Department of Civil and
Environmental Engineering

A preliminary study: The wind effect on the disproportionate collapse of an open-sided steel-concrete composite floor car park in travelling fires

Structure in Fire Forum

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10th April 2026

Introduction

Why “open” doesn't mean “safe”?

Extended fire spread

Luton Airport Car Park Fire - 10th October 2023

Structural failure

Introduction

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BSR Proposed Amendment *(HM Government): Open-sided car parks increased from REI 15 → REI 30 / REI 60.*

2026 consultation – proposed text

Consultation Ref ID 10.03

Table B2 Minimum periods of fire resistance

Purpose group of building	Minimum periods of fire resistance(1) (minutes) in a:						
	Basement storey* including floor over		Ground or upper storey				
	Depth (m) of the lowest basement		Height (m) of top floor above ground, in a building or separated part of a building				
	More than 10	Up to 10	Up to 5	Up to 11	Up to 18	Up to 30	More than 30
b. car park for light vehicles:							
i. open sided car park(7)	Not applicable	Not applicable	15 min†#	30 min†#(8)	60 min†#(8)	60 min†#(8)	60 min
ii. any other car park	90 min	60 min	30 min†	60 min	60 min	90 min	120 min‡

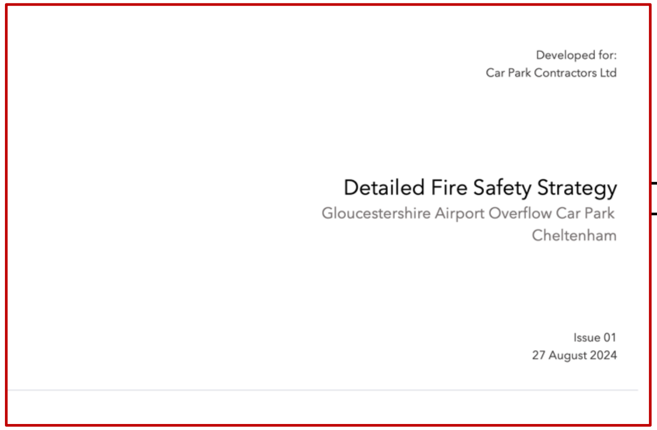
Large-scale fire incidents *in open-sided car parks in the UK from 2006 to 2023*

Incident	Location	Time	Building type	Sprinklered (Yes/No)	Fatalities/ major injuries	ehicle oss approx.)	Structural damage
Monica Wills House Car Park Fire	Bristol, UK	Dec. 2006	Reinforced concrete	Residential building (Yes) Car park (No)	1 fatality (smoke inhalation)	22	Severe structural damage with concrete spalling
Stansted Airport Car Park Fire	London, UK	Aug. 2010	open-air car park	NA	Not observed	24	Not applicable
Edinburgh Airport Car Park Fire	Edinburgh, UK	Apr. 2014	open-air car park	NA	Not observed	21	Not applicable
Kings Dock Car Park Fire	Liverpool, UK	Dec. 2017	Reinforced concrete	No	Not observed	150	Severe structural damage with concrete spalling
Luton Airport Car Park Fire	London, UK	Oct. 2023	Steel-composite	No	Not observed	450	Partial structural collapse
Silver Zone Car Park Fire	Bristol, UK	Dec. 2023	open-air car park	NA	Not observed	1	Not applicable

No life loss, delaying collapse at what cost?!

Background

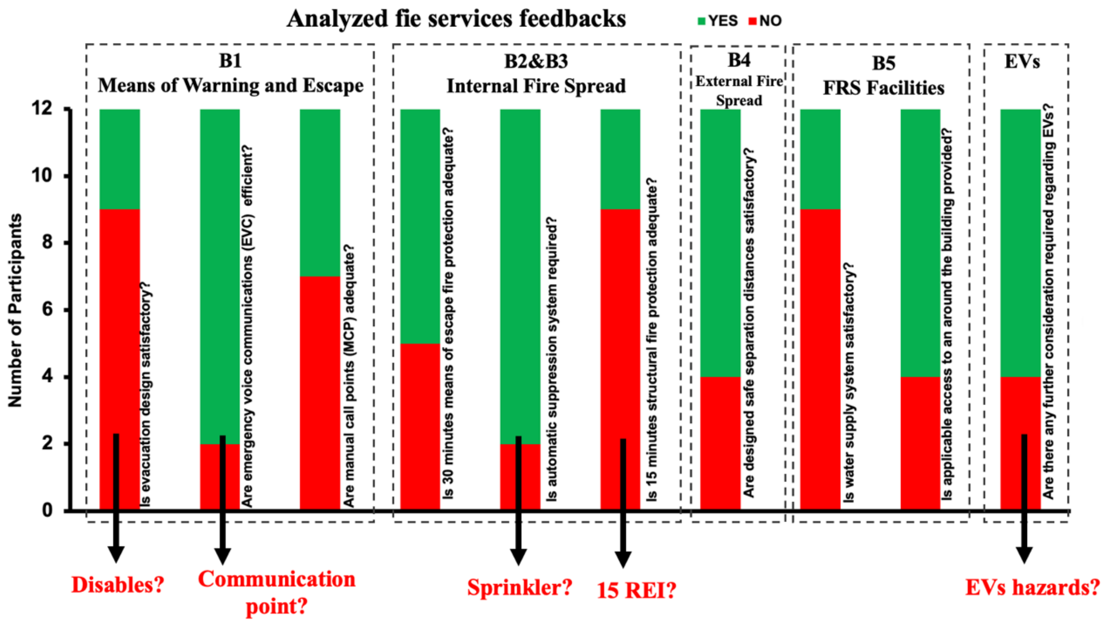
Previously presented:


Developed for:
Car Park Contractors Ltd

Detailed Fire Safety Strategy
Gloucestershire Airport Overflow Car Park
Cheltenham

Issue 01
27 August 2024

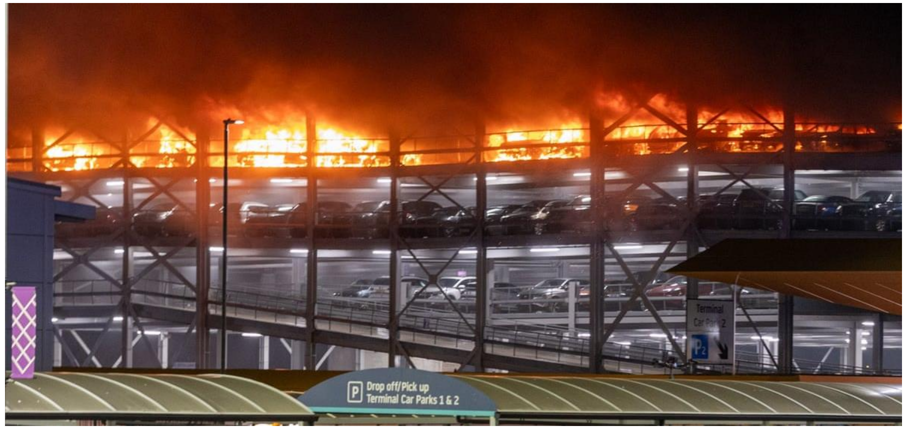
12 UK Fire Services feedback on the Fire strategy



What in the next step?

Is 15 REI adequate?

