Numerical investigation of fire and post-fire performance of CFT columns in an open car park fire

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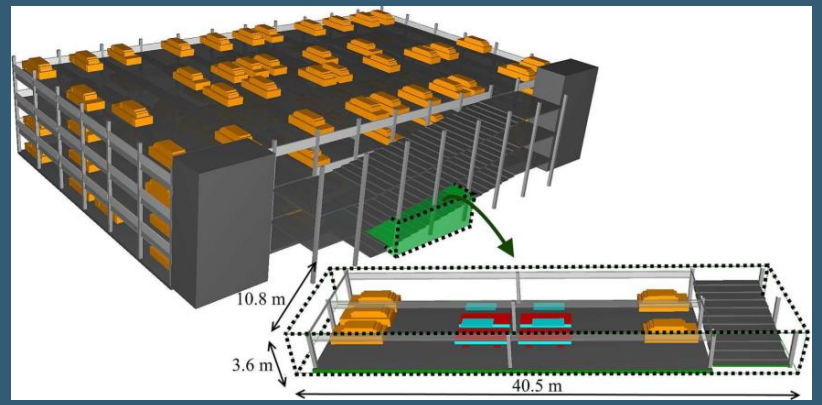
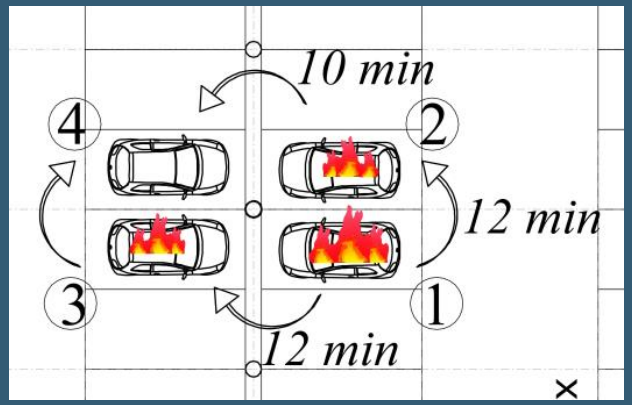
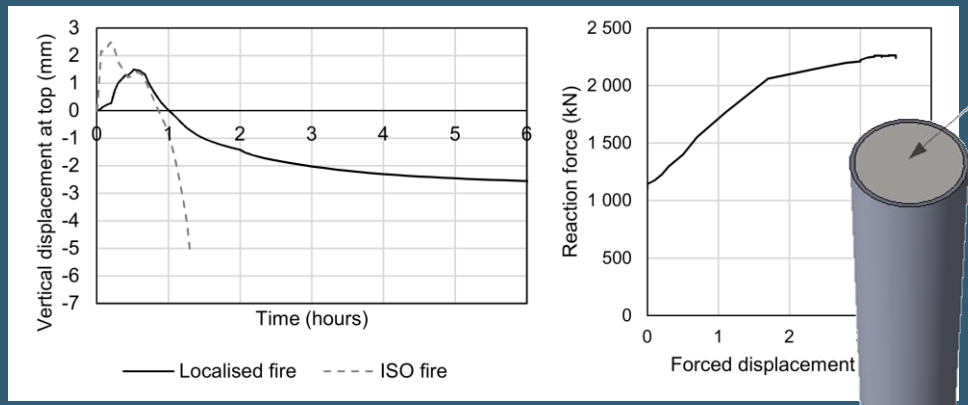
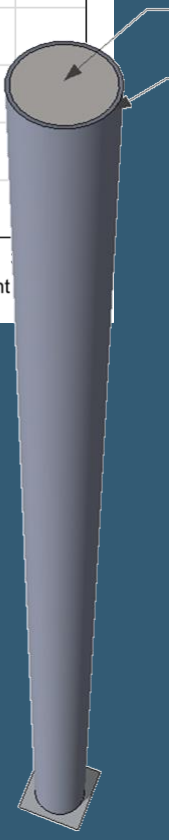
Agenda







