight storey steel framed building**



Beam to beam joint

Beam to column joint

Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Cardington fire tests

- **Main parameters of the building**
  - Length: 42 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

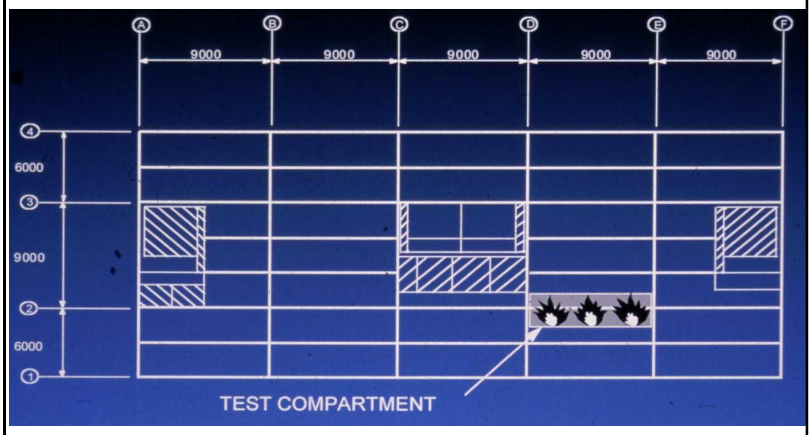
Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Cardington fire tests

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



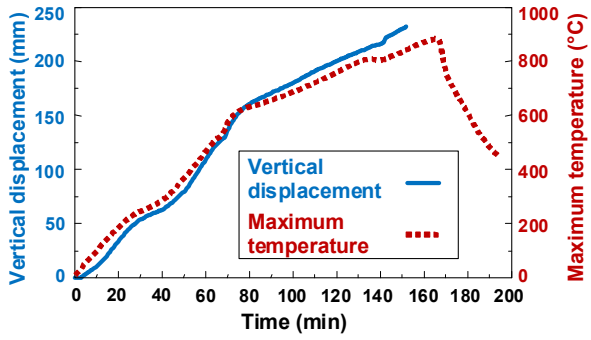
Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Cardington fire tests

- **Restrained beam test :** experimental results



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

Cardington fire tests

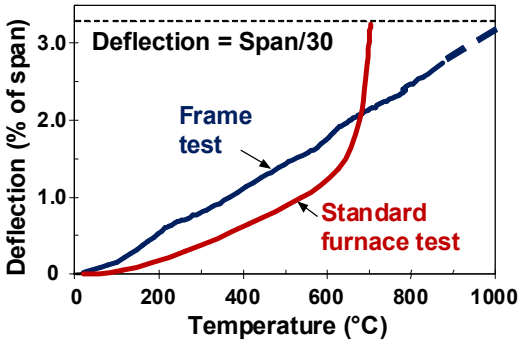
Fire tests of open car parks

Evidence from accidental fire

Cardington fire tests
Fire tests of open car parks
Evidence from accidental fire

Cardington fire tests

- Comparison with standard furnace fire test

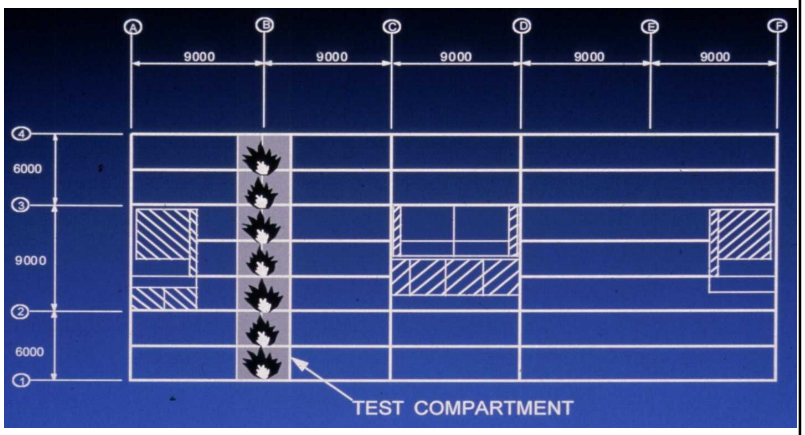


- Conclusion
  - No sign of failure in global composite floor system
  - Collapse at θ ≈ 650 °C if simply supported