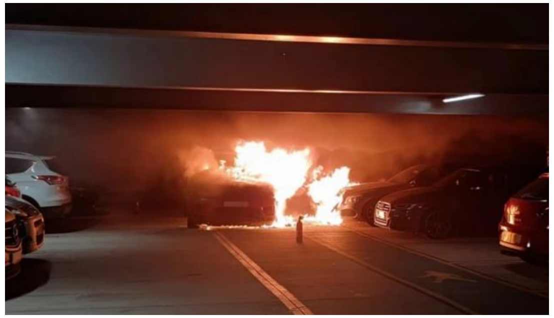
Case study: Luton Airport Car Park Fire - 10th October 2023

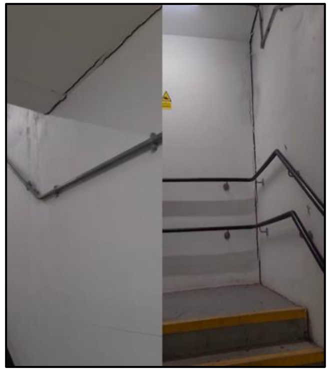


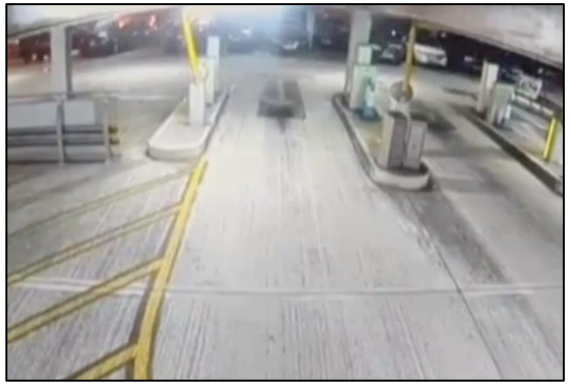
Fire dynamics in over ventilated large-compartment

Background

London 2023: Luton Airport Car Park Fire







- **20:47** First call to 999
- **20:55** First crew attendance
- **21:10** approx. 6 vehicles on fire
- **21:26** Crew Withdrawal
- **21:37** Nearly 80% of 3rd floor engaged
- **22:09** External fire fighting and keep fire limited to 3rd floor
- **23:02** Structural collapse of second floor into the first floor
- **00:00** Final partial collapse

Rapid vehicle-to-vehicle fire spread

From the Report:

At 21:10 hrs, the environment on the third floor was extremely hot intensified by an approximate **wind speed of 10 mph**, *contributing to the rapid fire spread and increase in temperature."*

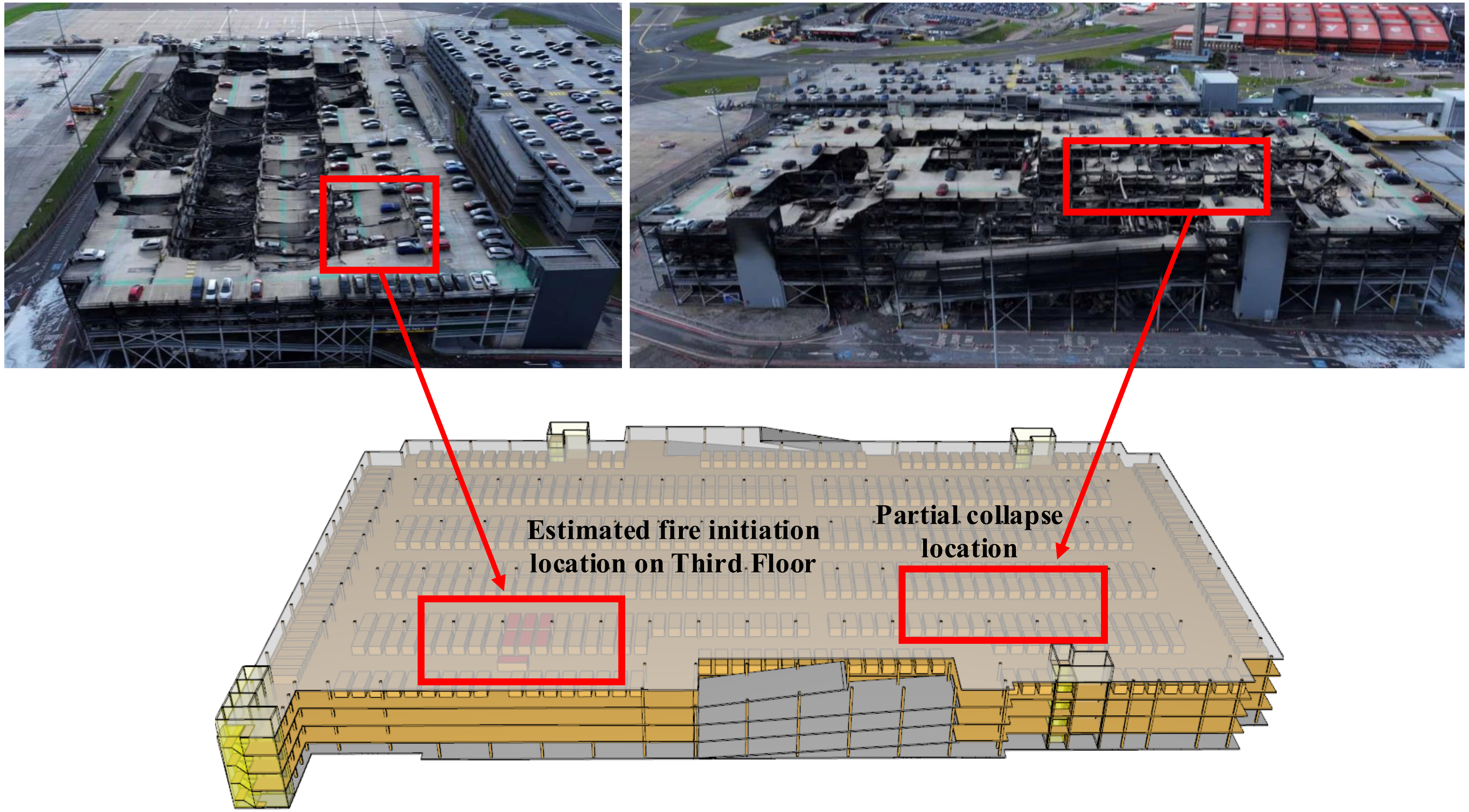
Bedfordshire Fire and Rescue Service, 'Significant incident report: London Luton Airport Terminal Car Park 2', Luton, Bedfordshire, Oct. 2023. Accessed: Apr. 04, 2026. [Online]. Available: https://www.bedsfire.gov.uk/wp-content/uploads/2024/01/Significant-Incident-Report-London-Luton-Airport-Terminal-Car-Park-2.pdf

FDS Model Development

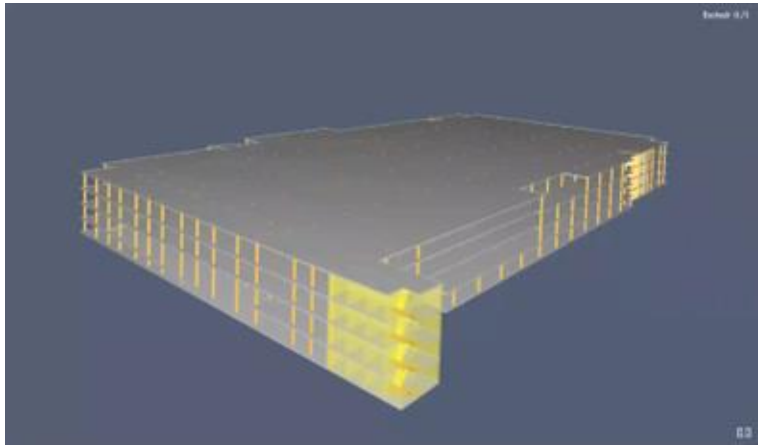
- ***Geometry***

A CFD model was developed in Fire Dynamics Simulator (FDS 6.10.1), with the geometry created in PyroSim. The model consists of a multi-mesh computational domain representing the car park structure and vehicle layout.