Geometry & Load → Fire Scenario → Structural response after fire



Replicability

dataverse.harvard.edu/dataverse/CFT_szymkuc

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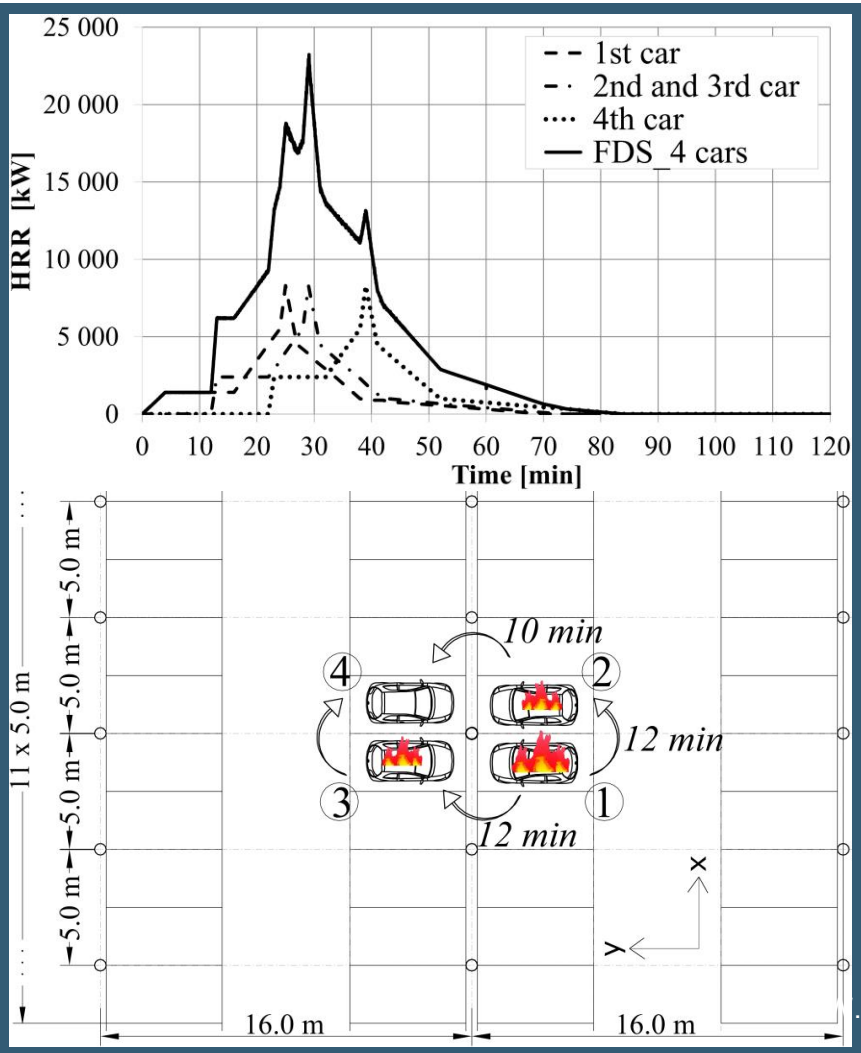
Including:
- presentation
- Abaqus input files
- scripts to handle data

PUBLIC DOMAIN

Car park fire



Four-storey 32 x 55 m car park

16.0 m x 5.0 m	parking module
2.5 m x 5.0 m	parking spot
3.0 m	storey height

Typical scenario for columns:

t = 0 min	1st car ignites
t = 12 min	2nd and 3rd car ignites
t = 22 min	4th car ignites

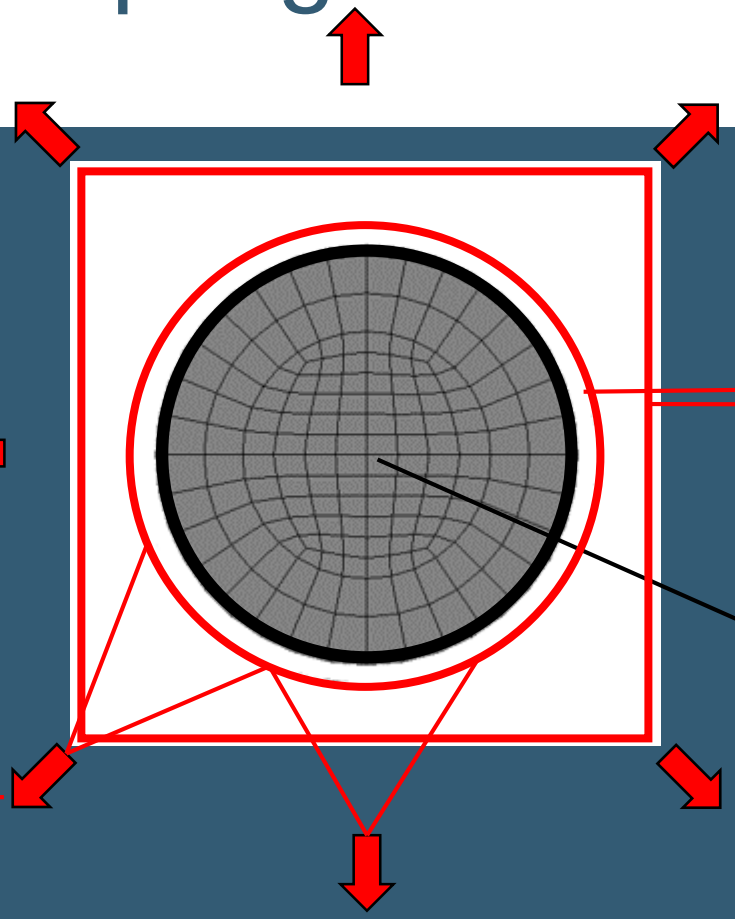
HRR: Schleich et al. (1999)