Cardington fire tests
Fire tests of open car parks
Evidence from accidental fire

Cardington fire tests

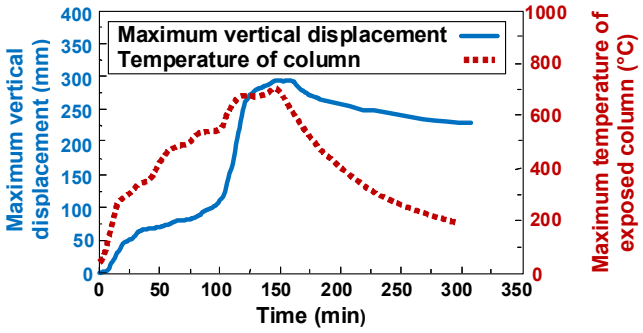
- Plane frame beam test



Cardington fire tests
Fire tests of open car parks
Evidence from accidental fire

Cardington fire tests

- **Plane frame test : experimental results**



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

Cardington fire tests
Fire tests of open car parks
Evidence from accidental fire

Cardington fire tests

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

- **Conclusion**
  - Squashing of unprotected part of column
  - No further collapse despite above local failure

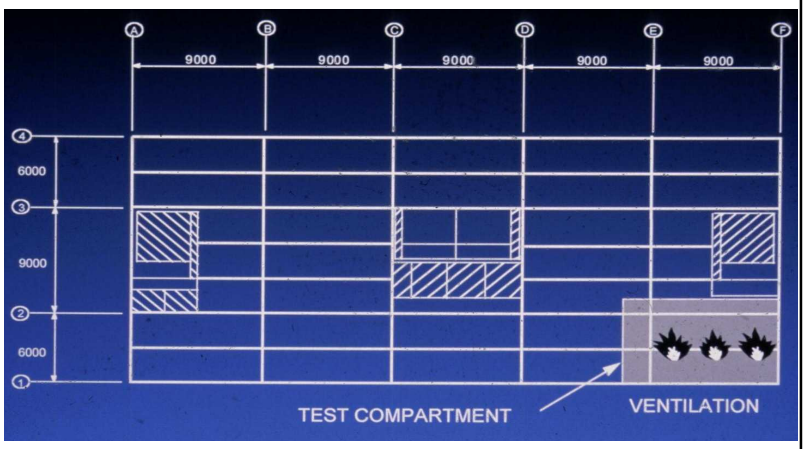
Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Cardington fire tests

- **Corner compartment test**



Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Cardington fire tests

- **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

Fire tests of open car parks

Evidence from accidental fire

Fire during the test

Deformed floor after the test

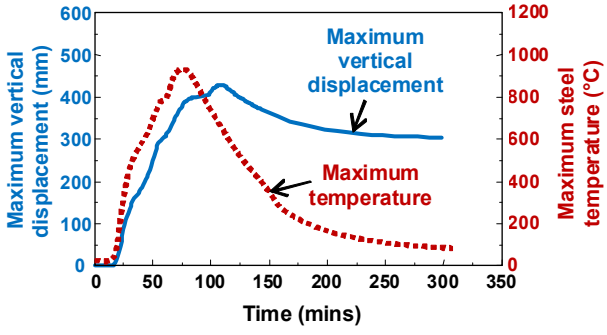
Cardington fire tests

- **Corner compartment test :** experimental results

Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire



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

Cardington fire tests

Cardington fire tests

Fire tests of open car parks

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 despite important heating of steel

