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Fire safety of underground parking spaces

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Parking: facts and figures

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In densely populated regions, underground/indoor car parks are increasingly popular

- Parking structures built to serve residential buildings (often underground as part of the basement)
- Large underground car parks to serve shopping centers, airports, hospitals, offices (indipended units)
- Public underground car parks in big cities

50 % of all occupied housing units have a garage or carport (66% in USA)

Europe: about **10 mln *multi private garages*** for apartment buildings

There are 270 mios of cars in Europe and on average cars are parked **23 h/day**

Underground parkings characteristic

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- architecturally diverse
- a place of constant innovation
- high fire load,
- excellent ventilation conditions for fire
- potentially large number of users
- built as part of larger investments

Fires in car parking

Underground car parks are confined spaces which are relatively dangerous due to the high risk of vehicle fire.

Commercial parking garages in USA (2014-2018) = 1.858 fires

Car park with 100 vehicles, 20 litres of gasoline /each = around **56 GJ of energy = *13,4 tons of TNT***.

Modern parking garages tend to have **narrower parking spaces**, with increasing use of **vertical stacker systems**, leading to more densely packed fuel loads.

HRR of the cars

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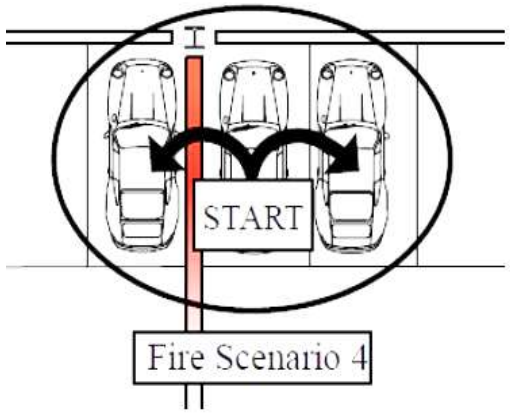
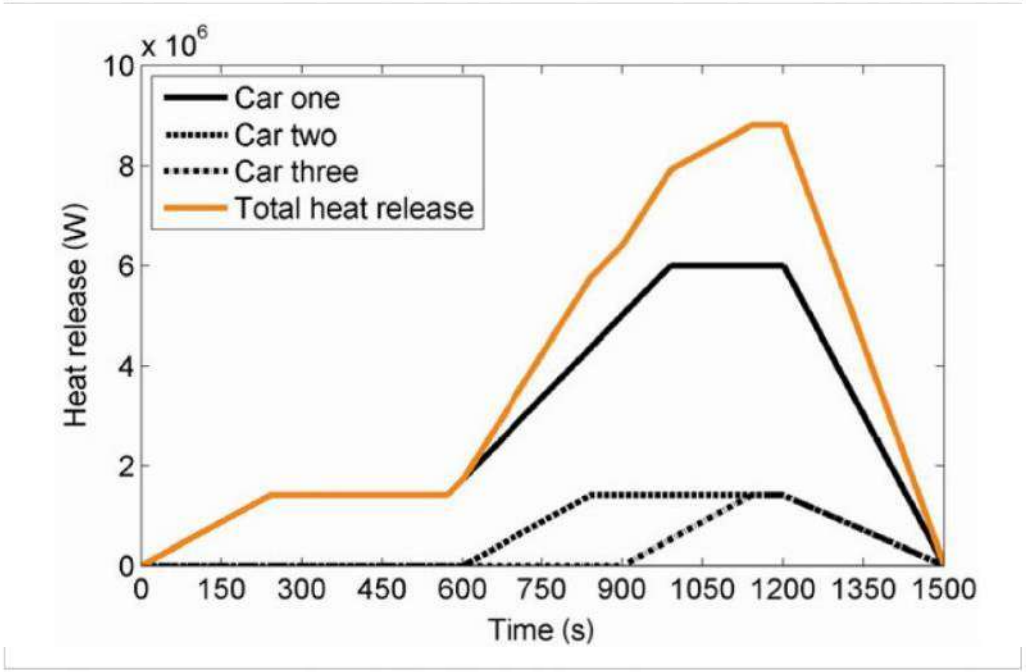
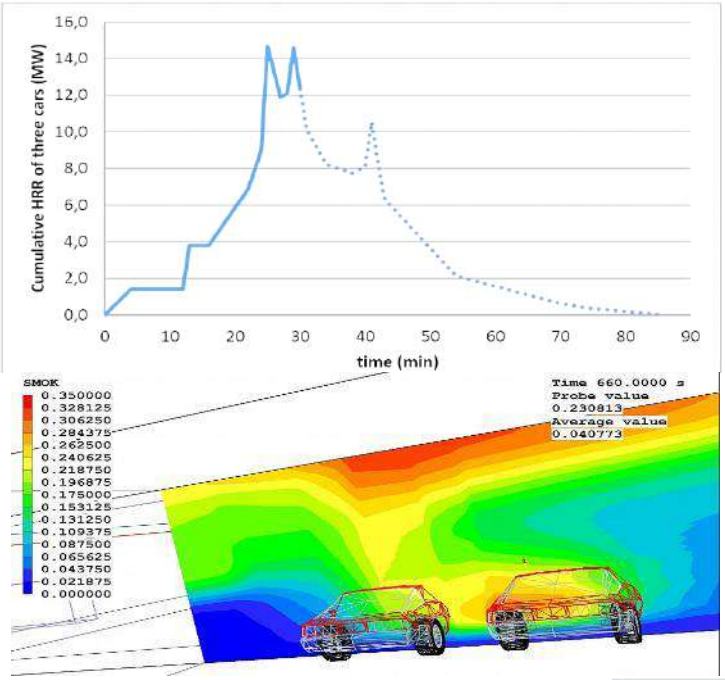
Traditional assumptions for fire safety design of car parks were based on the premise **that cars burn slowly, fuel tanks rarely explode and fire spread to adjacent vehicles only occurs slowly, if at all.**

Three-cars fire HRR is approximately 4MW at 12 minutes, constant until 15 minutes before rising to a peak 16MW at 26 minutes, then decays to 9MW at 38 minutes, peaking again slightly to 11MW at 40 minutes and decaying at 60 minutes.