Car park fire

- A single car is implemented as a cuboid platform with a burning top surface, burning tires and a roof.
- Simple pyrolysis model is used by specifying the HRRPUA. Most of the heat release rate is prescribed to the top of the cuboid platform
- The influence of external weather conditions is not considered
- FDS 6.6.0

CFD-FEM coupling

1. BNDF approach
2. AST GAS approach



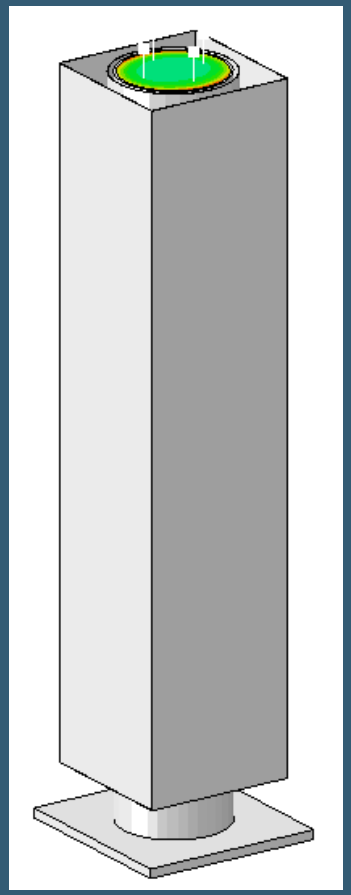
Dummy square AST surfaces: used with data from BNDF files (in Abaqus and sometimes FDS)

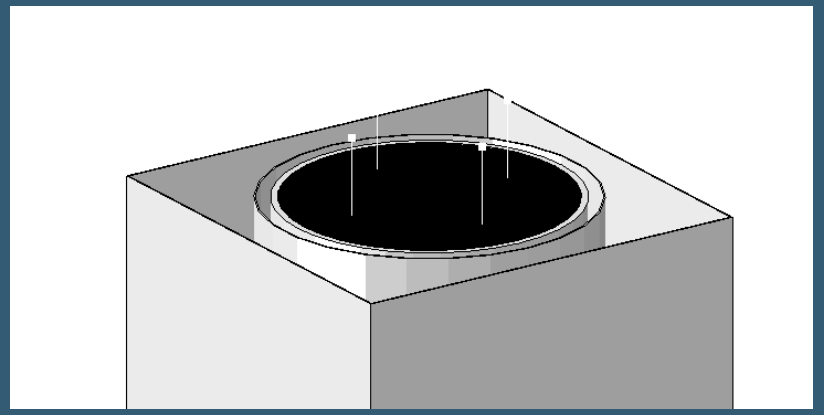
AST GAS devices facing 0 and 315° (only in FDS)

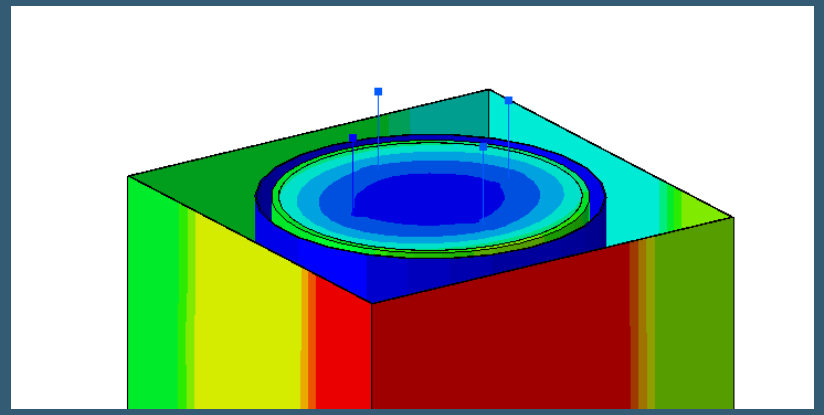
concrete-filled steel tube (Abaqus only)

$$\dot{q}_{tot} = \varepsilon\sigma\left(T_{AST}^4 - T_{CFT,surface}^4\right) + h_c\left(T_{AST} - T_{CFT,surface}\right)$$

CFD-FEM coupling







BNDF approach:

BNDF output is requested:

