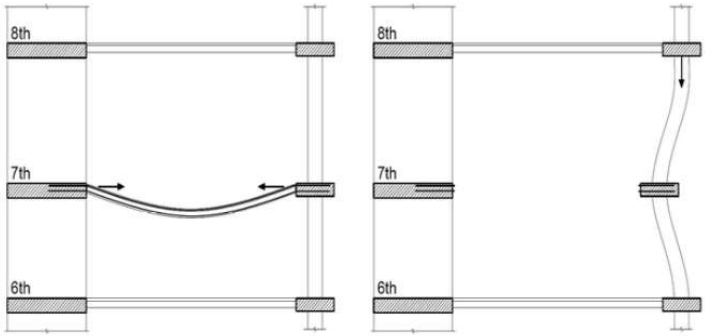
# Effects of fire on concrete structures – Failures

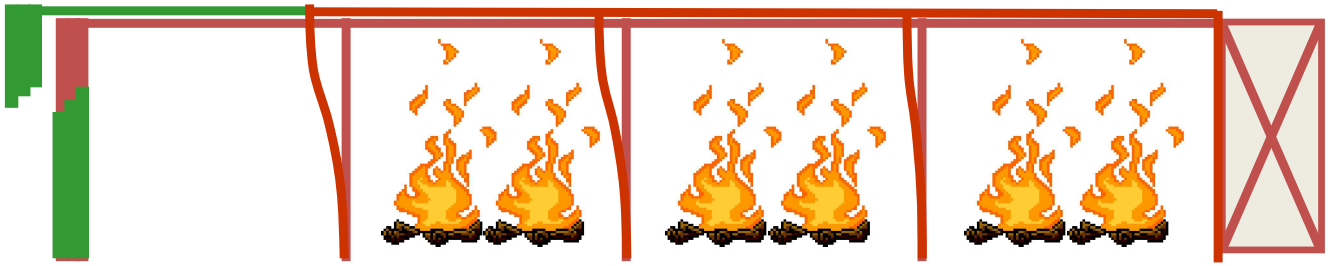
- Delft Faculty of Architecture building (2008)
  - RC building
  - Fire from coffee vending machine
  - Fire spreads
  - Progressive collapse
    - Hypothesis[1]: loss of flexural capacity, large deflections of floors, catenary action (pulling) leading to failure of columns
    - Evidence suggests system response + spalling

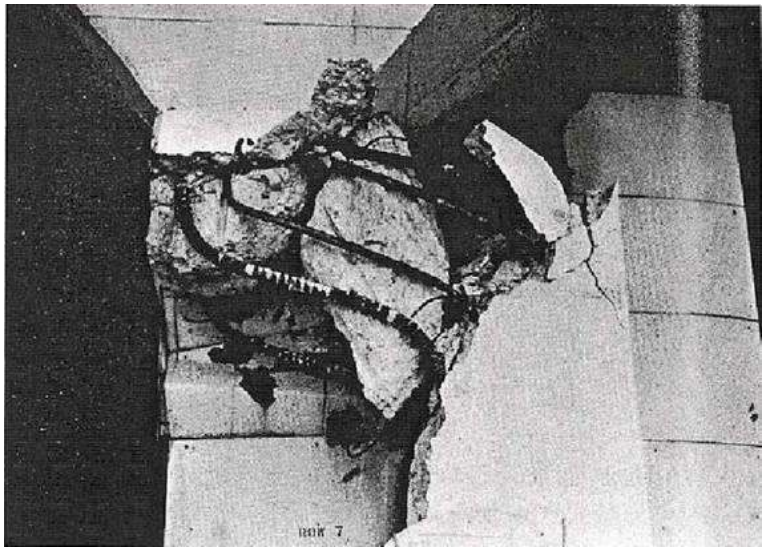


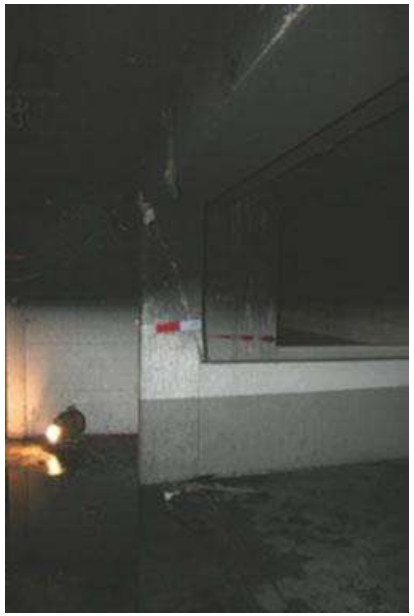

[1] Engelhardt, et al. (2013). Observations from the fire and collapse of the faculty of architecture building, delft university of technology.