Open car parks

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Based on these assumptions (a car every 12 minutes, max 3 cars), the ISO/TC92/SC4 (Design fire scenarios and design fires) in 2005 suggested to avoid passive fire protection of structural elements in semi -open car parks.

Something unexpected…
The «Kings Dock Car Park - Liverpool», 01.01.2018

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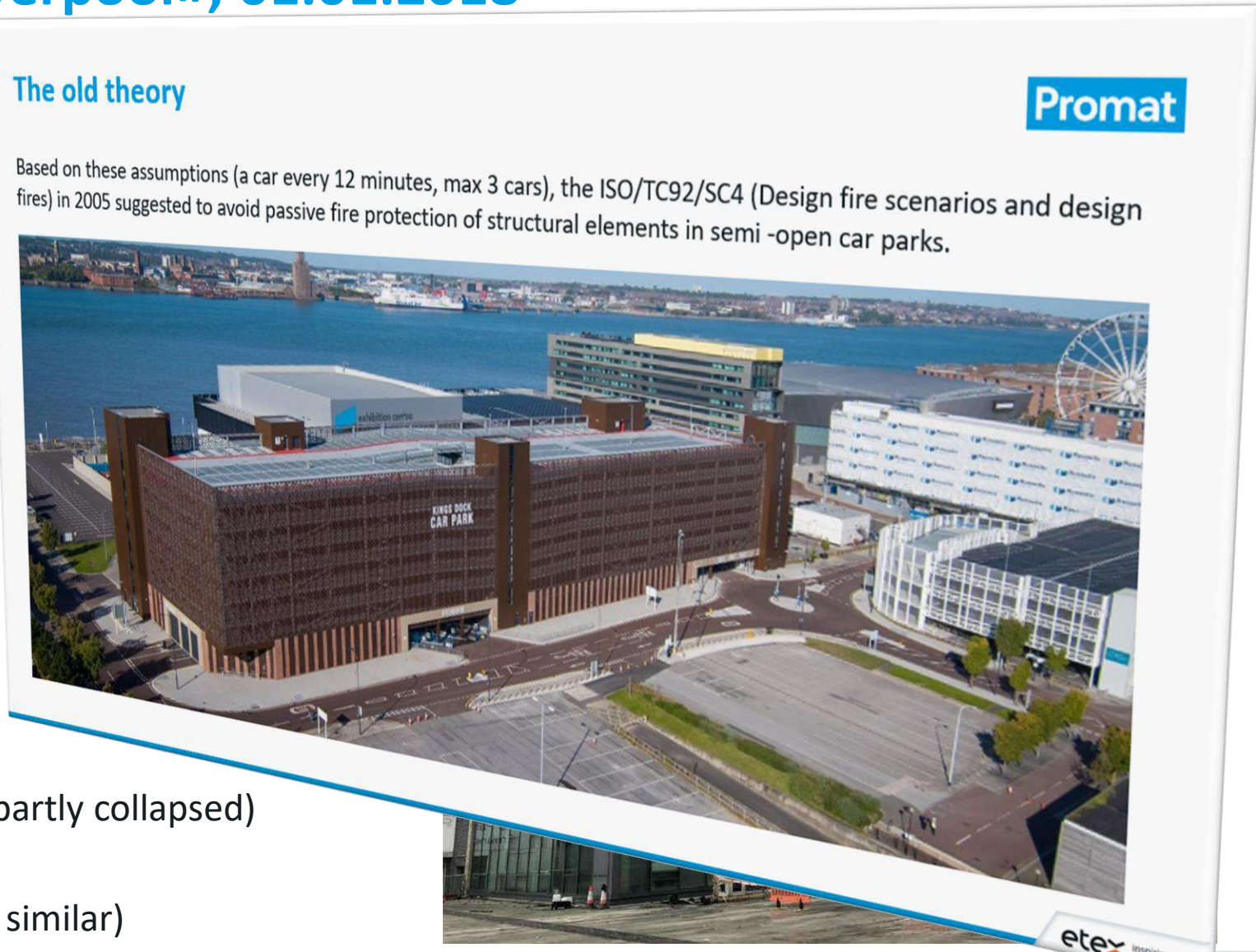
1.400 cars destroyed

Some floors collapsed



- No fire compartments
- No sufficient fire resistance of concrete slabs (partly collapsed)
- No automatic fire control system (sprinklers or similar)

New challenges

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In recent years, **a series of large fires** (Liverpool, Cork, Stavanger, Warsaw) brought the car park fires safety in the focal point of the public discussion.