Incident vs. model configuration

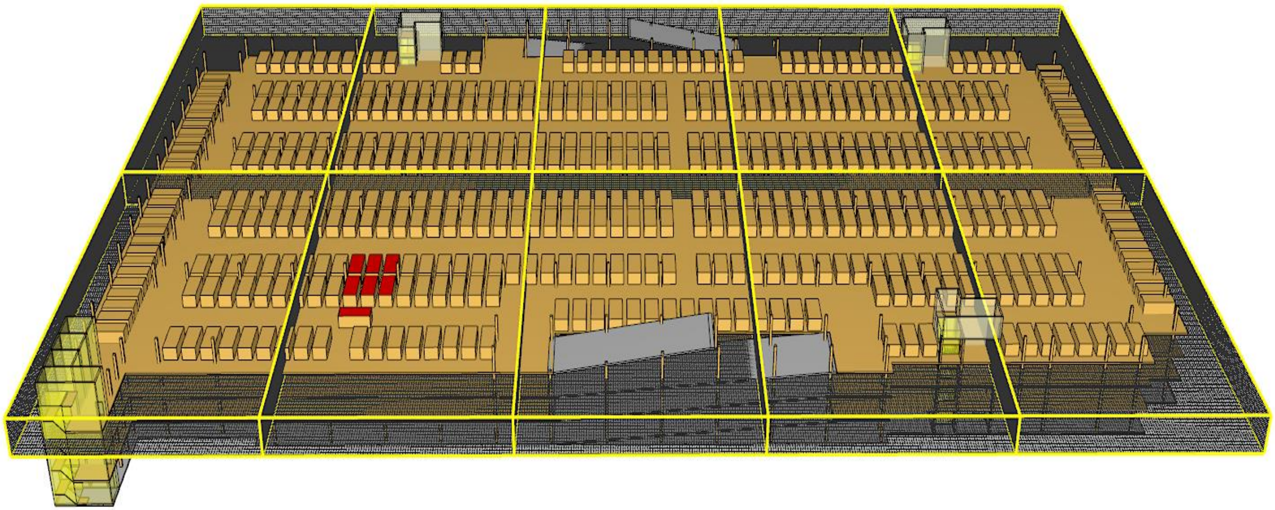


Pre-incident structural condition



FDS Model Development

- ***Mesh configuration***

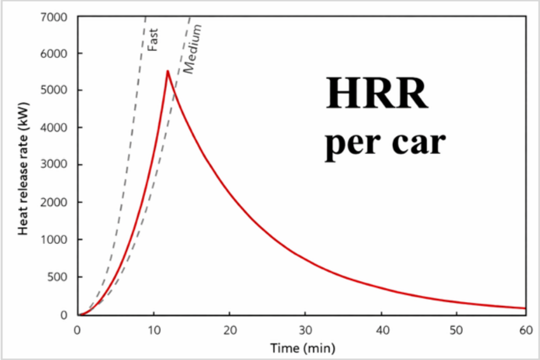


Baseline case, cell size: 0.30m × 0.30m × 0.30m
Refined case, cell size : 0.15m × 0.15m × 0.15m
Domain extent: Third floor to fourth floor
Parallelisation: 10 meshes partitions
Computing platform: Barkla2 HPC, University of Liverpool

- ***vehicle fire model***

Fire definition

1. Time-controlled burners
2. HRRPUA: 900 kW/m²
3. Fire area (per vehicle): 7.56 m² (1.8 × 4.2 m)
4. Growth rate: Medium (t^2 fire, 0.0163 kW/s²)

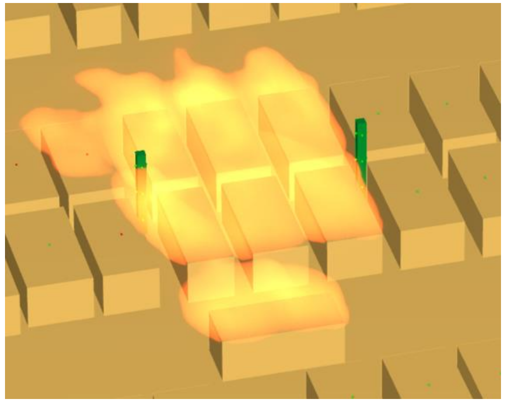


Other setup:

1. Simple pyrolysis
2. Soot yield: 0.1 kg/kg
3. CO yield: 0.1 kg/kg

- ***Fire spread***

1. Activation: Sequential ignition
2. Simultaneous ignition of first 7 vehicles

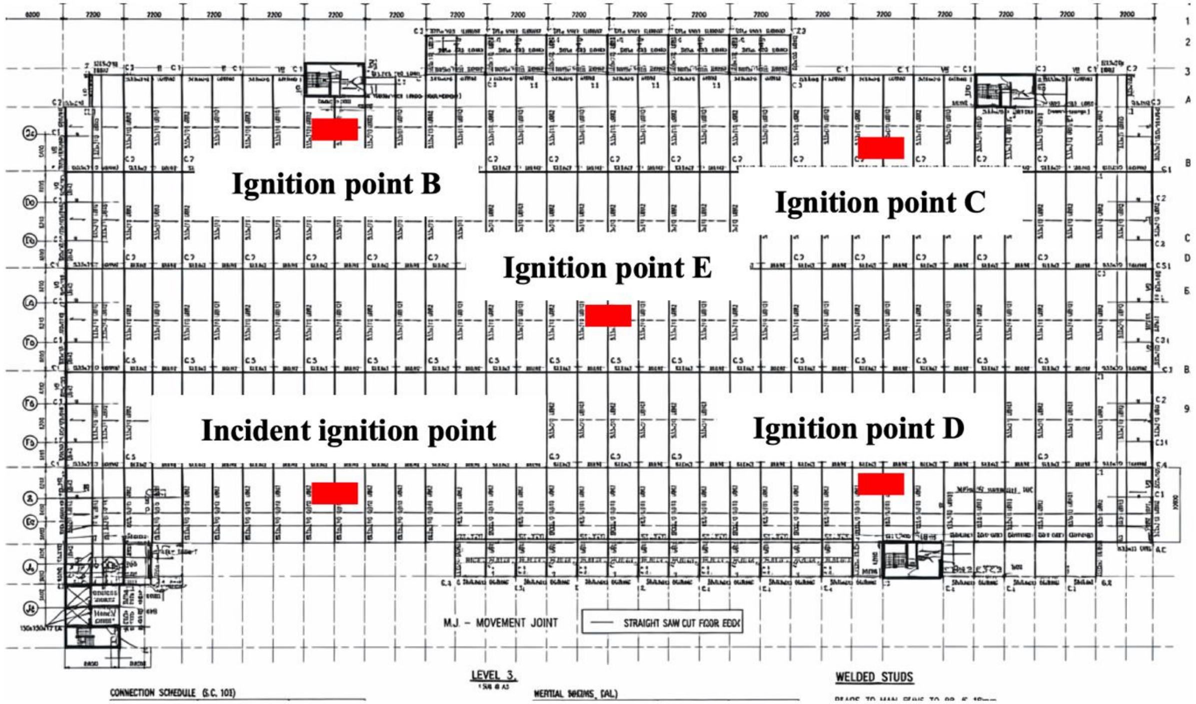


M. Z. Mohd Tohir and C. Martín-Gómez, 'Evaluating fire severity in electric vehicles and internal combustion engine vehicles: A statistical approach to heat release rates', Fire Technol, 2025, doi: 10.1007/s10694-025-01711-3.

FDS Model Development

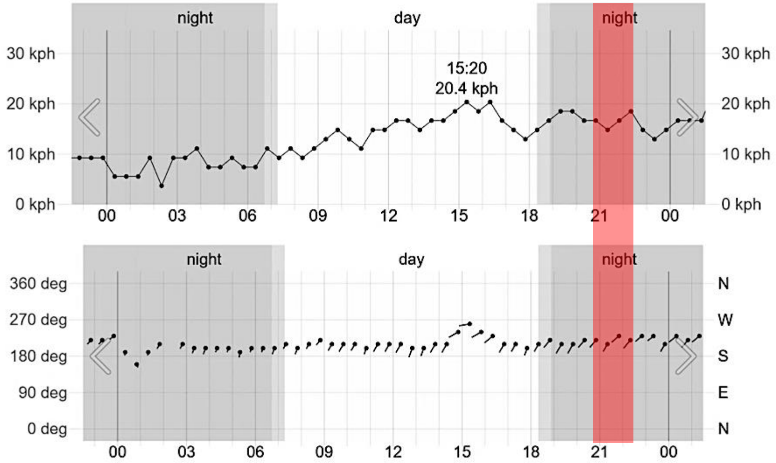
- *Parametric study*

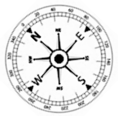
Ignition locations

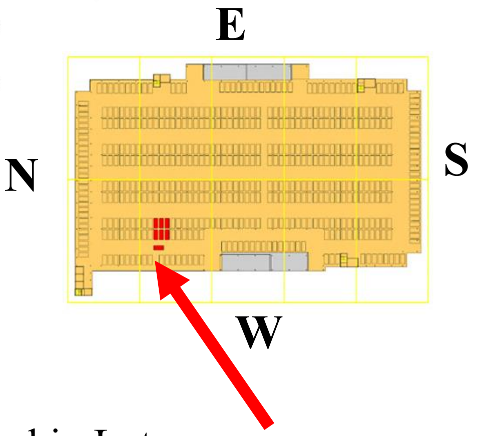


Third-floor layout with incident and parametric ignition locations (B–E)