# Effects of fire on concrete structures – Failures

- "Tour d'Ivoire" parking in Montreux Switzerland (2010)[1]
  - Thermal elongation of the concrete slab
  - Collapse in shear of a column several meters away from the fire



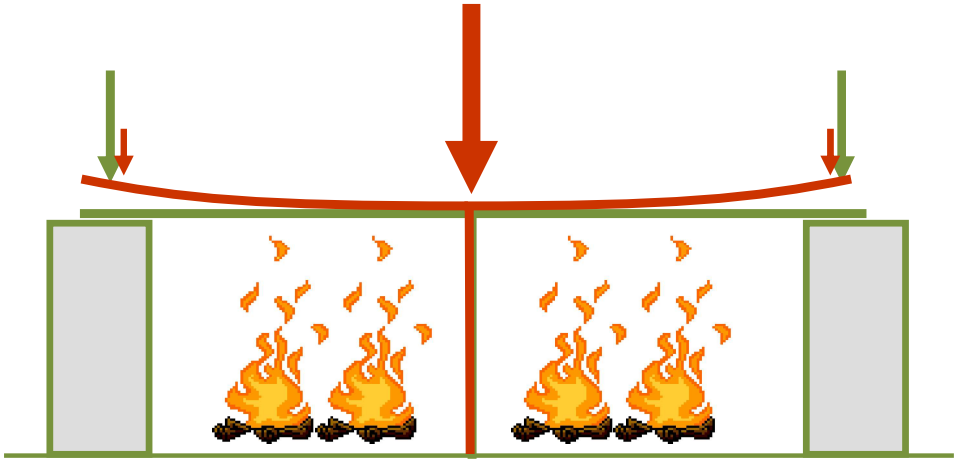




[1] Burnier, O. (2011). Reconstitution de l'incendie de deux voitures dans le parking de la Tour d'Ivoire à Montreux, le 9 décembre 2010.

# Effects of fire on concrete structures – Failures

- Collapse of an underground car park in Switzerland (2004)
  - Poor design
  - Shear punching of the concrete flat slab linked to restrained sagging of the slab