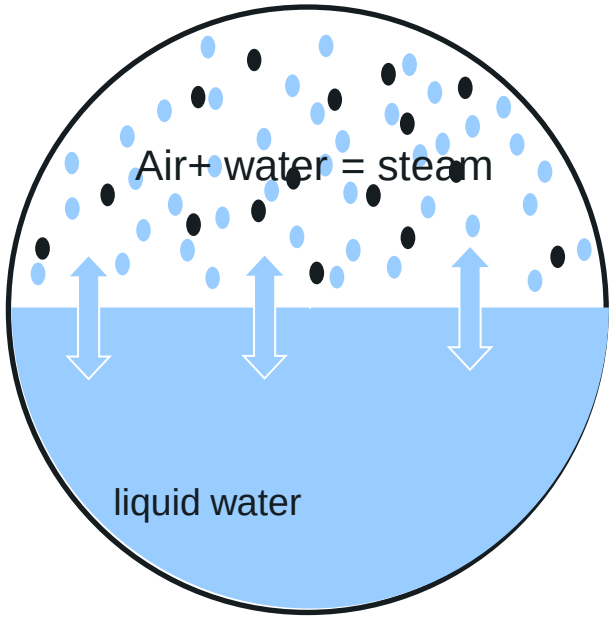
Furthermore, we are **approaching the unknown:**

the new fuel vehicles (EV and hybrid) offers challenges that we have not faced in the past.

Fires in car parking

If a garage fire reaches a certain critical size, it cannot be controlled or extinguished, leading to a construction disaster

Fire resistant of concrete- Spalling



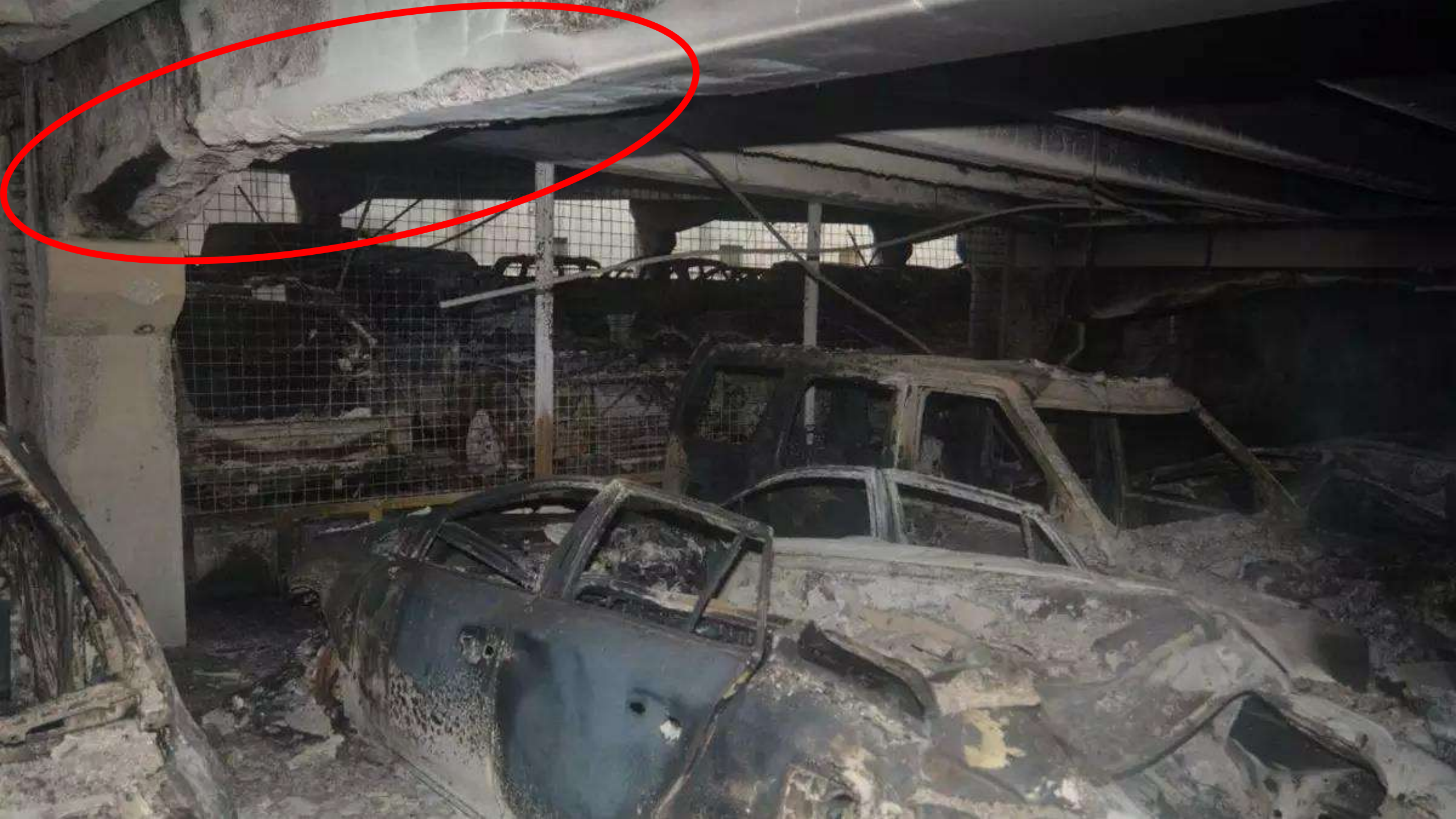
1l water – 1700 l steam

spalling of unprotected concreteIt usually starts less than 5 minutes after the fire starts.