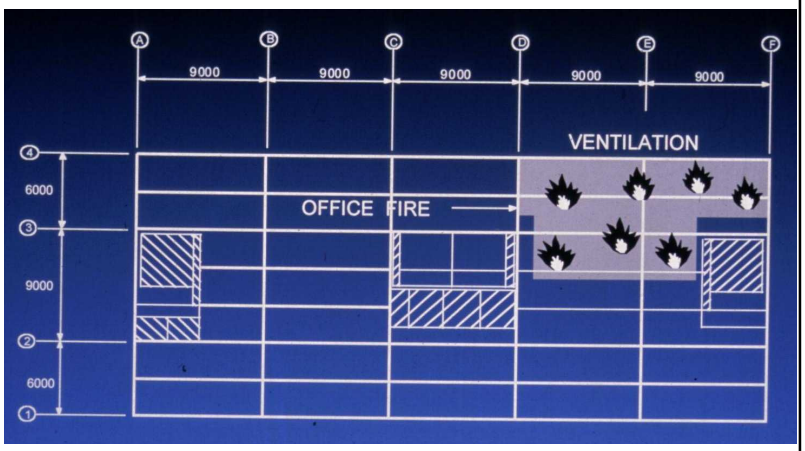
Cardington fire tests

Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

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



Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Cardington fire tests

- **Demonstration test :** set-up

Fire load with real office furniture

Openings with normal glazed windows

Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Cardington fire tests

- **Demonstration test :** experimental results

Early stage of fire

Fully developed fire

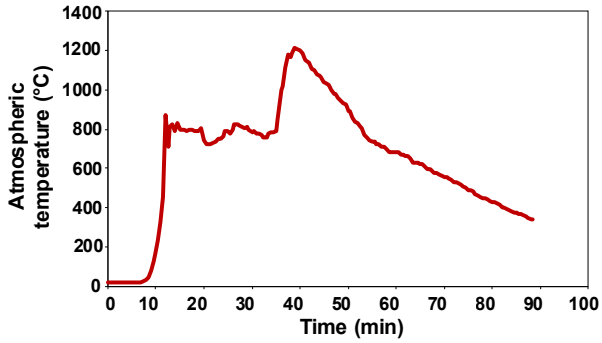
Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Cardington fire tests

- **Demonstration test : experimental results**



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

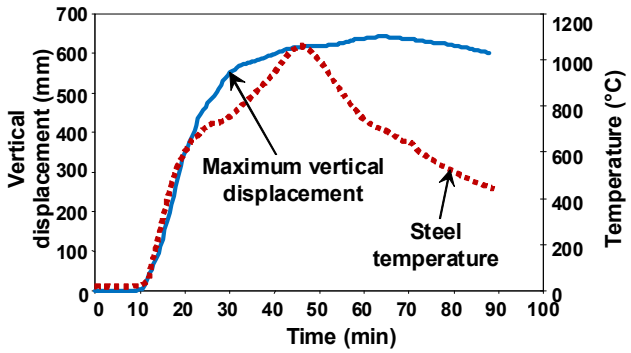
Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Cardington fire tests

- **Demonstration test : experimental results**



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

Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Cardington fire tests

- **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 **despite important heating of steel and deflection of the floor**

Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Cardington fire tests

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

Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Cardington fire tests

- **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**

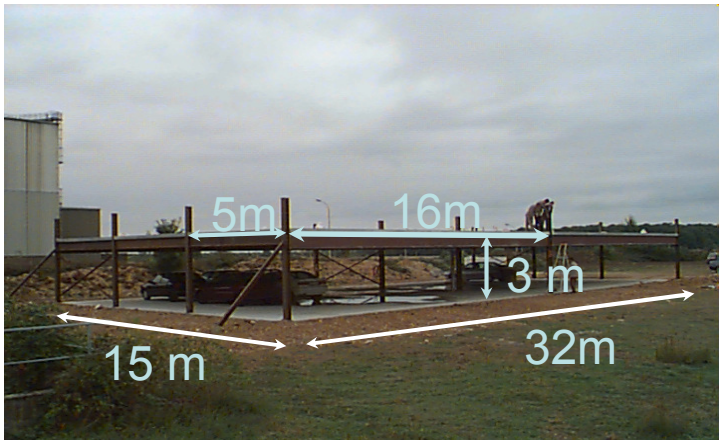
Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Fire tests of open car park