Wind Condition







Wind direction and speed in Luton Airport – 10th October 2023

Approx. Wind direction

Wind direction (Southwest)	Wind speed (m/s)	Time (min)
150°	4.1	0
160°	4.3	20
155°	4.4	40

Bedfordshire Fire and Rescue Service, confidential communication, 2024

Simulation results

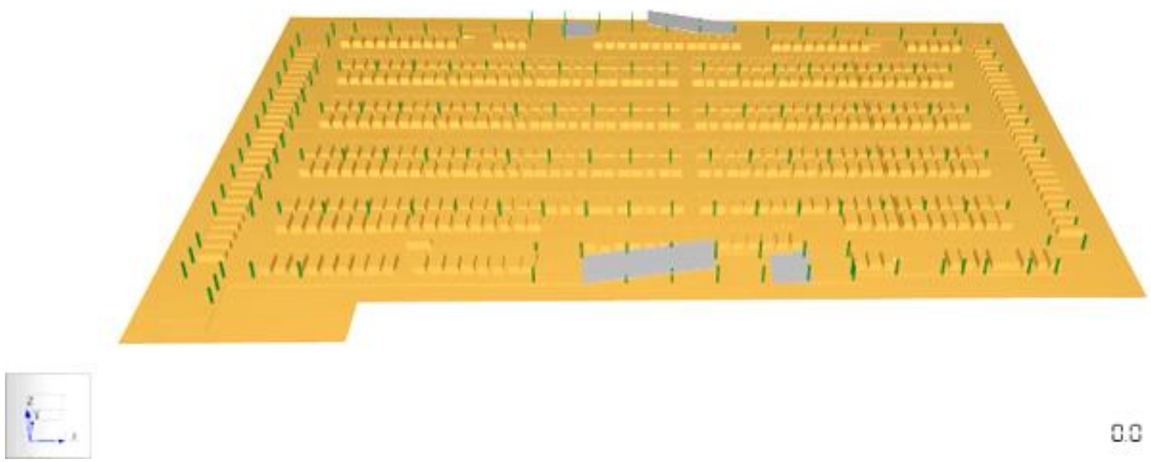
- *Fire spread*

Travelling Fire Scenarios

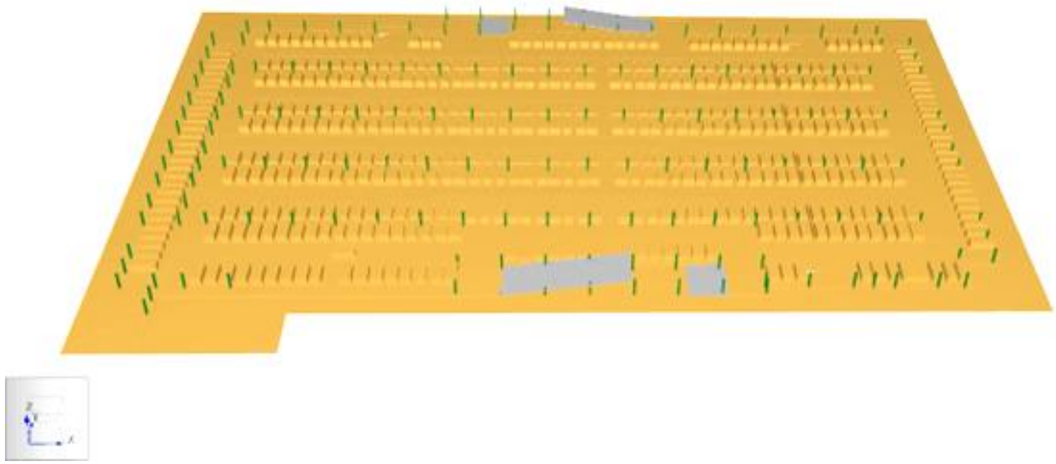
Ignition location	Position on the floor slab	Wind condition
A (incident)	Incident ignition location	5 m/s wind, or no wind
B	Edge of floor slab	5 m/s wind, or no wind
C	Edge of floor slab	5 m/s wind, or no wind
D	Edge of floor slab	5 m/s wind
E	Centre of floor slab	5 m/s wind

Ignition location A (incident)

5 m/s wind



No wind



Simulation results

- *Fire spread*

Ignition location A (incident)

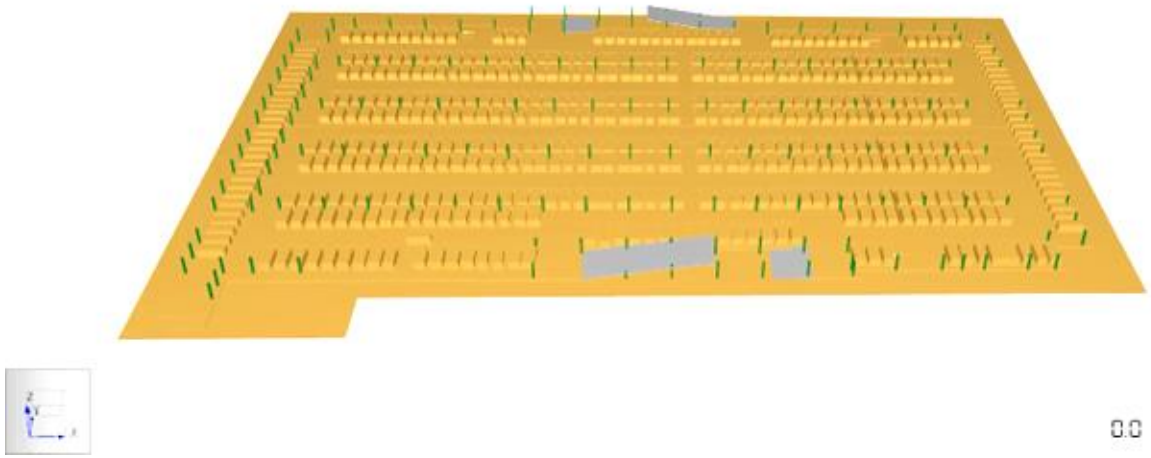
With 5 m/s wind

1. Directional travelling fire develops along wind path
2. Fire propagates ~88 m across the floor
3. ~81 additional vehicles involved
4. Peak HRR ≈ 280 MW (large-scale fire development)
5. Wind-driven pre-heating drives rapid vehicle-to-vehicle ignition

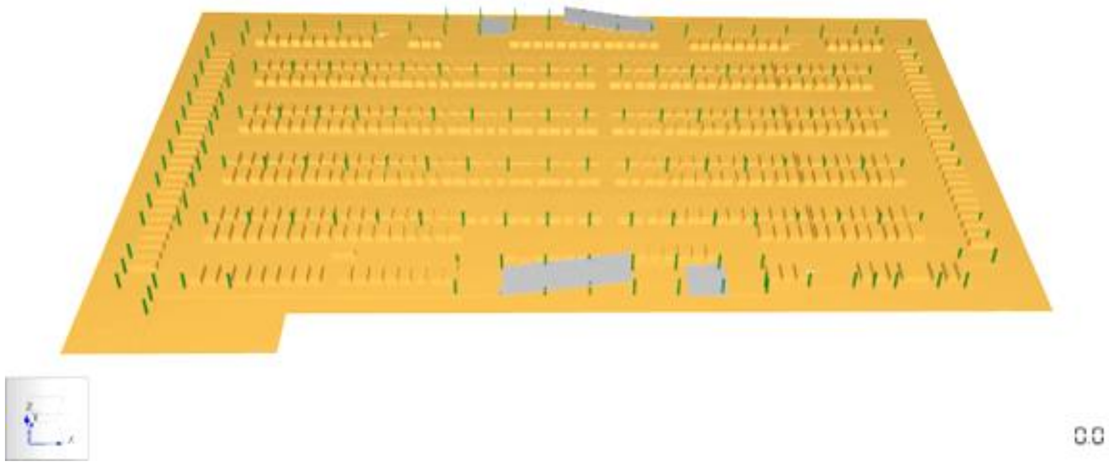
Without wind

1. Fire remains localised around ignition zone
2. Limited spread (~8 additional vehicles)
3. Peak HRR ≈ 40–50 MW
4. Symmetric fire growth dominated by radiation from flame and smoke