Gradually reduces the cross-section of the concrete, typically exposing the steel reinforcement in 10-30 minutes depending on the rate of spalling and the depth of the reinforcement.

Chipping of unprotected concreto usually starts at concrete surface temperatures ranging from 200 to 400 oC

Concrete spalling is the resultLarge geometries, high compression and high concrete strengthHigher humidity (than in buildings)



Don’t’ forget the indirect costs…

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Stavanger Airport in Sola, Norway fire, 7.1.2020

300 *ca* cars destroyed.

5 stories steel building collapse.

Almost 3 years to rebuilt it.

- No sprinklers.
- Very limited fire protection and compartmentation.

Stavanger Airport in Sola, Norway fire

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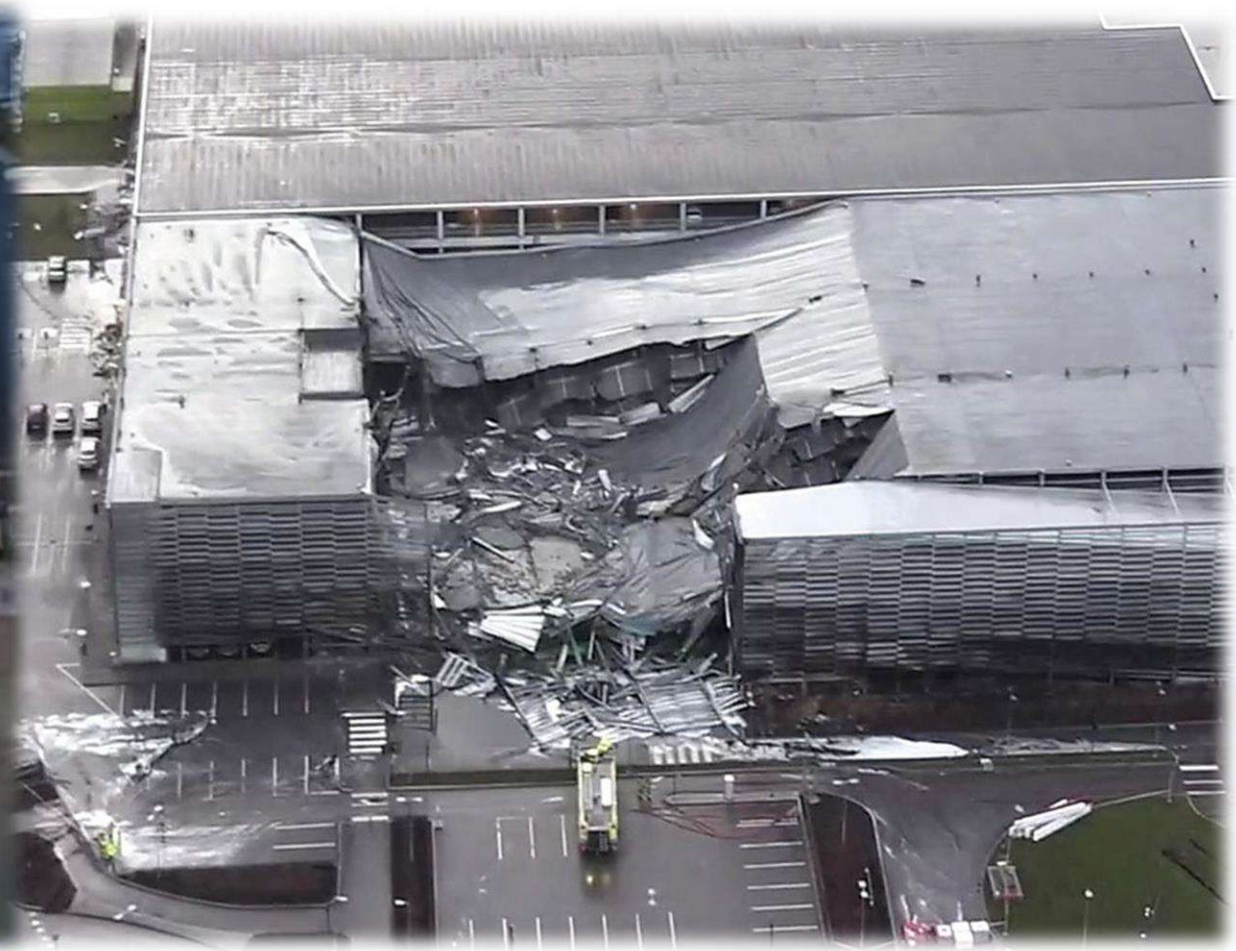