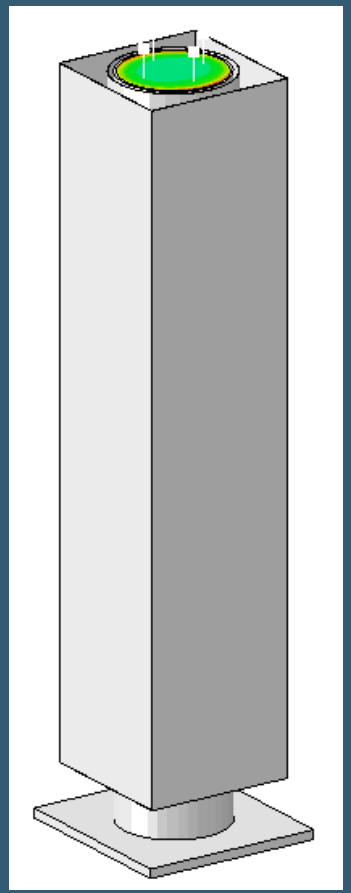
&BNDF QUANTITY='ADIABATIC SURFACE TEMPERATURE' /

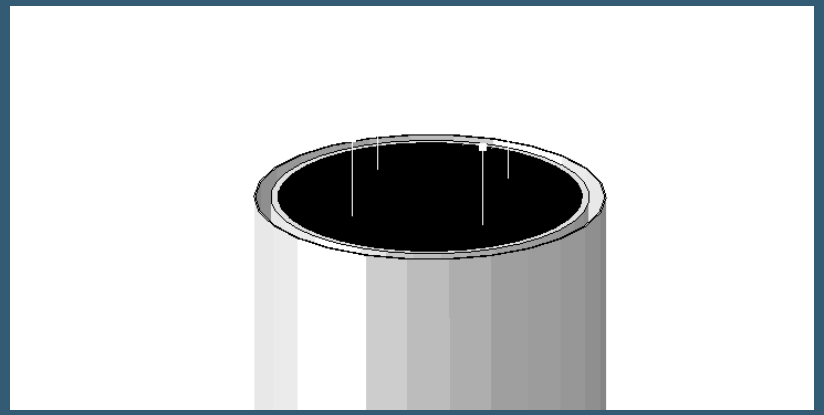
BNDF temperatures prescribed to "dummy" surface (square)

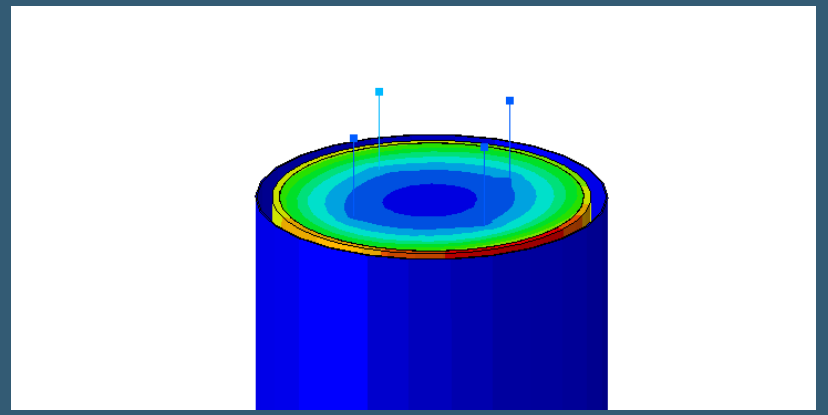
Heat transfer between two bodies and in solid (CFT) is calculated in Abaqus

Every node of "dummy" surface has a history of AST defined.

CFD-FEM coupling







AST GAS approach:

DEVC output is requested (8 on each height):

&DEVC ID = XXX', QUANTITY='ADIABATIC SURFACE TEMPERATURE GAS'…

DEVC temperatures prescribed to "dummy" surface (circular)

Heat transfer between two bodies and in solid (CFT) is calculated in Abaqus

Every node of "dummy" surface has a history of AST defined.