5 m/s wind



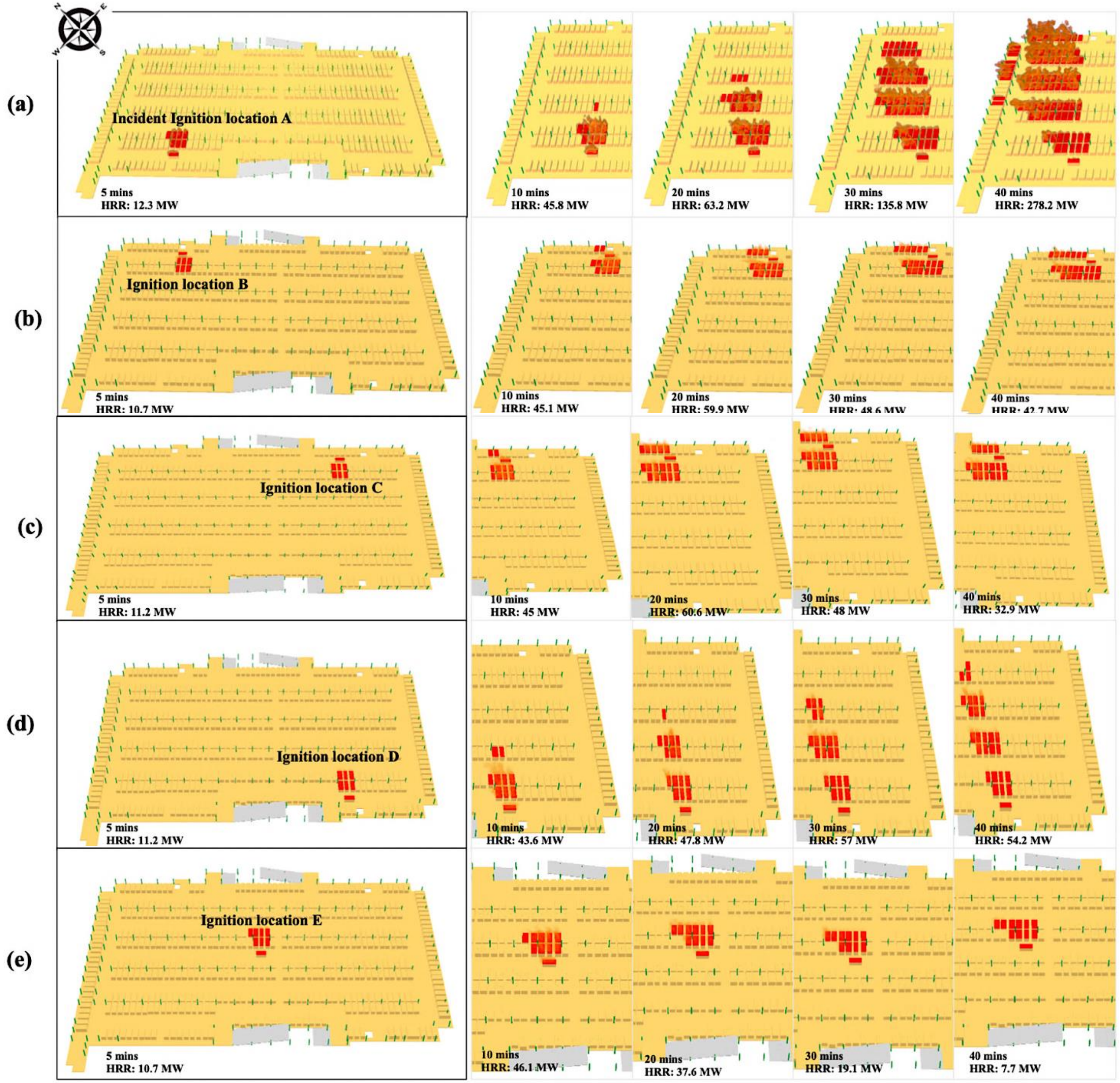
No wind



Simulation results

- *Fire spread*

5m/s wind



Influence of ignition location under wind

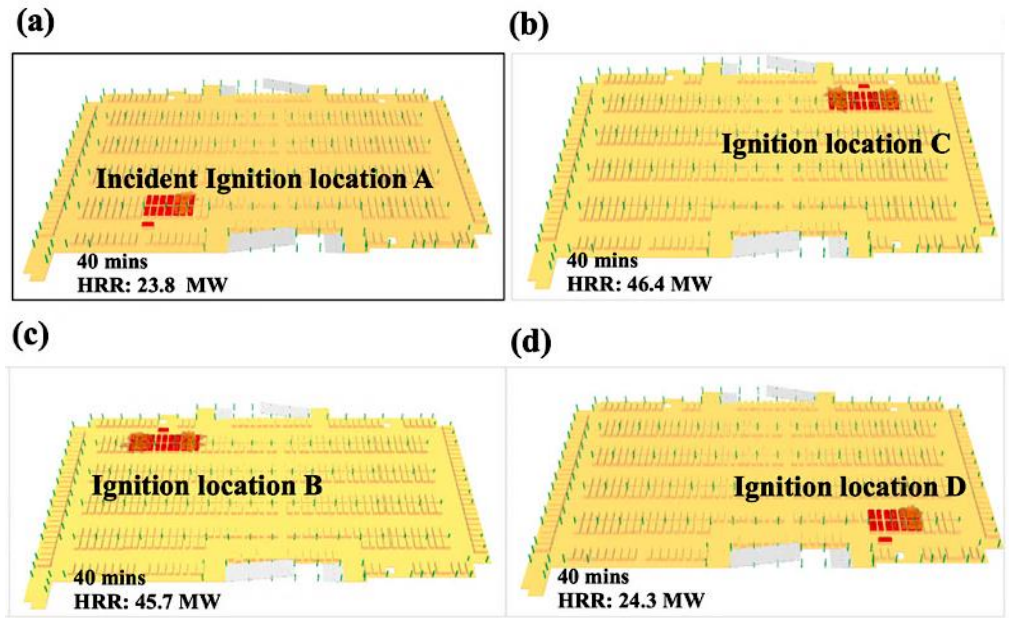
Ignition locations A/D → long diagonal travelling fire (max spread)

Ignition locations B/C → limited spread (edge → reduced fuel continuity)

Ignition location E → confined fire (central)

Fire Spread governed by **alignment of wind direction and fuel distribution**

No wind



No wind

Fire spread remains localized and symmetric

Limited vehicle involvement (~8 additional vehicles)

Peak HRR ≈ 40–50 MW

Dominated by radiation from flame and smoke

Simulation results

- *Structural response*

With 5 m/s wind

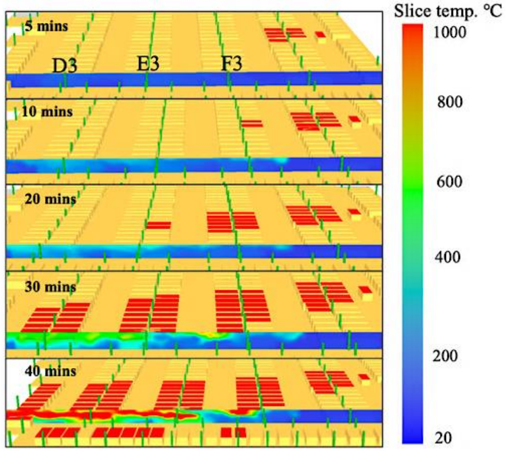
1. Travelling fire produces **moving thermal front across floor**
2. Peak gas temperatures > **1000°C** in fire path
3. Sequential heating of columns → **delayed peak response**
4. Max column temperatures ~700–800°C
5. Utilisation increases progressively → **no immediate failure**
6. Structural demand spreads spatially (not localised)