Górczewska fire (Poland) 16.10.2020

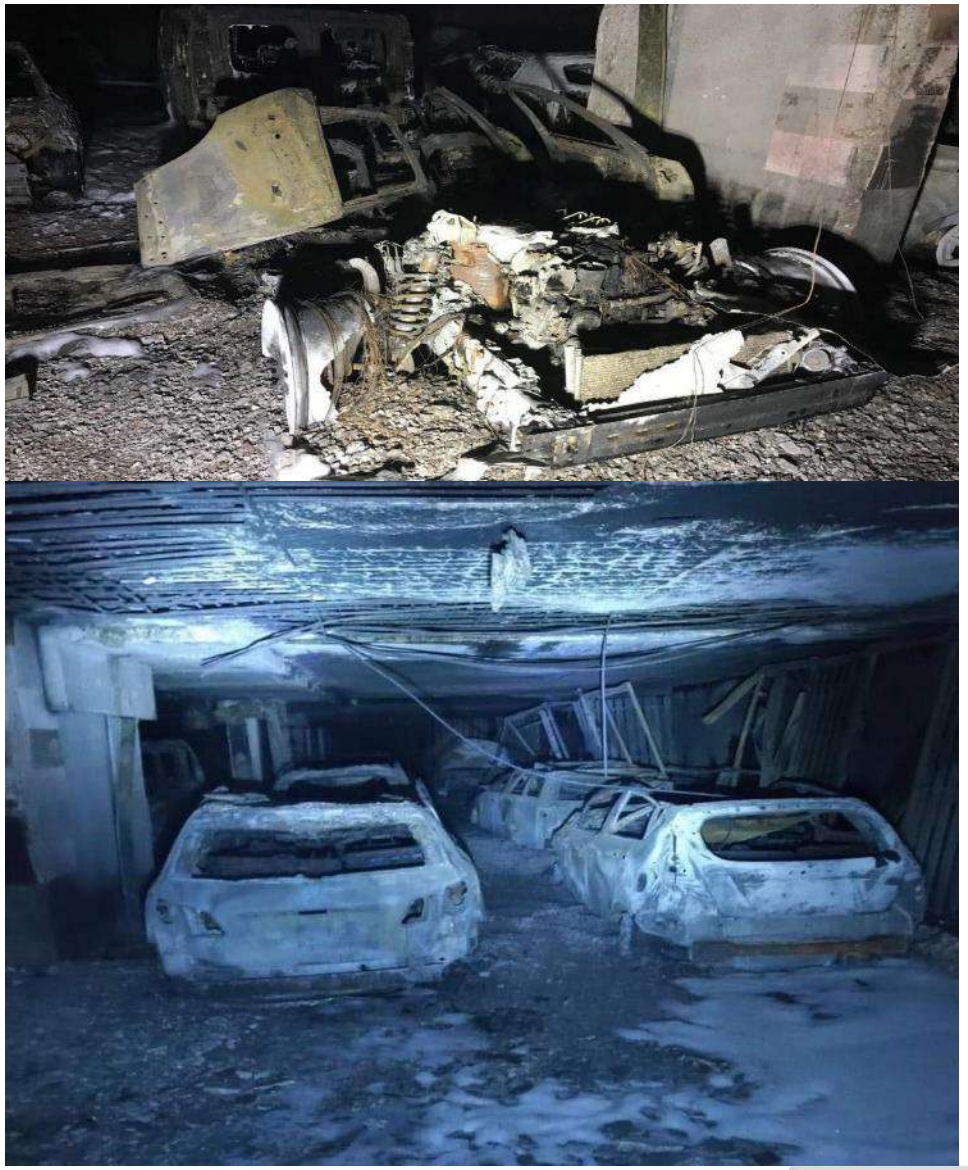
50 *ca* cars destroyed

One building widely damaged (concrete spalling), other buildings without water and electricity for 2 weeks.

People came back to the Apartments few weeks ago

Insurance companies refuse to pay (the residents had insured apartments, not the garage).

- No smoke extraction, smoke detectors or sprinklers. No structural protection.




Dräger

Consequences

Parking structures can lead to very large economic losses.

Even in apartment or office building's garages, although they are generally small (3-30 cars), the damages can be enormous (smoke damages in flats, unusable apartments, structural repairs, burning insulations ...).

New challenges

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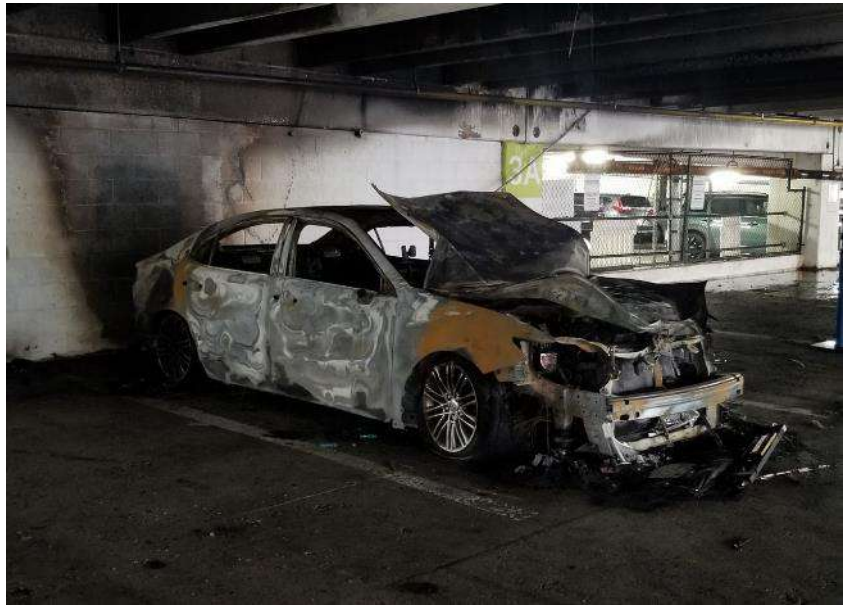
Tests of multiple **modern vehicles** (and the most recent large fires) have shown very rapid fire spread between vehicles in parking garage configuration, on the order of 10-20 minutes.

Recent fire testing on modern cars confirmed that **previous assumptions and perceptions are no longer valid**.