Part II:
Materials: during and after heating

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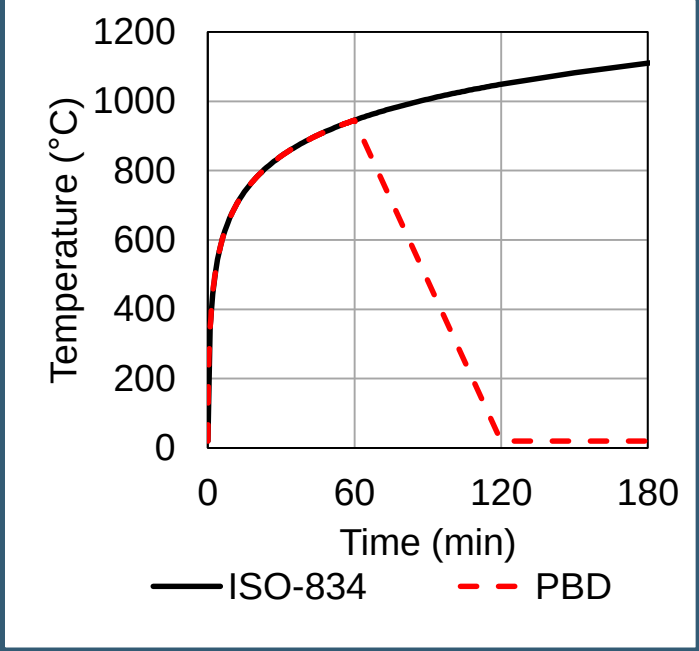
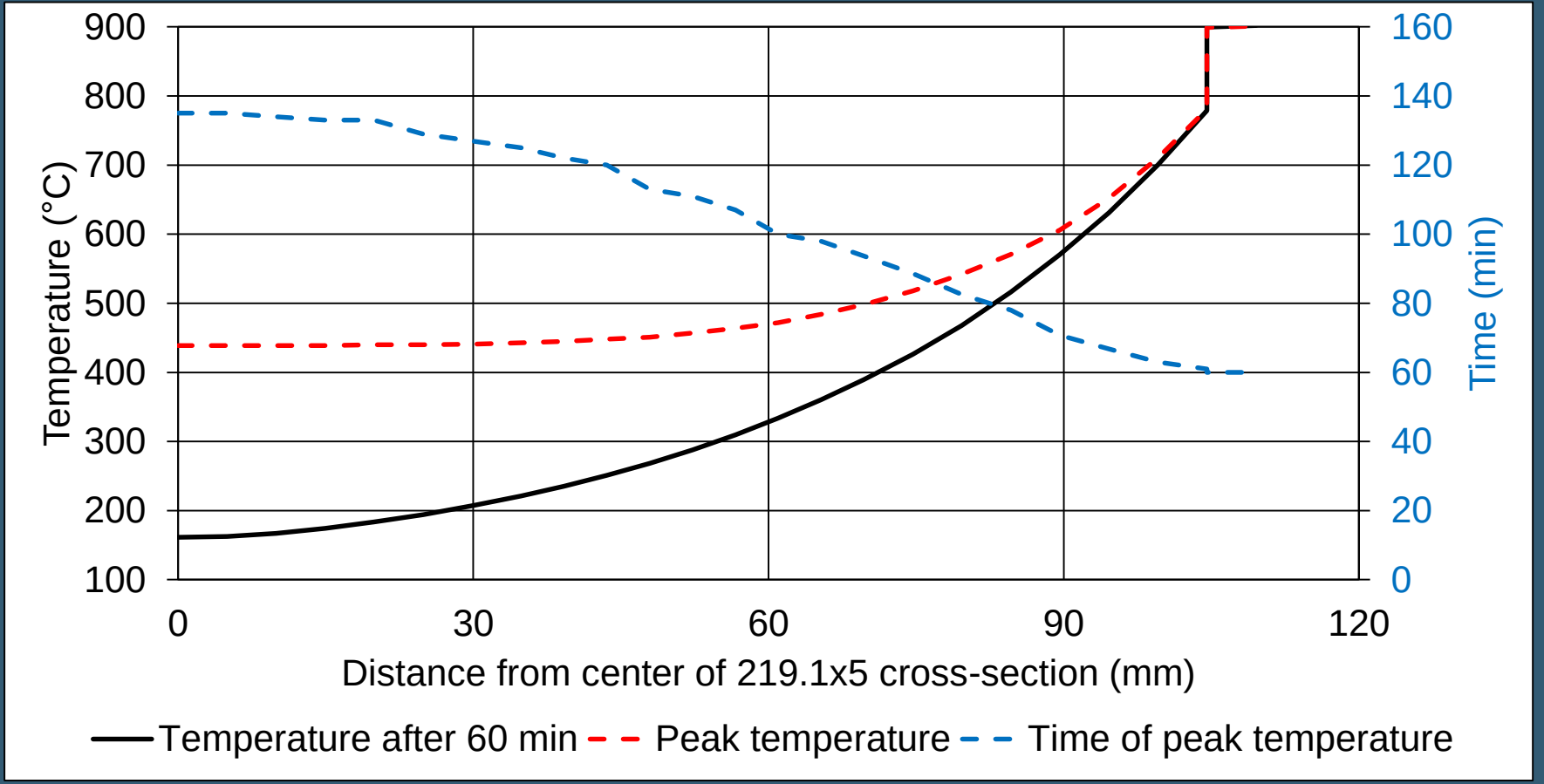
- During fire exposure:
  - Eurocode properties during heating
- During and after cooling:
  - Steel: fully reversible ($\theta_{steel,max}$ = 400°C)
  - Concrete:
    - thermal & strength properties: non-reversible
    - thermal expansion: reversible
  - Non-reversible properties with USDFLD and UVARM