No wind

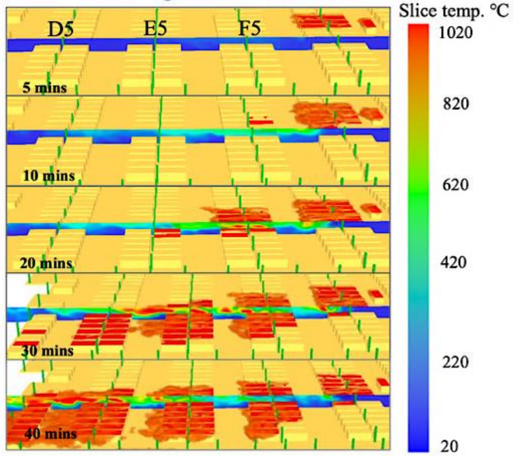
1. Heating remains **localized near ignition zone**
2. Lower peak temperatures (~400–600°C range)
3. Limited columns affected
4. Utilization remains minimal

Incident ignition location (A)

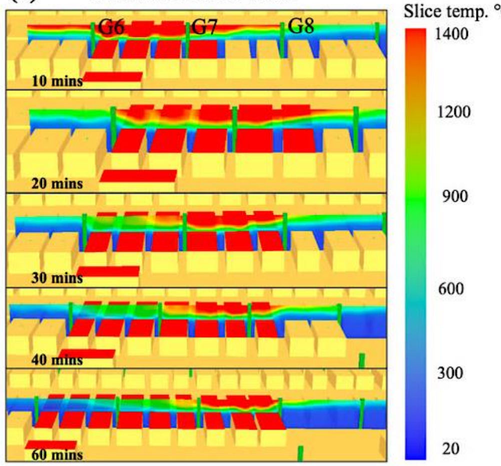
(a) Incident loc-left column-5m/s wind

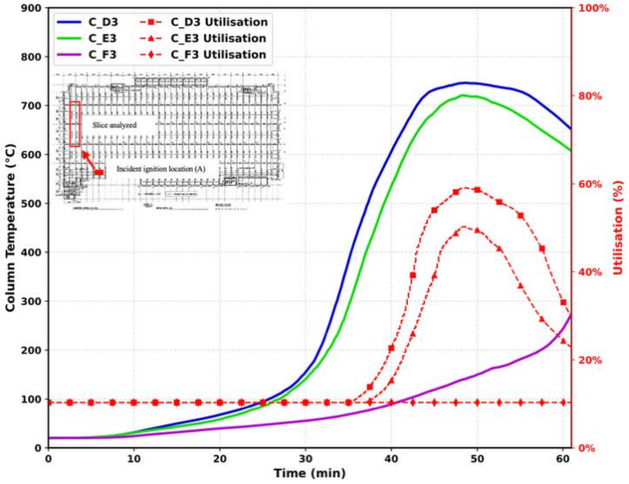


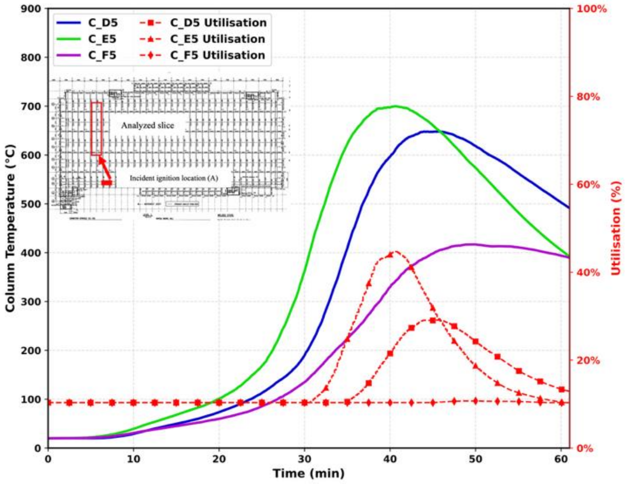
(b) Incident loc-right column-5m/s wind

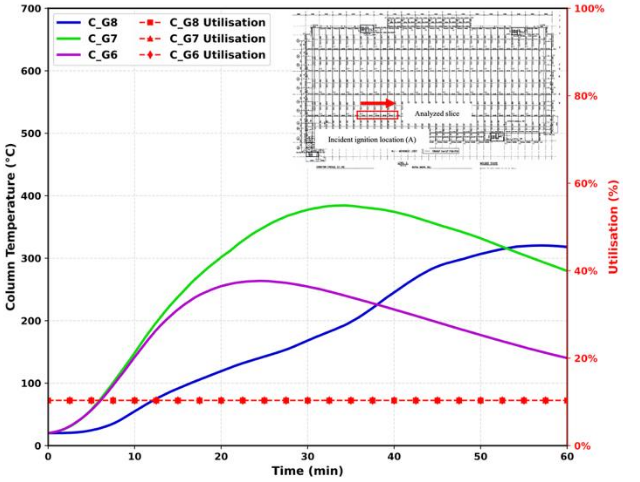


(c) Incident loc-no wind









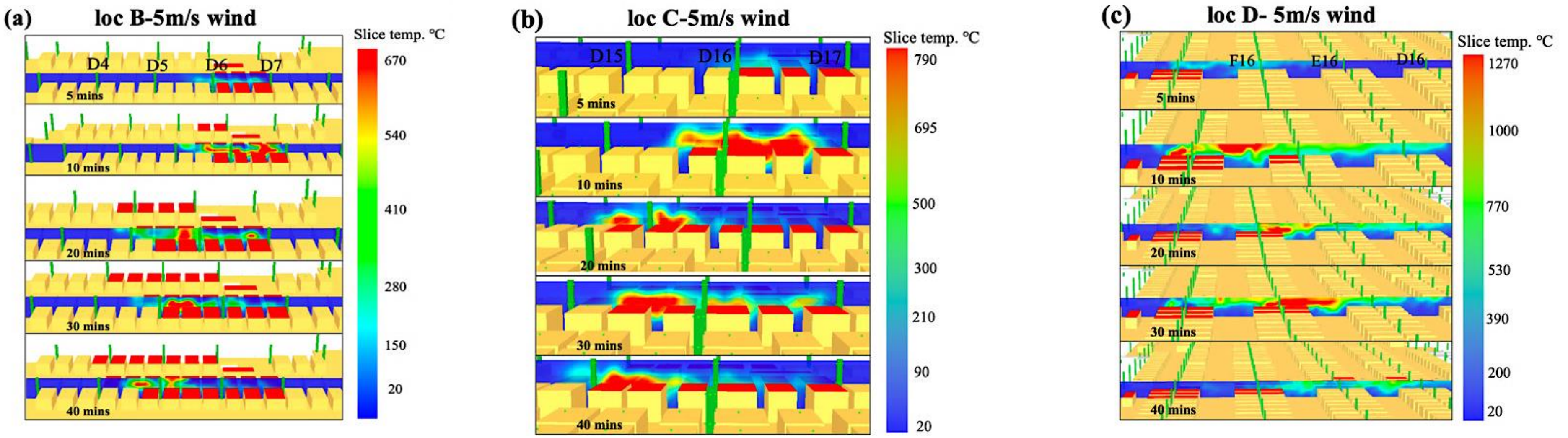
Simulation results

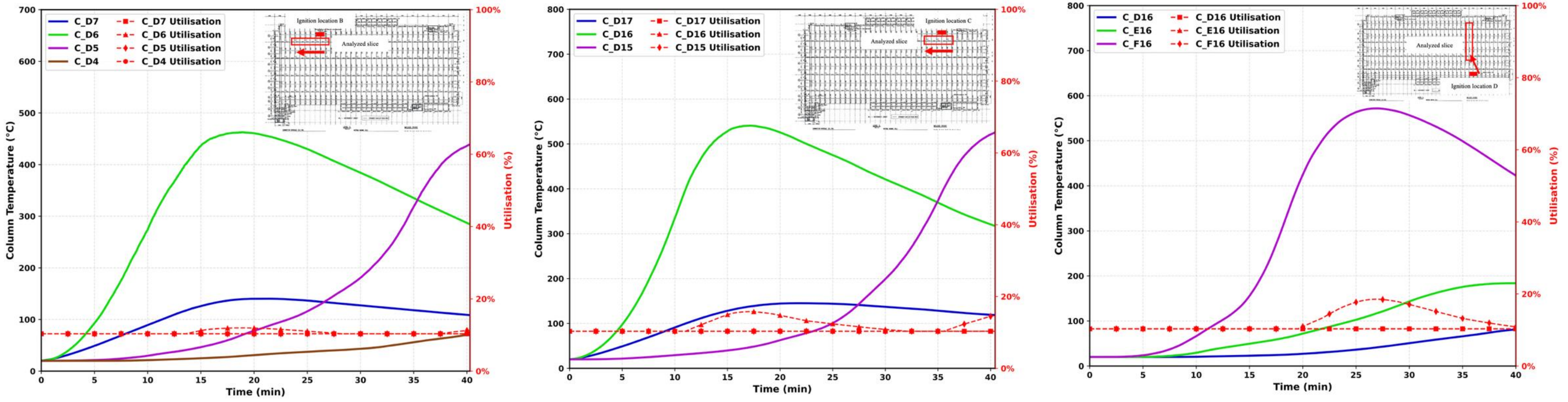
- *Structural response*

Ignition locations B-D under 5m/s wind

