AESG

www.aesg-me.com

AESG

Computational Fluid Dynamics (CFD) Simulation of Building Fires

UCLan Fire and Evacuation Modelling Seminar, 17 Nov 2021

EIC117, UCLan,Preston, PR1 7DR, UK

Introduction

Jianqiang Mai, Dr MEng BEng CEng MIFireE

Associate Director, AESG

Email: j.mai@aesg.com Mob 07449789665

AESG: 5 offices in UK, Middle East, and Singapore

>150 consultants

27 nationalities

Fire and Life Safety, Façade, Sustainability, Acoustics, Environmental, Building Physics

Presentation plan

- Building fires and benefits of doing CFD
- Residential corridor and stair smoke control
- Atrium smoke control system
- Atrium temperature control system
- Warehouse smoke control and extended travel distance
- Car park and basement smoke clearance
- Thermal radiation and external fire spread
- Sprinkler and smoke detection simulation
- Micro-climate simulation

Building fires

- Grenfell Tower fire: a turning point for fire safety industry
- Fire cannot be avoided in civil buildings
- Fire risk cannot be reduced to 0
- Mitigate fire risks
  - Fire containment
  - Fire suppression
  - Smoke control
  - Evacuation
- CFD can play a significant role in fire safety
  - Today’s focus is from design perspective

CFD

- CFD = Computational Fluid Dynamics
- CFD can provide dynamic fluid flow fields, heat transfer, chemical reaction, and mass transfer
- Today’s focus is industry applications, not theory
- CFD software
  - FDS
  - Ansys Fluent
  - Ansys CFX
  - Others

Benefits of CFD in fire and life safety in building design

- Make some complex system design possible without experimental study
- Size the required extraction flow rate of fans
- Cost effective solutions (non-fire rated glazing, fewer smoke reservoirs, less smoke vents)
- More accurate separation distance calculations
- More accurate calculation of sprinkler activation time, smoke detection time, air velocity, temperatures, pressures, and etc.
- Justify extended travel distances/reduced escape width

Residential corridor and stair smoke control

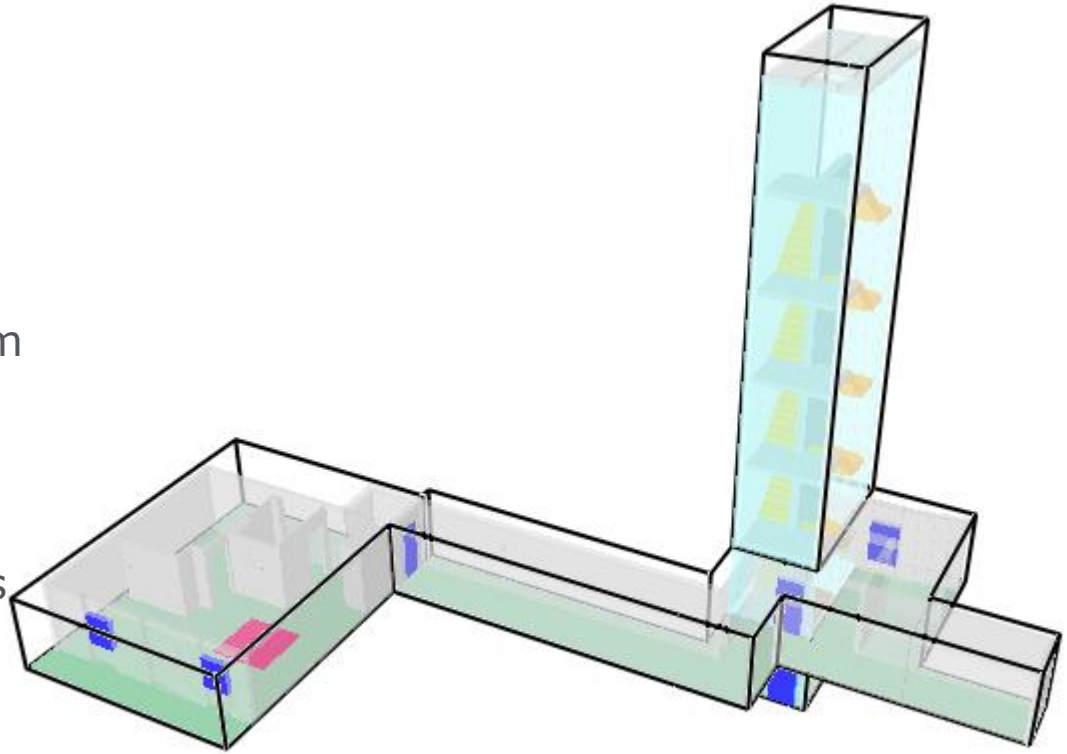
- Protect escape stair
- Protect residential corridors
- Clear smoke from corridor
- Difference between small buildings and large buildings
- System types
  - Natural smoke extraction system
  - Mechanical smoke extraction system
  - Pressurization system (not in today’s presentation)