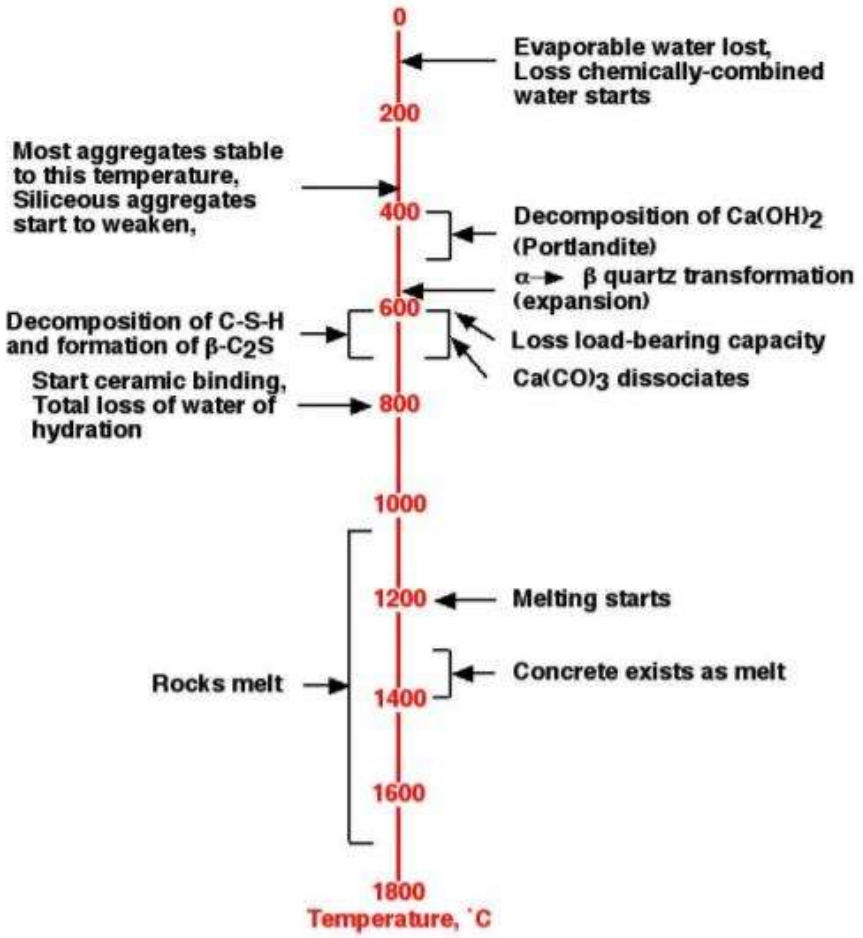


# Effects of fire on concrete structures – Material behavior

Physiochemical processes in Portland cement concrete during heating

Concrete deterioration of properties:

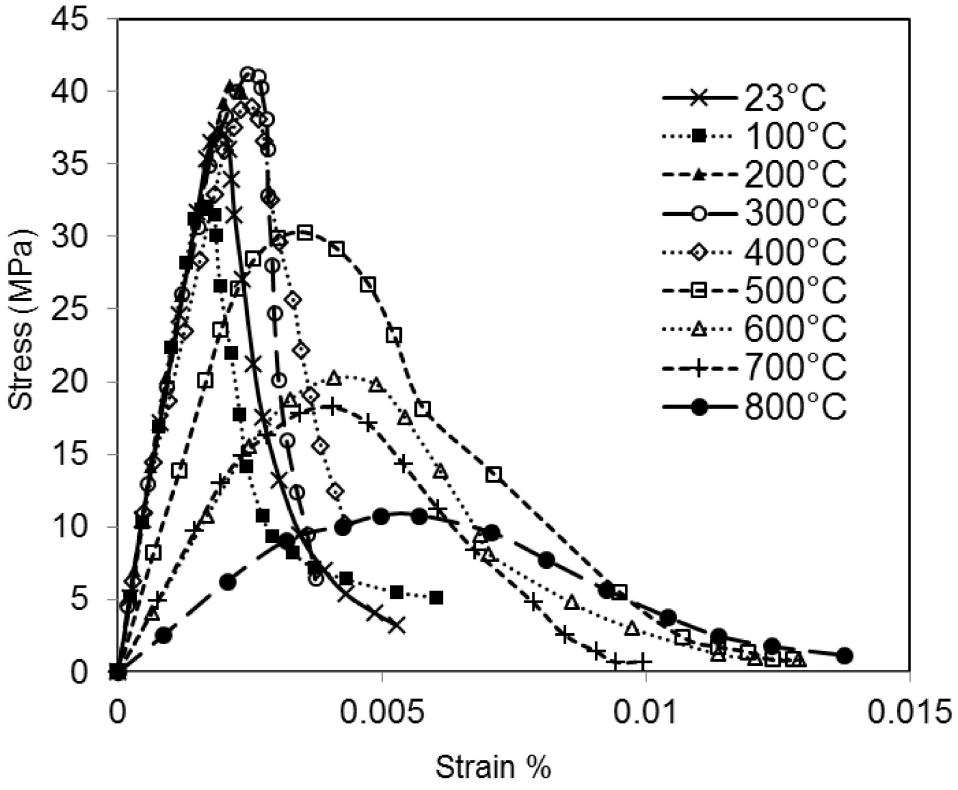
- At microscopic scale: changes in cement paste and in aggregates; thermal incompatibility between the two.
- At structural scale: influence of temperature level, heating rate, applied loading, moisture level.



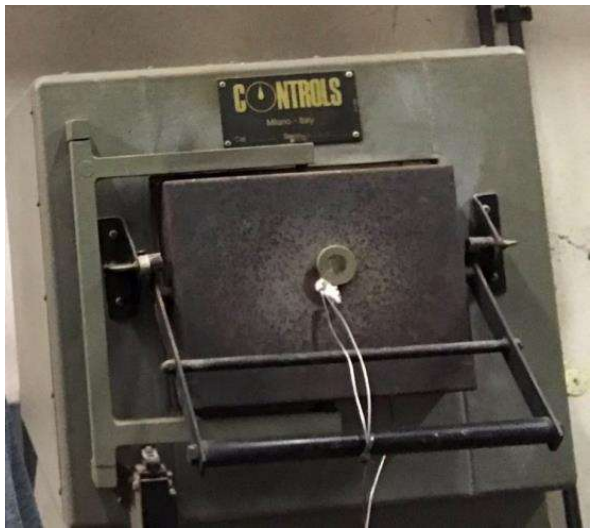

Adapted from Khoury (2000)