Test data from older vehicles (>15-20 years) should not be used as the basis for development of codes and regulations.



New challenges

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Increase in fire hazard due to changes in vehicle design and increased use of plastics and other combustible materials. These have an effect on the fire behaviour: heat release rate (HRR), fire duration, heat flux to nearby objects.

Change in fire hazard associated with modern vehicle has three major causes:

1. Larger vehicles with increased use of polymers (from 1976 to 2018, the **weight of plastic materials increased by 91%,** from 83 kg to 159 kg)

2. The typical maximum heat release rate (HRR) from older to newer cars **has increased from 4 MW to 6-8 MW**

3. **Rapid growth of alternative fuel vehicles: hybrid electric (PHEVs), fully electric (EVs) and hydrogen fuel cell.**

Electrical Vehicles (EV)

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- EV fires are not that different from internal combustion vehicle fires……however, the dynamics of fire development in the garage can be terrifying (regardless of the fuel) and sometimes we underestimate it

Alternative fuel vehicles: sales growth

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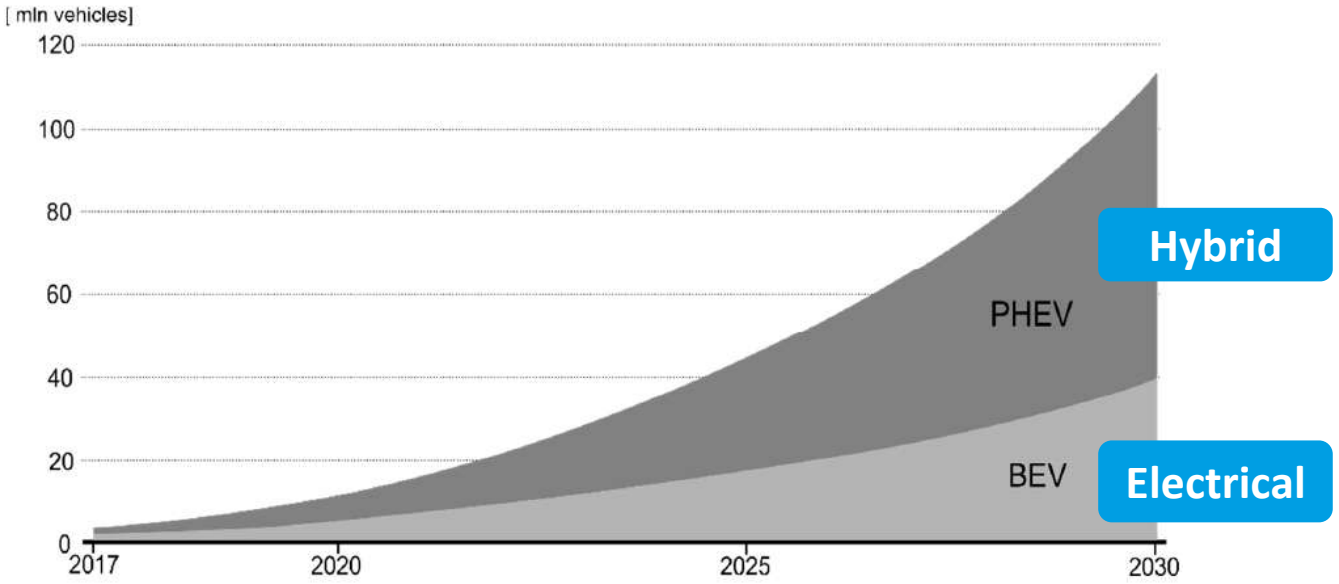