Under 5 m/s wind

1. **Ignition locations B/C (edge)** → limited heating → low column utilization
2. **Ignition location D →** directional heating along wind → moderate response
3. No case reaches **baseline-level structural demand**





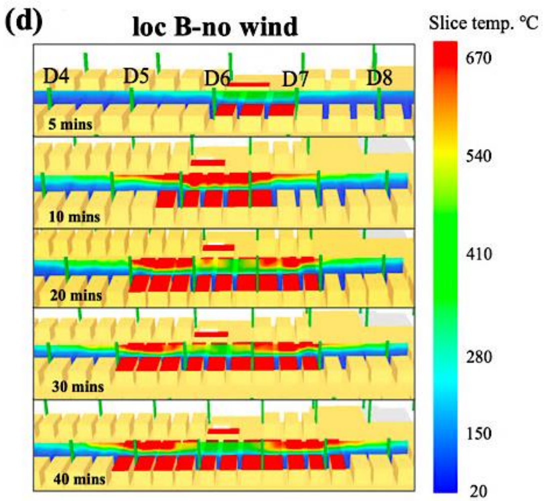
Simulation results

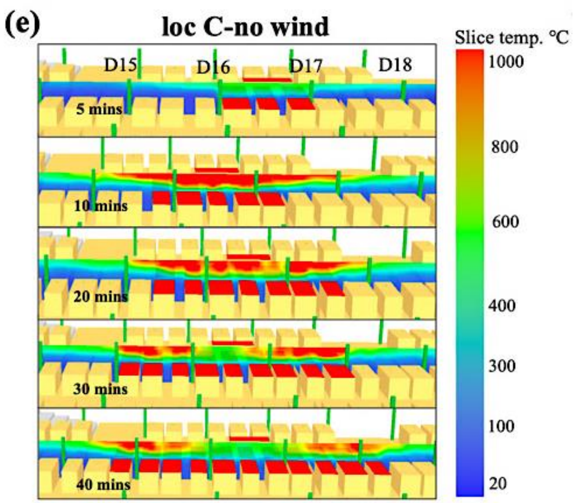
- *Structural response*

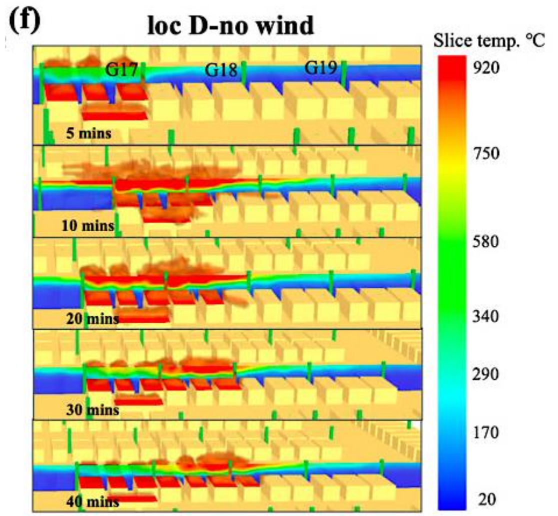
No wind

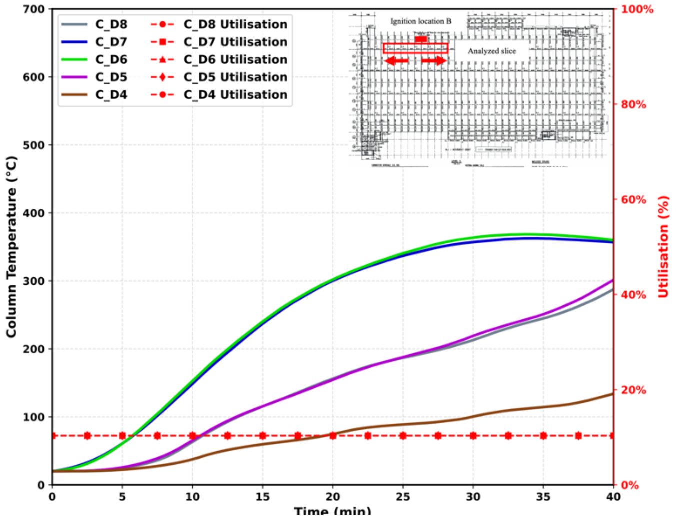
1. Symmetric, slower fire spread
2. Lower and more **uniform temperature rise**
3. Reduced peak temperatures vs. wind cases
4. Differences between B–D become **less significant**
5. Fire spread governed by **fuel distribution, not wind**