Residential corridor and stair smoke control

- System components of natural smoke extraction system
  - AOVs to corridors
  - AOVs to stair
  - Door closers
  - Smoke detection systems
  - AOV control and operation systems
  - Fire doors
  - Corridor and stair enclosures
- Design considerations
  - One flat on fire
  - Medium fire growth rate fire
  - Travel distance/exposure time

Residential corridor and stair smoke control

- CFD example of natural smoke extraction system
  - Typically for buildings less in 30m in height
- What are important
  - Geometry
  - Boundary conditions
  - Vents
  - Design fire

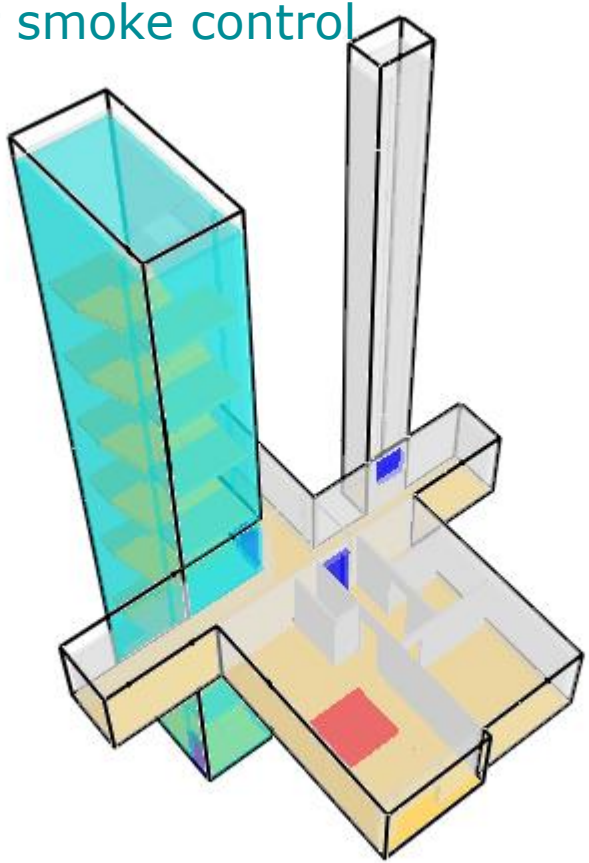


Residential corridor and stair smoke control

- System components of mechanical smoke extraction system
  - Extraction fans and smoke shafts to corridors
  - AOVs to stair
  - Door closers
  - Smoke detection systems
  - AOV control and operation systems
  - Fire doors
  - Corridor and stair enclosures
- Design considerations
  - One flat on fire
  - Medium fire growth rate fire
  - Door open forces
  - Time to tenability recover/smoke clearance time

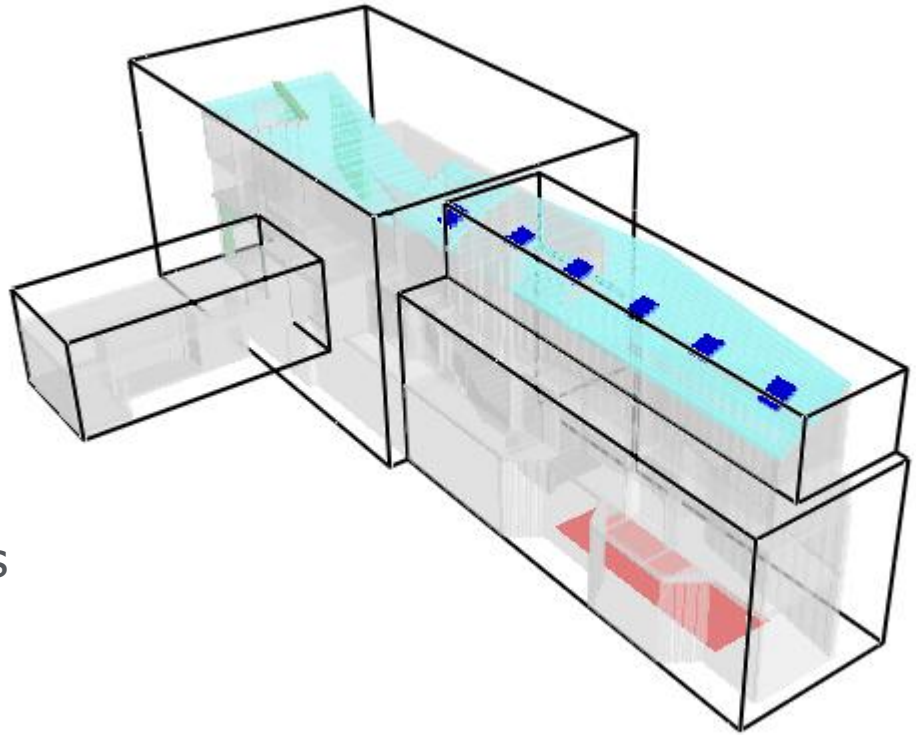
Residential corridor and stair smoke control