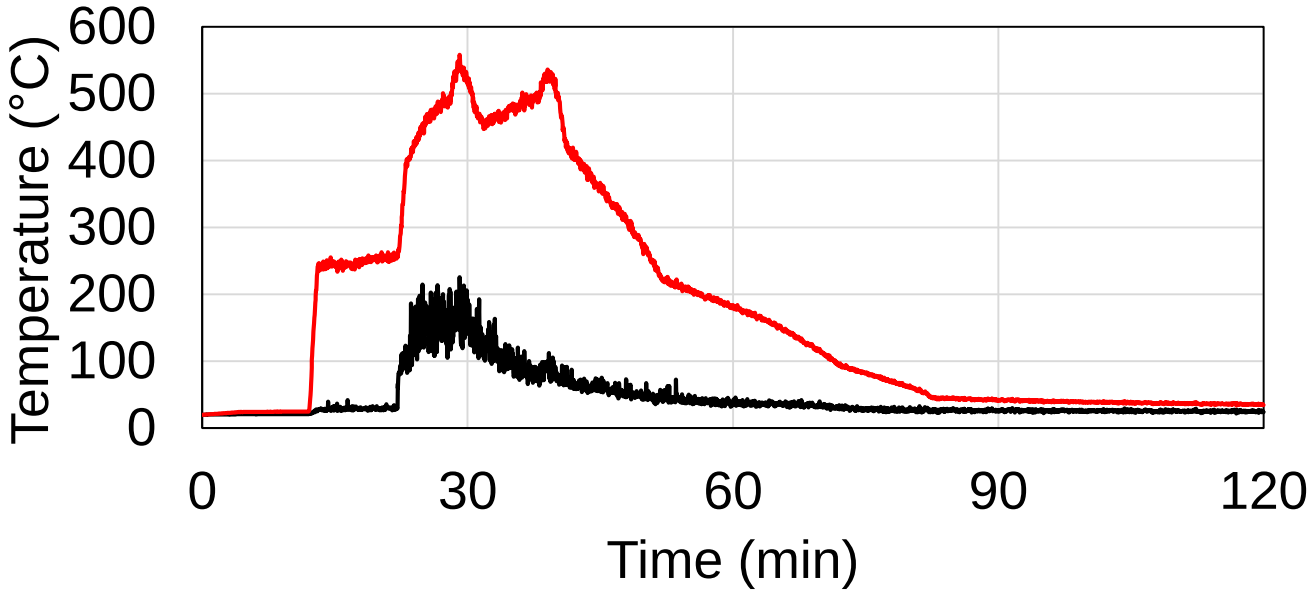
Temperatures during cooling





Part III:
Column: Thermal and Structural response

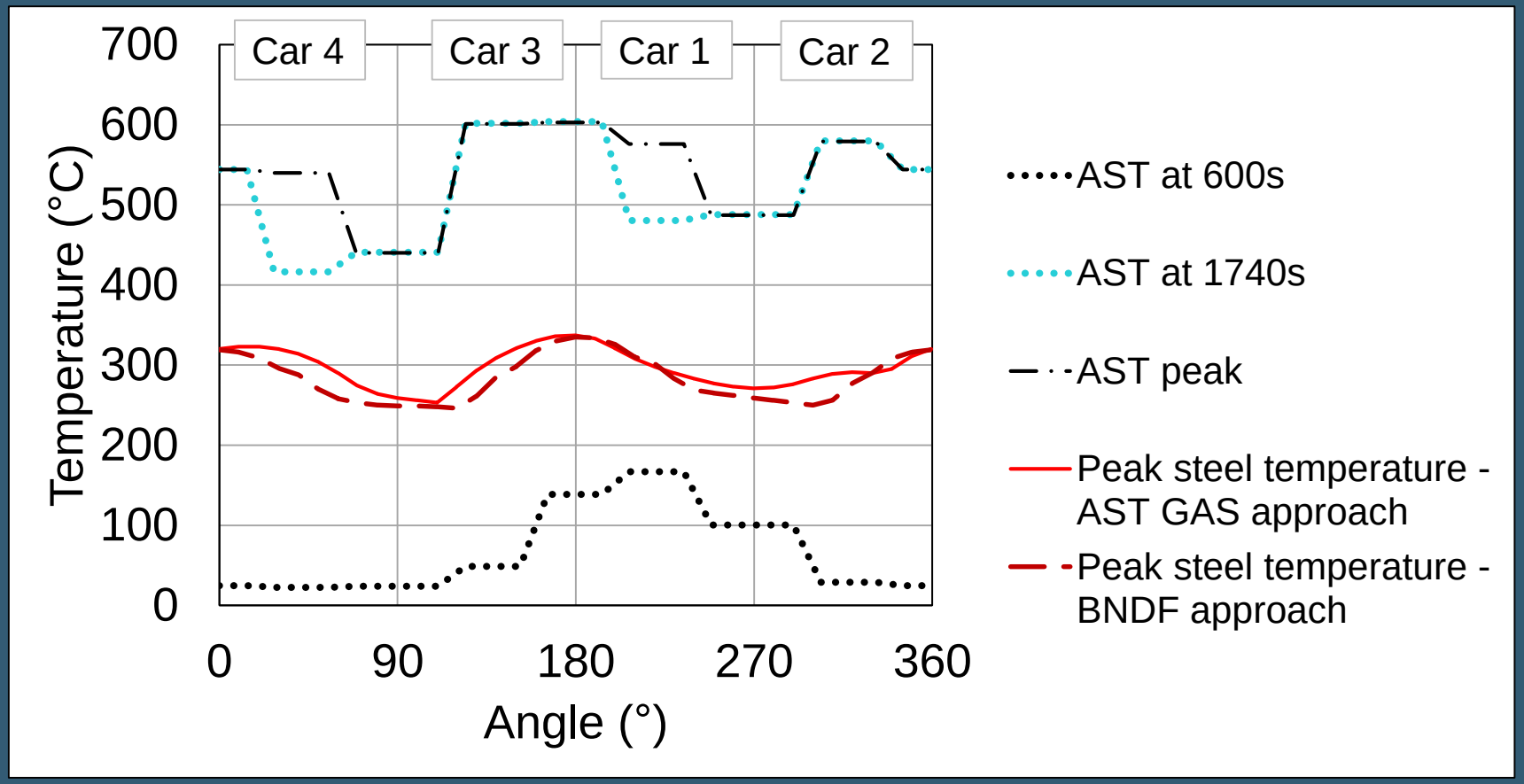
AST vs. gas temperature



AST and gas temperature close to the column surface at height z≈1.2

Highest temperatures at this point:
- gas temperature: 226°C
- AST: 558°C

Temperatures along circumference