- **One storey steel framed building**



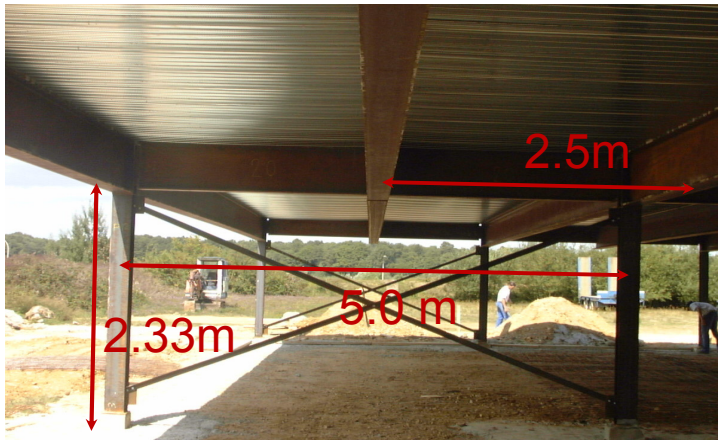
Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Fire tests of open car park

- **One storey steel framed building**



Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Fire tests of open car park

- **Main parameters of the structure**
  - Length: 32 m in 2 spans of 16 m
  - Width: 15 m in 3 spans of 5 m
  - Height of storey: 3.0 m
  - Steel members: IPE for beams and H for columns
  - Composite slab: normal weight concrete with a total depth of 120 mm and a re-entrant steel deck
  - Steel mesh:
  - Steel joints: double angle web cleats for beam-beam joints and end plates for beam-column joints
  - Applied load: real cars

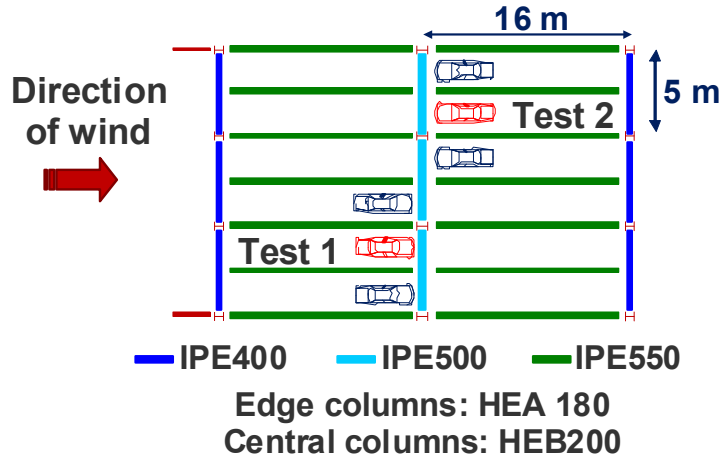
Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Fire tests of open car park

- **Two fire tests involving three cars in each**



Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Fire tests of open car park

- **Experimental results (test 1)**

0 min

Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Fire tests of open car park

- **Experimental results (test 1)**

10 min

Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Fire tests of open car park

- **Experimental results (test 1)**

33 min

Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Fire tests of open car park

- **Experimental results (test 1)**

62 min

Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Fire tests of open car park

- **Experimental results (test 2)**

0 min

Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Fire tests of open car park

- **Experimental results (test 2)**

10 min

Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Fire tests of open car park

- **Experimental results (test 2)**

25 min

Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Fire tests of open car park

- **Experimental results (test 2)**

44 min

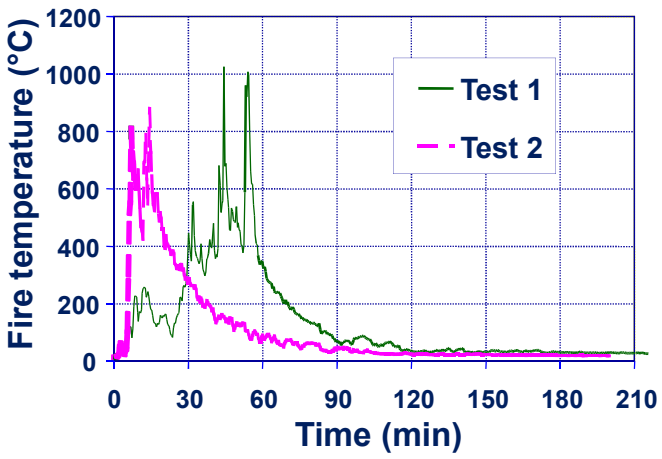
Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Fire tests of open car park