- CFD example of mechanical smoke extraction system
  - Geometry
  - Boundary conditions
  - Design fire
  - Ext. flow rate?
  - Pressure (door open force)
  - Travel distances and tenable conditions



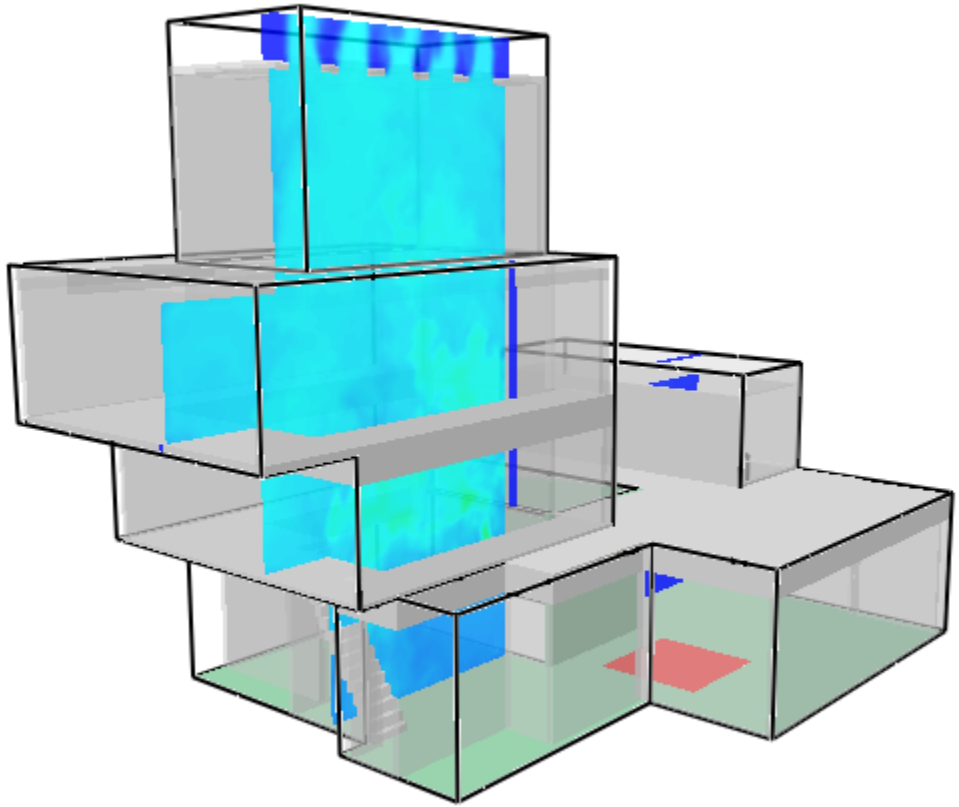
Atrium smoke control system

- Atrium smoke control system – tenability
- Atrium with open balcony escape routes
- Typically used for buildings adopt simultaneous evacuation
- Difficult for FF phase of residential buildings