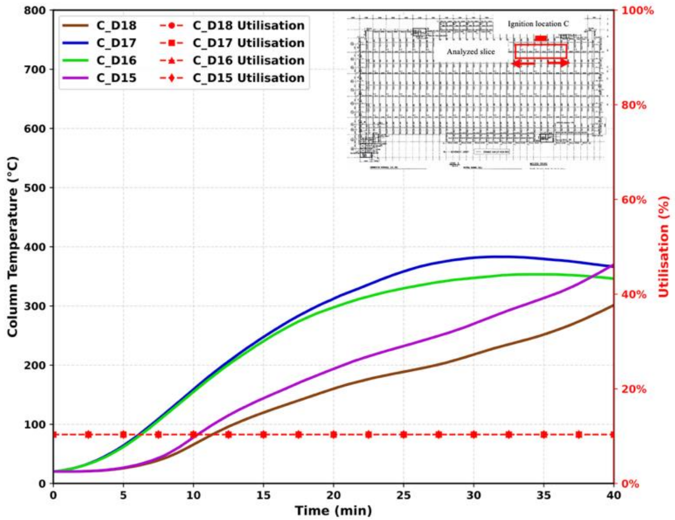
Ignition locations B-D -no wind

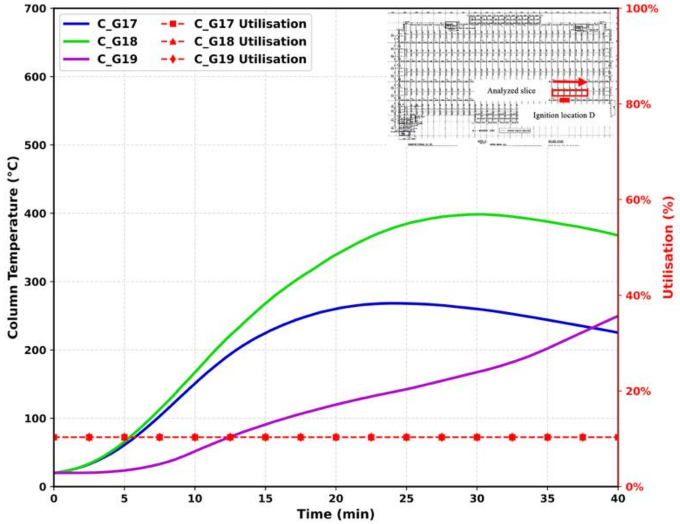












Simulation results

- ***Heat release rate (HRR)***

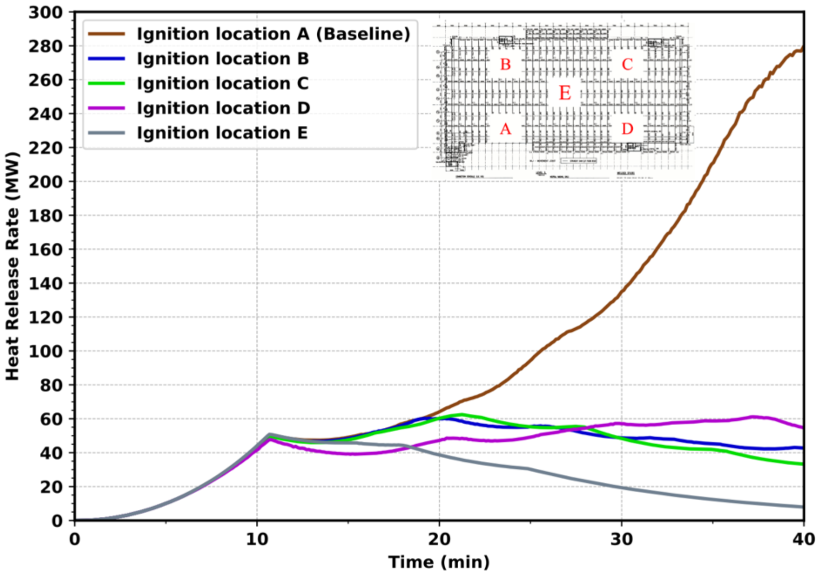
Under 5 m/s wind

1. Strong HRR escalation for **baseline case (A)**
2. Sustained growth → **travelling fire development**
3. Other locations (B–E): lower, stabilised HRR

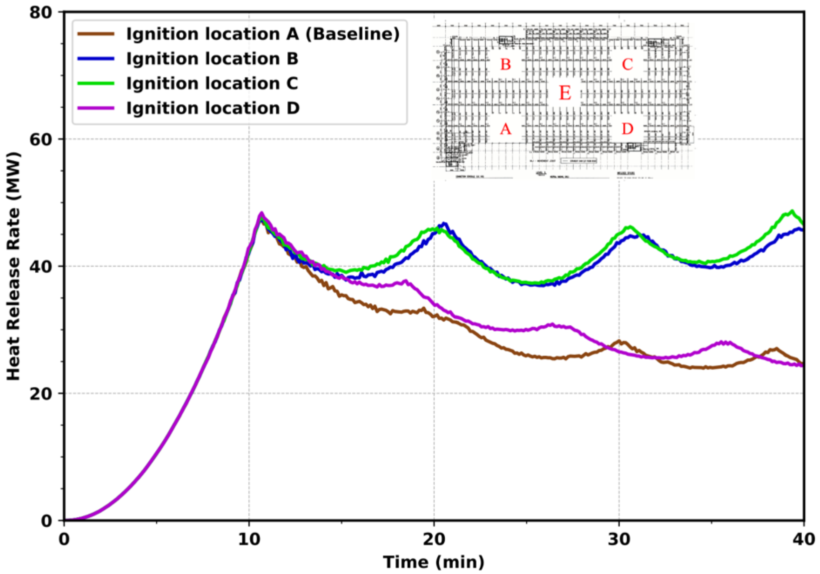
No wind

1. HRR limited to ~40–50 MW across all cases
2. No sustained growth → **fire remains localized**
3. Minimal sensitivity to ignition location

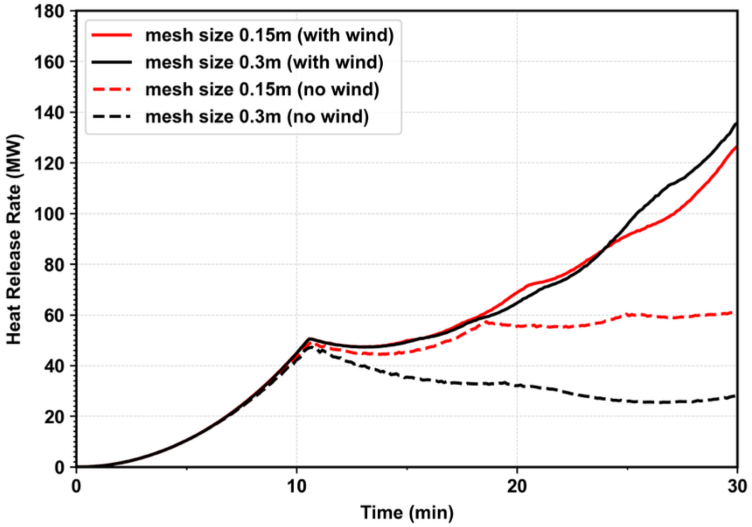
5m/s wind



No wind



*fire growth trends were preserved in both meshes. Differences became more noticeable in the no-wind case, where the finer mesh better captured plume-driven local ignition, but the 0.30 m mesh was still adequate for the large-scale parametric study **with wind**.



Conclusion

- ***Under 5 m/s wind scenarios:***

1. 5 m/s wind (baseline A):
2. Travelling fire over ~**88 m**
3. ~**81** vehicles involved
4. Fire duration extended to ~**40 min**
5. Peak HRR ~**280 MW**
6. Steel temperatures >**750°C**
7. Column utilization ~**50–60%**

- ***No wind scenarios:***

1. Localised fire development
2. Peak HRR ~**48 MW**
3. Steel temperatures ~**300–400°C**
4. Utilisation remains near **ambient levels (~10–20%)**

- ***Ignition location impact:***

1. Ignition locations aligned with wind **→ Longer fire paths → higher structural demand**
2. Other locations → **confined spread + lower utilisation**

- ***Mesh sensitivity:***

The mesh sensitivity analysis showed consistent HRR development between the 0.30 m and 0.15 m mesh resolutions under wind conditions.

Structural demand in open-sided car parks is governed by wind-driven travelling fire behaviour and its spatial alignment with ignition location.

Limitations and future research

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- ***Model limitations***

1. Inconsistency between real incident and model fire spread scale
2. Simplified ignition method for vehicle fire (heat-flux criterion)
3. Simplified pyrolysis / uniform vehicle properties
4. Prescribed fire growth (HRR per vehicle)
5. Simplified initial ignition (7 vehicles assumption)
6. Simplified vehicle distribution (uniform layout)

- ***Future development***

1. Calibrating towards real incident behaviour (LLA-scale spread)
2. Transition to surface temperature–based ignition (more realistic radiation + feedback)
3. Introducing material variability + combustible components in vehicles
4. Develop fuel-controlled fire spread based on vehicle fuel load
5. Refine early-stage ignition modelling & progressive vehicle-to-vehicle spread
6. Applying realistic parking distributions & occupancy pattern

Any other feedback is more than welcomed!

Acknowledgements

Funding Bodies

ASHTON | FIRE

UNIVERSITY OF LIVERPOOL

UKRI Research England

Upcoming presentation

Structures in Fire 2026

Queen's University

About myself

UNIVERSITY OF LIVERPOOL

PhD student of Fire safety Engineering (July 2024-present)

Sharif University of Technology

MSc and BEng of Material Science and Engineering

Project title: "Design of car parks against fire: is the current guidance adequate?"

Supervisors: Dr Xu Dai, Dr Charlie Hopkin, Dr Martina Manes, and Professor John Bridgman

ANY QUESTIONS?

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