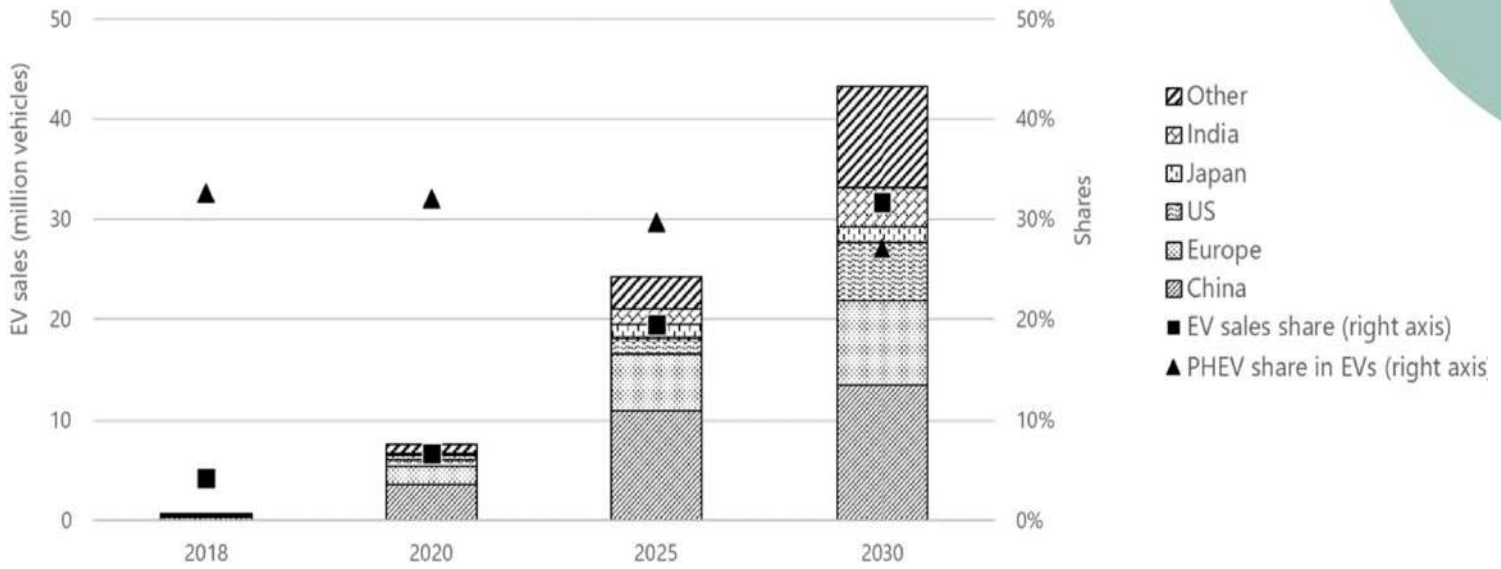

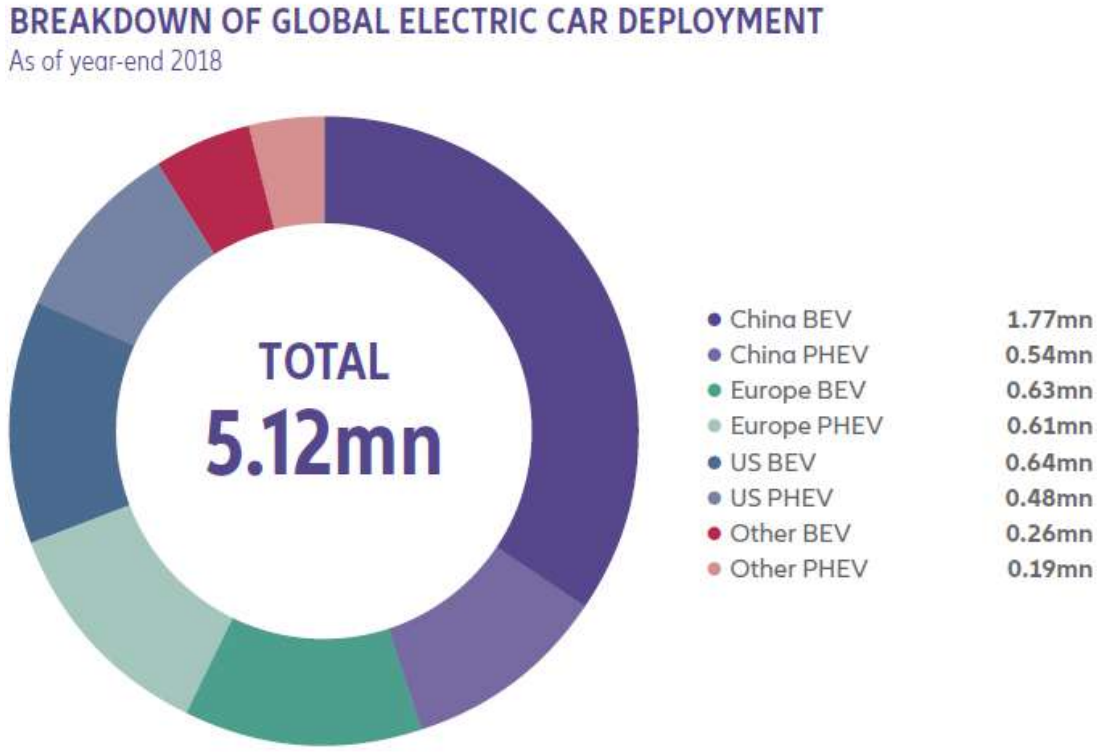

Current policy decisions around the globe are forecast to result in more than 100 million electric cars on the roads in 2030,

New challenges

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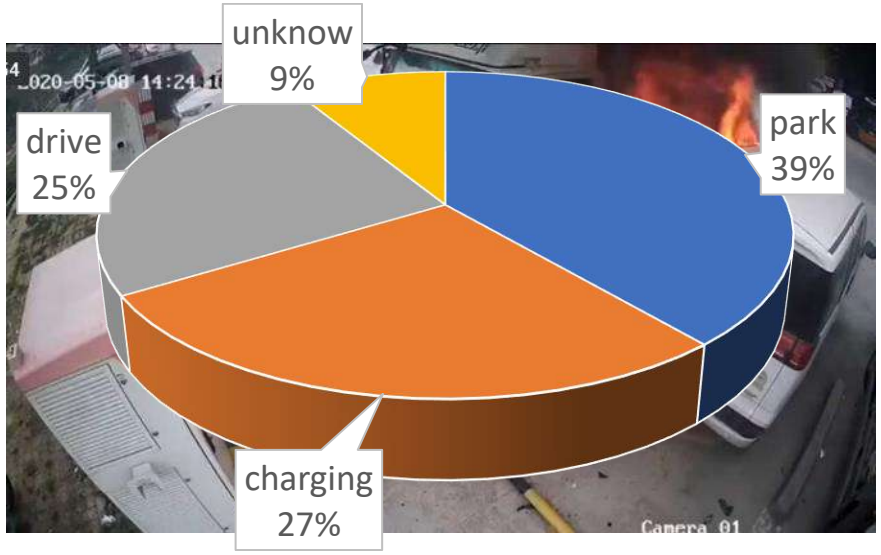
Increasing usage of alternative fuel, sometimes resulting in dramatically altered fire characteristics: **fire duration, fire spread, HRR.**

Recent researches says battery electric vehicles have just a 0.03% chance of igniting, compared to ICE vehicle's 1.5% chance, while **hybrid electrics, (high voltage battery + internal combustion) have a 3.4%.**

Moreover, in case of **indoor charging** in closed underground garages of commercial, office and residential buildings, the risk is hardly predictable.