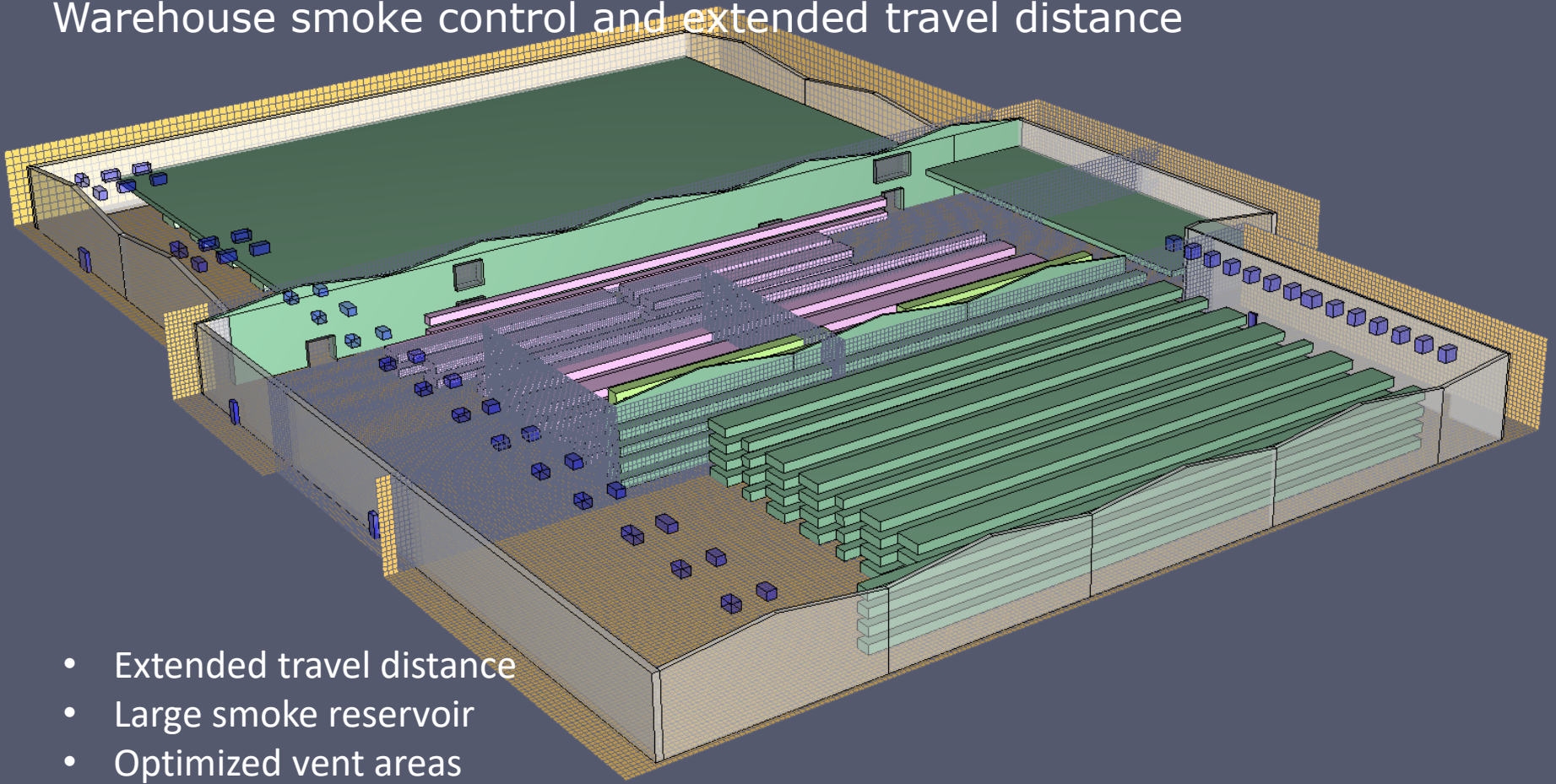
Atrium smoke control system

- Temperature control system
- Used to justify the fire rating of the atrium façade
- Smoke retardant construction instead of fire rated
- D30, D60, D90, D120, DA



Time: 468.0

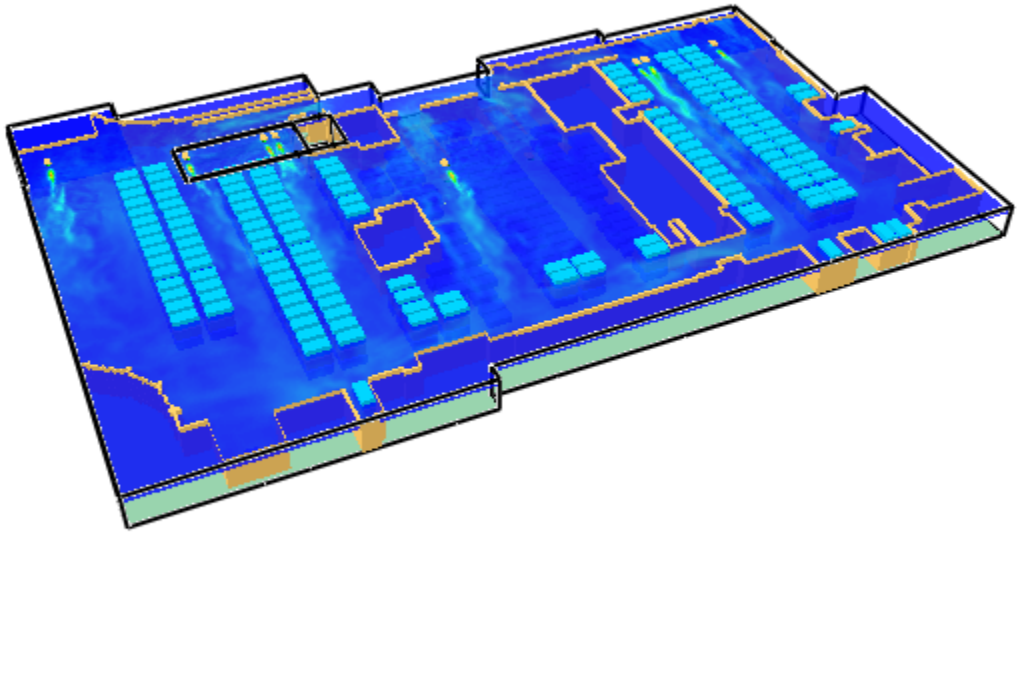
Warehouse smoke control and extended travel distance