- **Experimental results : gas temperature**



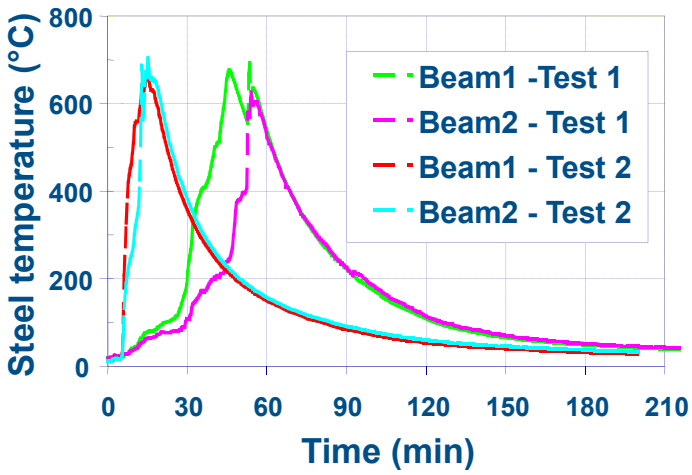
Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Fire tests of open car park

- **Experimental results :** steel temperature



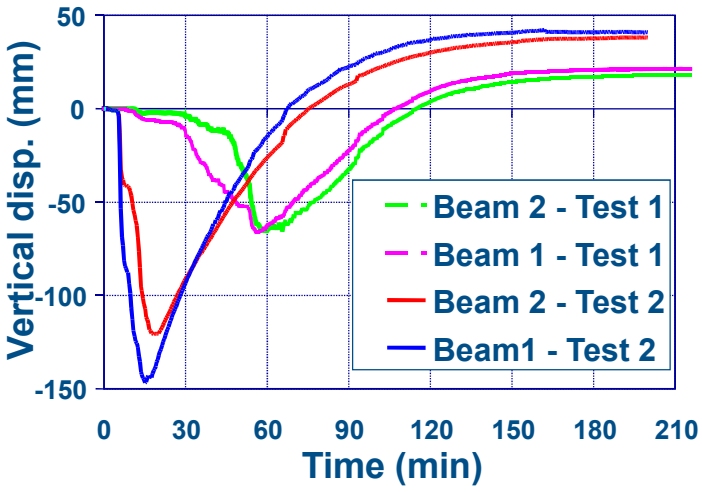
Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Fire tests of open car park

- **Experimental results :** steel temperature



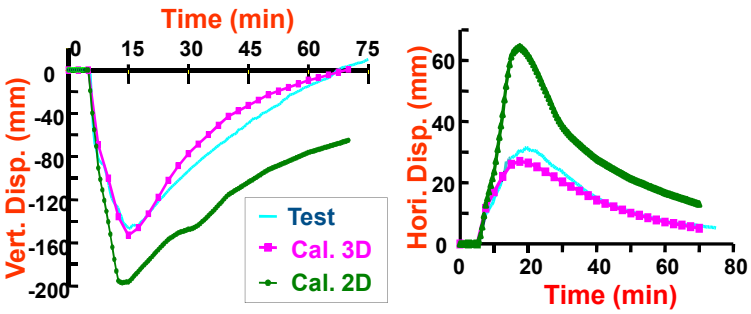
Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Fire tests of open car park

- **Effects of 3D membrane effect**



- **Conclusion**
  - Reduction of displacements with 3D membrane effect compared to 2D portal frame behaviour

Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Accidental fires and other fire tests

- **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

Cardington fire tests

Fire tests of open car parks

Evidence from accidental fire

Accidental fires and other fire tests

- **Australian fire tests**
  - Full scale composite floor system
  - Fire load: 52 kg/m² of wood cribs
  - Fire temperature more than 1228 °C
  - No collapse of the floor