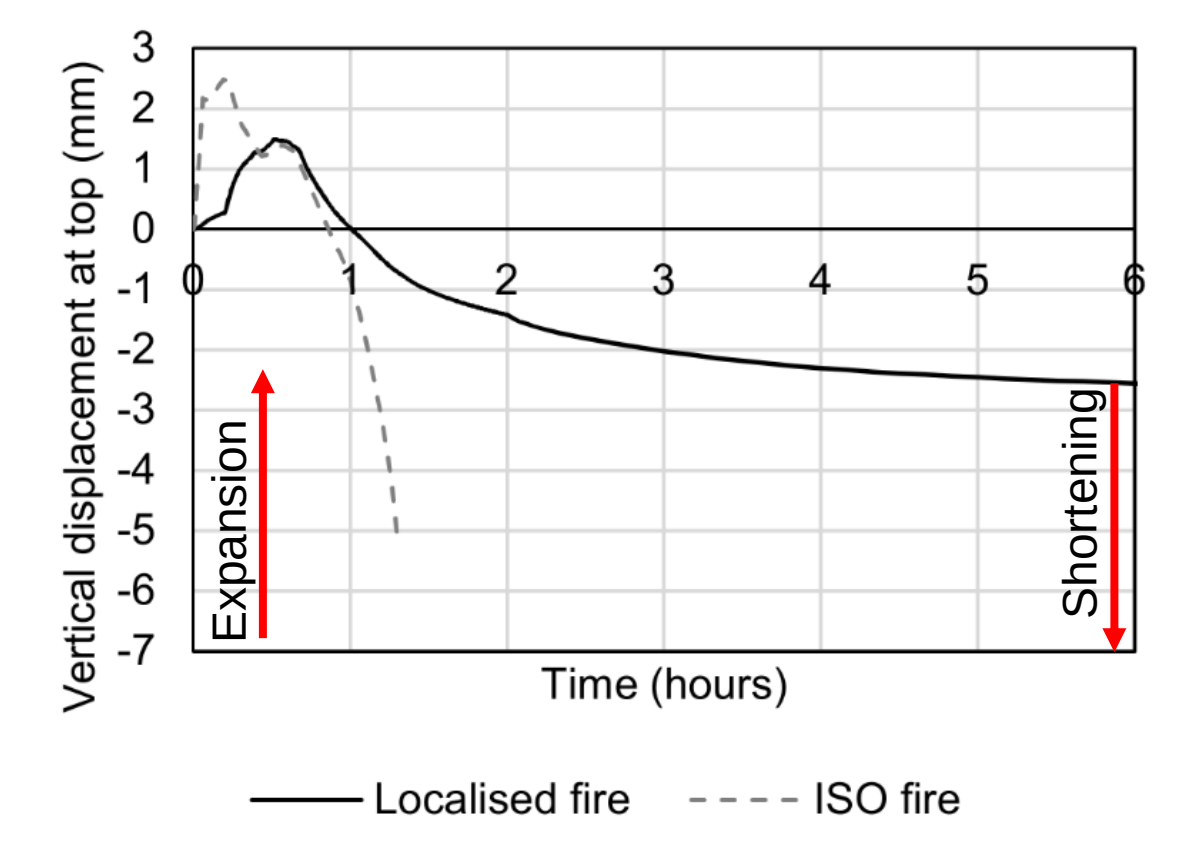
600 s:
only car 1 is in fire

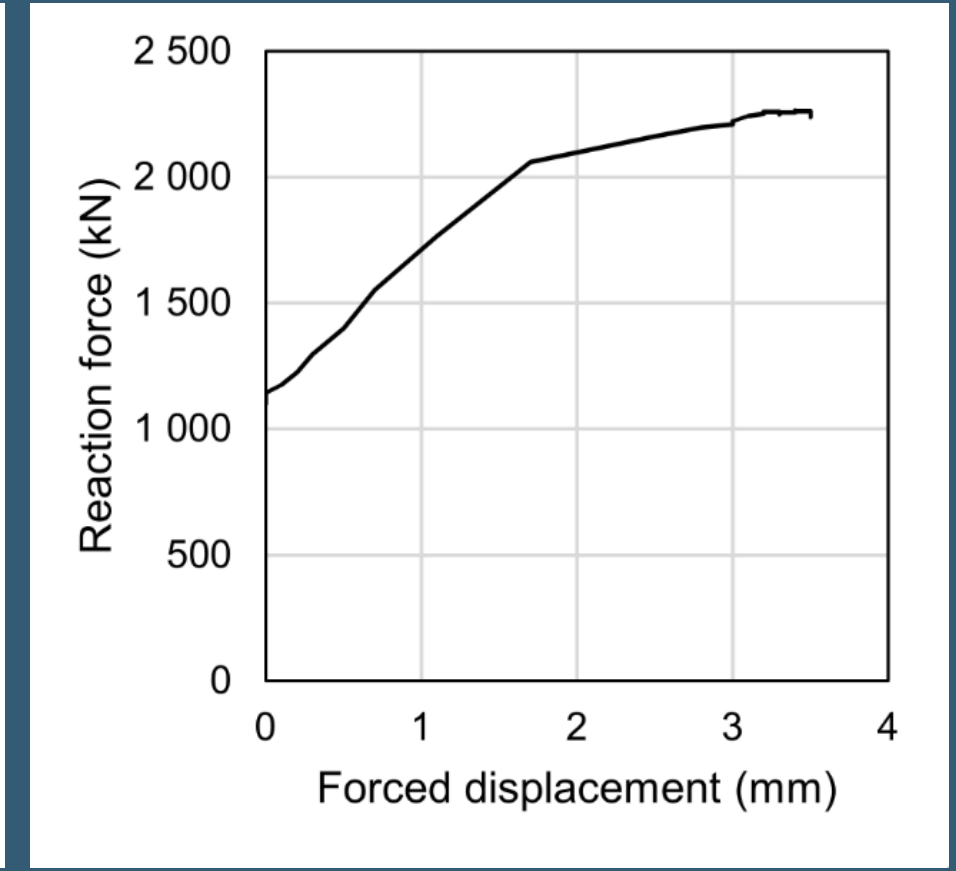
1740 s:
all cars are burning,
peak of HRR

Difference between AST GAS and BNDF approach are negligible

Temperatures at z=1.6 m

Mechanical response





Conclusions

- Coupling between CFD and FEM is presented to provide temperature data around column during both heating and cooling stage
- Abaqus is used to calculate:
  - temperatures inside the column,
  - performance of column during the ISO and localised fire

  Taking into account non-reversible material properties of concrete
- Although the recorded temperatures are rather low, it is shown that general framework for performance-based approach is established

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