- Extended travel distance
- Large smoke reservoir
- Optimized vent areas

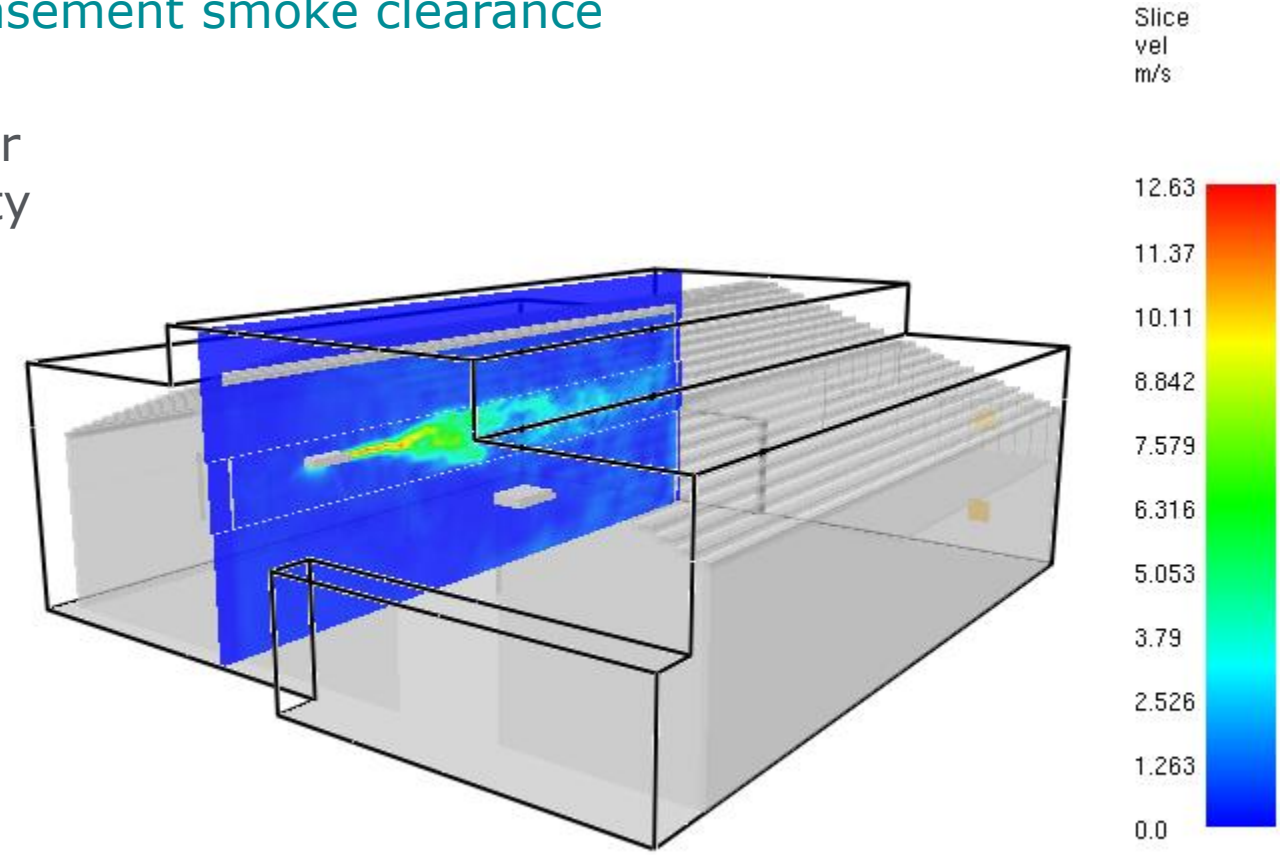
Car park and basement smoke clearance

- CFD example of car park smoke clearance system
  - Jet fans
  - Air changes
  - Stagnant areas