# Effects of fire on concrete structures – Material behavior

- Behavior of concrete in compression at elevated temperature
  - Strength decreases and ductility increases
  - Nonlinear

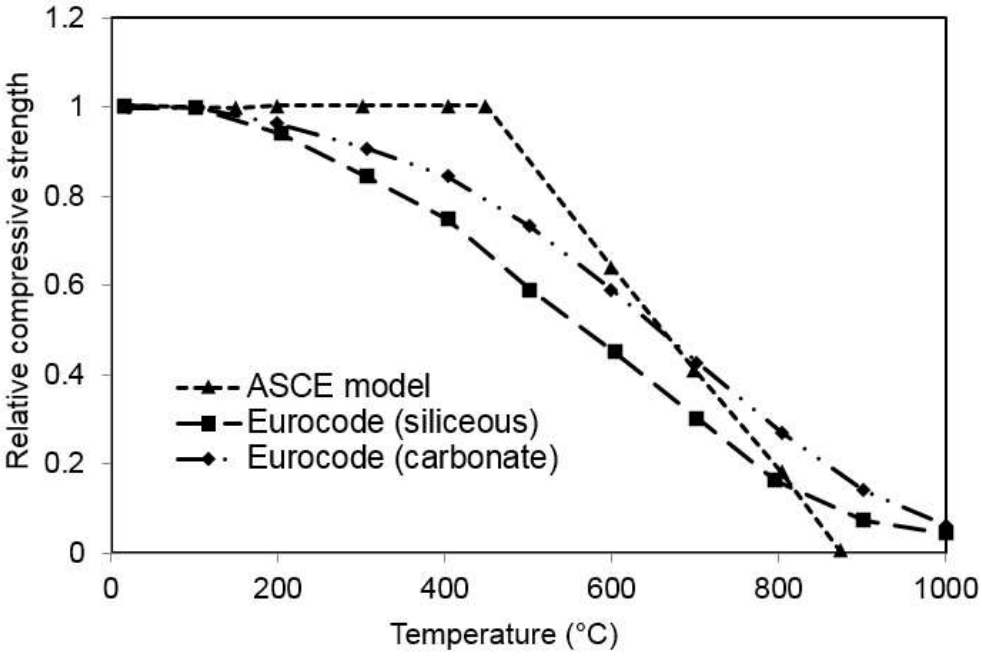


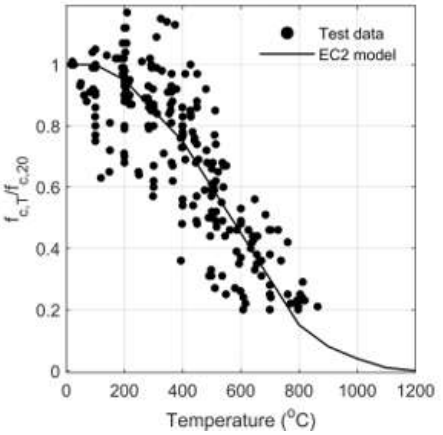

Stress-strain response (compression) of normal strength concrete at elevated temperatures



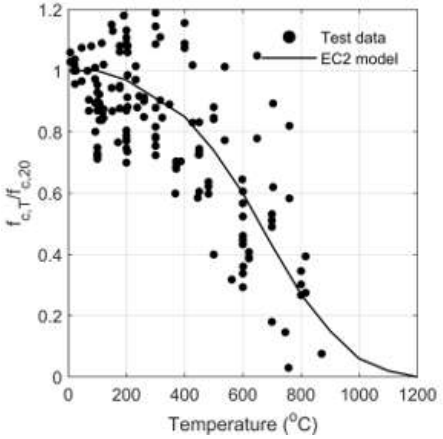
# Effects of fire on concrete structures – Material behavior

- Reduction of compressive strength with temperature
  - Strength reduced to ≈50% at 600°C
  - Depends on aggregates (siliceous < calcareous)
  - Retention factors $\left({}^{f_{c,T}}/_{f_{c,20°C}}\right)$ given in codes
  - Variability (differences in test protocol, concrete mixes, etc.)




Siliceous concrete
(silica, granite, sandstone)




Calcareous/carbonate concrete
(limestone, dolomite)