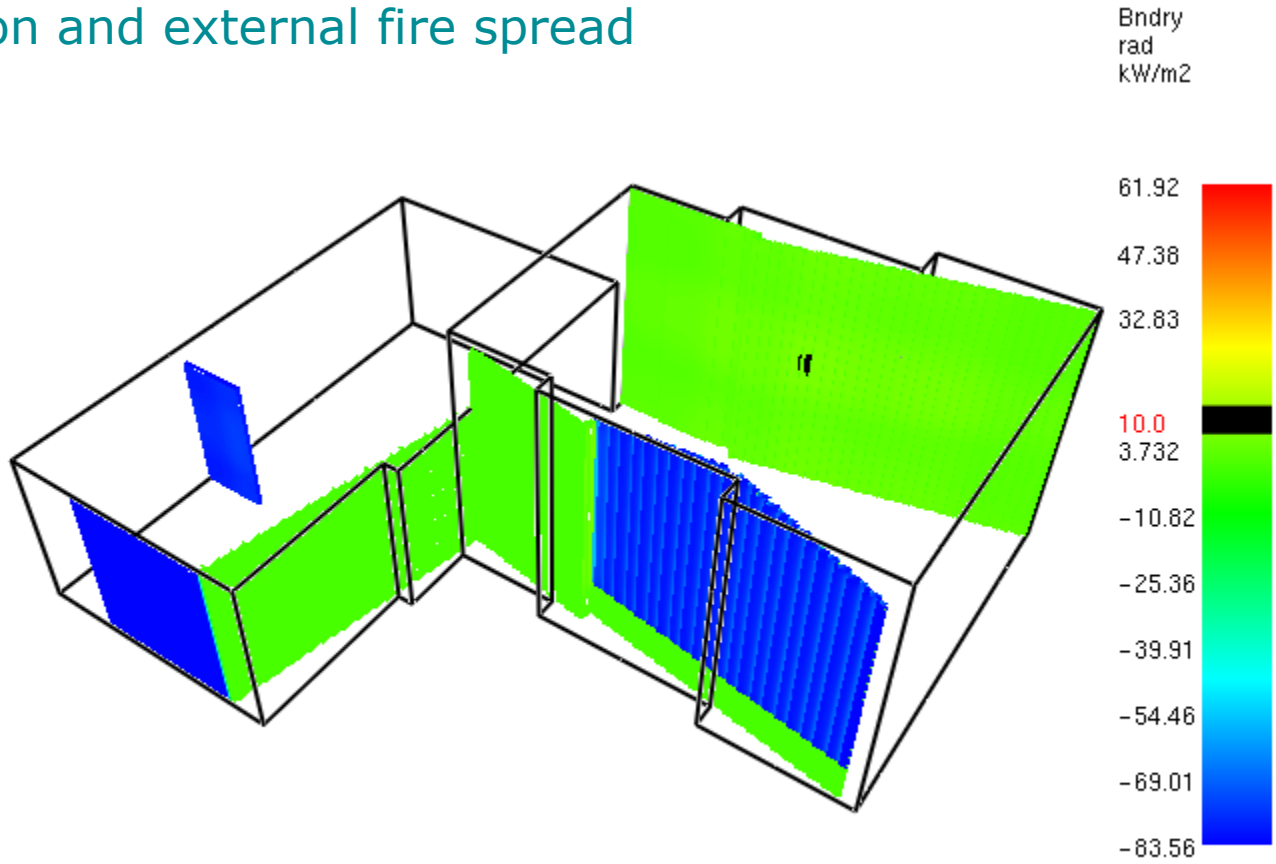
Car park and basement smoke clearance

- CFD example of car park-jet fan velocity field



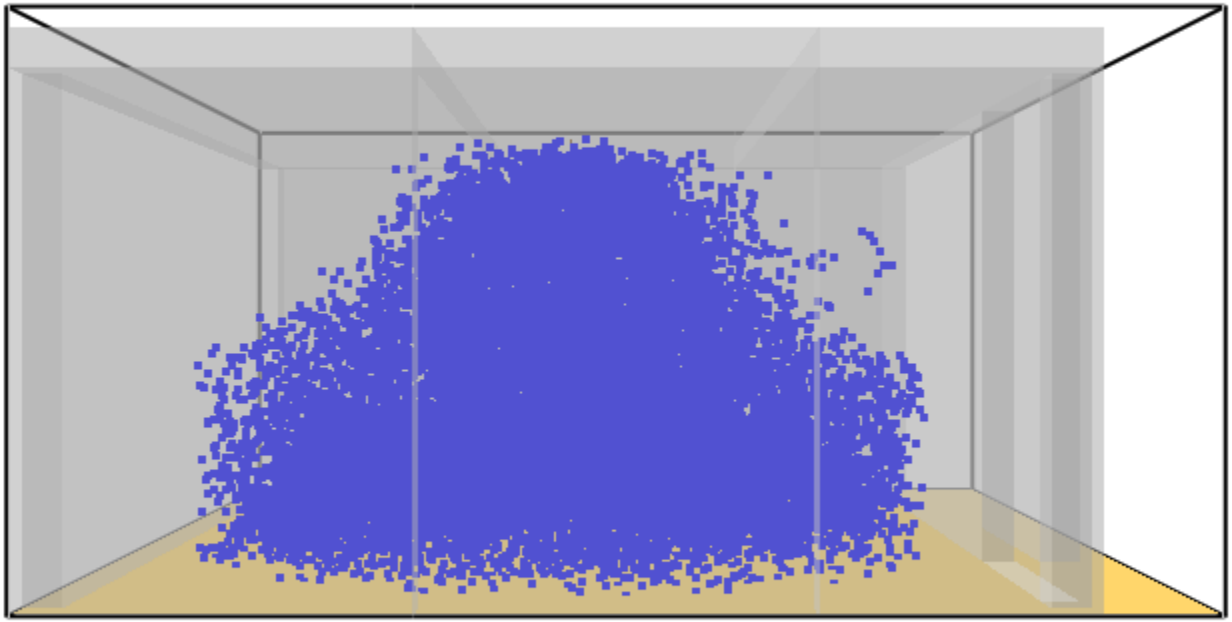
Thermal radiation and external fire spread

- CFD example of thermal radiation simulation
  - Simple boundaries BR 187
  - Complex boundaries CFD
  - Can take into consideration of humidity



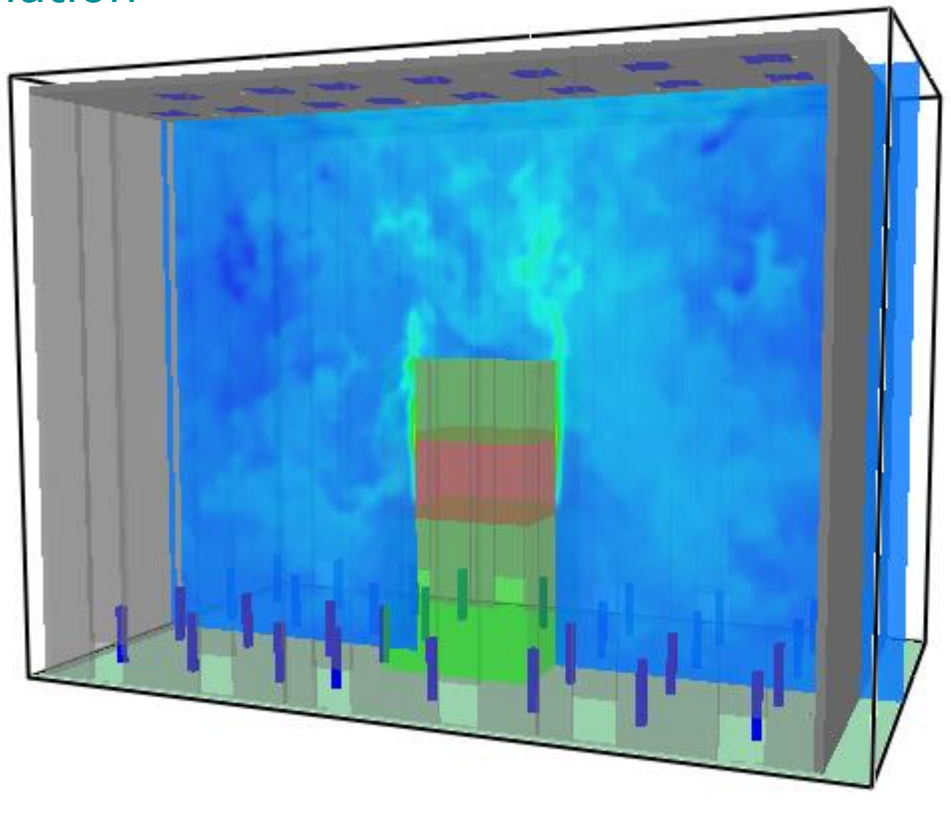
Sprinkler and smoke detection simulation

- CFD example of sprinkler activation
  - Sprinkler activation time
  - Water spray pattern
  - Coverage area



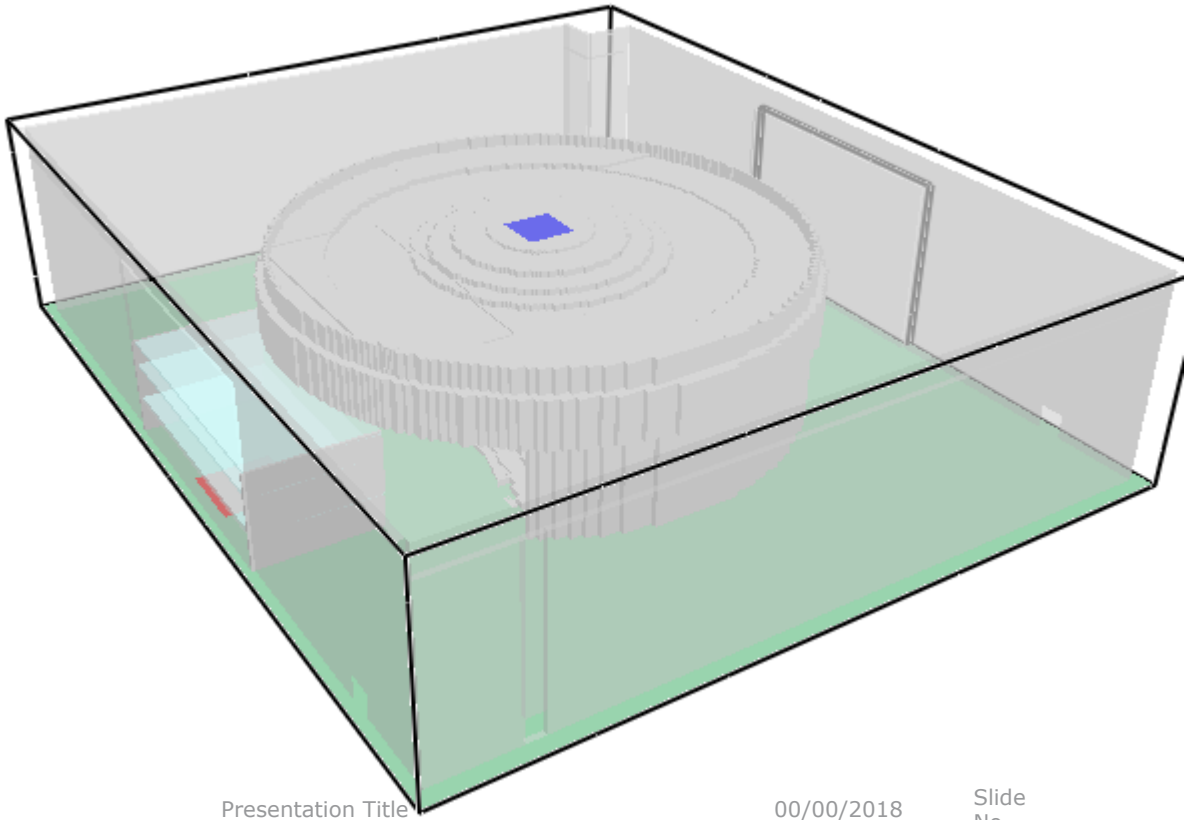
Micro-climate simulation

- CFD example of air conditioning systems
  - Blow cool air in
  - Extract warm air
  - Control temperature and humidity
  - Heat sources include heaters, human bodies, solar energy



Complex geometry – is it an issue?

- With the help of Pyrosim, complex geometry can be simulated reasonably good for most buildings by FDS
- Some complex geometries cannot be simulated reasonably good by FDS and should use other software
- Computer power limit



Physical thermal properties

- Density, specific heat, thermal conductivity, and thickness of walls/floors/ceilings
- Fire size, fire growth rate, soot/species yields, and chemical reaction
- Flame temperature
- Thermal radiation from flames
- Heat of combustion of fuel
- Heat production per kilogram of Oxygen (13.1MJ/kg)
- Humidity, ambient temperature, and ambient atmospheric pressure
- Multi-layer walls/ceilings/floors – U-value of building elements

Other properties

- Activation of fire protection facilities
- Timeline of events during simulation
- Door open/close – closing time, opening force
- Vents – open/close (automatic or manual), ramp up/down, area, installation height, installation direction
- Fan performance – activation, ramp up/down, fan curve
- Movement of fires (e.g. travelling fire)
- Tenability for escape
- Tenability for firefighting

QDR report and CFD model

- QDR = qualitative design review => CFD inputs
- Approval of QDR report by building control
- 3rd party review
- Fire service consultation
- Client's design aspiration
- CFD report
- ME design
- Management and maintenance of systems

AESG

Thank You

Questions?

www.aesg-me.com