Small absolute number of vehicles and incomplete statistics *on vehicle fires by traction power obstructs making strong conclusions on fire rate.*



Not only cars…

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Statistics show that the recharging of **electric bicycles and scooters** batteries caused several fires

- The New York City Fire Department has reported more than **100 fires** linked to e-bikes in 2021.
- **130 fires** in London (2021)
- Estimated 2021: more than **4.000 fires/** year all around the world

The new challenges

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Researchers suggest a **comparable heat release of EV to ICE,** but there are some **differences in the initial phase of fire development** (not yet precise information, experimental data, statistics…)

The fire can be longer and lithium-ion batteries are more difficult to extinguish, **requiring a large amounts of water**.

It may take up to 24 hours to extinguish: additional resources or letting the battery continue to burn (an important manufacturer: *storing the fire damaged vehicle in open area at least 15 mt from exposures*)

High voltage battery can **release toxic vapors** in fire, including sulfuric acid, nickel, lithium, copper and cobalt.

Rescue teams

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Alternative fuel vehicles pose new challenges to firefighting and rescue personnel, including new toxic gases emissions and need for excess use of water.

Some countries have already banned electric vehicles (EVs) from the enclosed car parks in the absence of knowledge.
Instead of banning, we need to learn how to manage and mitigate the risk.

Structural fire protection

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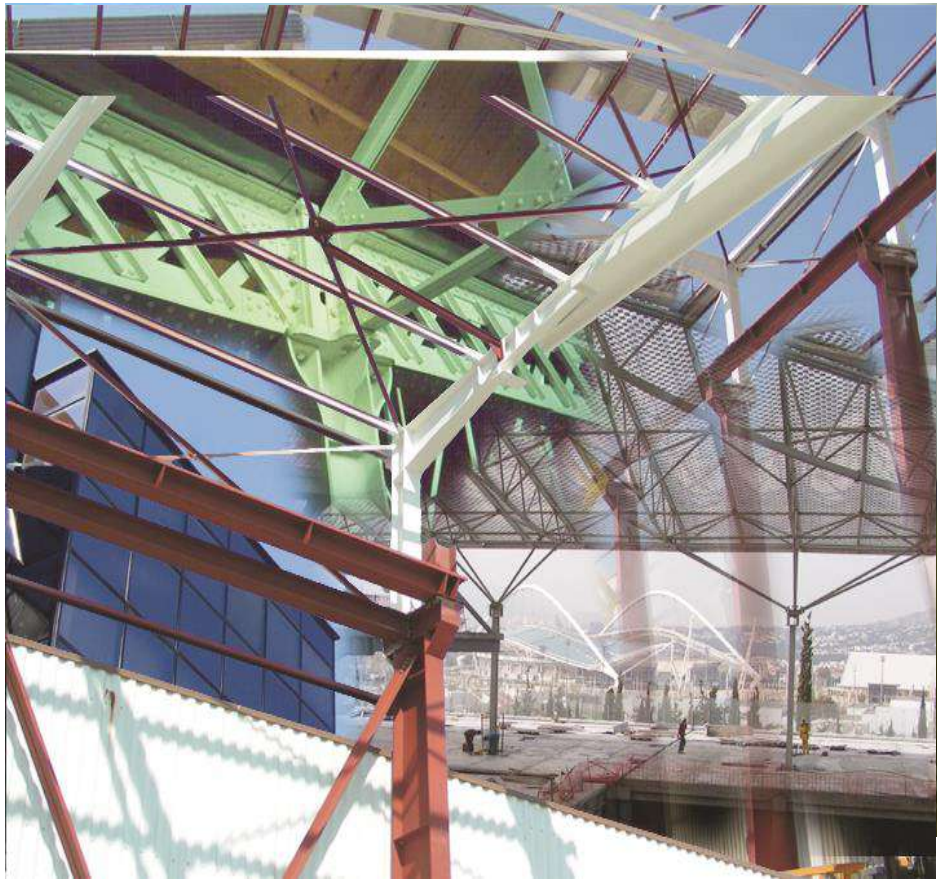
- The stability of a building in a fire depends upon the performance of all the component parts of the structure.
- Structural elements (structural steel, concrete, etc.) **must remain stable during the whole fire exposure** (without collapse).
- **Fire protective materials** (sprays, boards, intumescent paints) prevent the collapse of loadbearing structures.



Special case – concrete spalling

Concrete structures may be subject to the **spalling effect**, even if they do not collapse.

Spalling is a separation of pieces of concrete from the surface layer (expulsion of portions of concrete).

It’s difficult to predict spalling effect, but it can happen often, especially in car parkings, as demonstrated in **many recent fires**.

Spalling of concrete causes serious damage to concrete structures, with significant economic costs.


SB6E
PB5
B3

Structural protection: solutions

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Boards

- Mechanical resistance
- High fire resistance *(alternative: special boards for tunnel fires)*

Spray (SFRM)

- Fire + acoustic
- Lightweight

Intumescent paints

- Low thickness
- Aesthetical aspect /colour

Compartmentation

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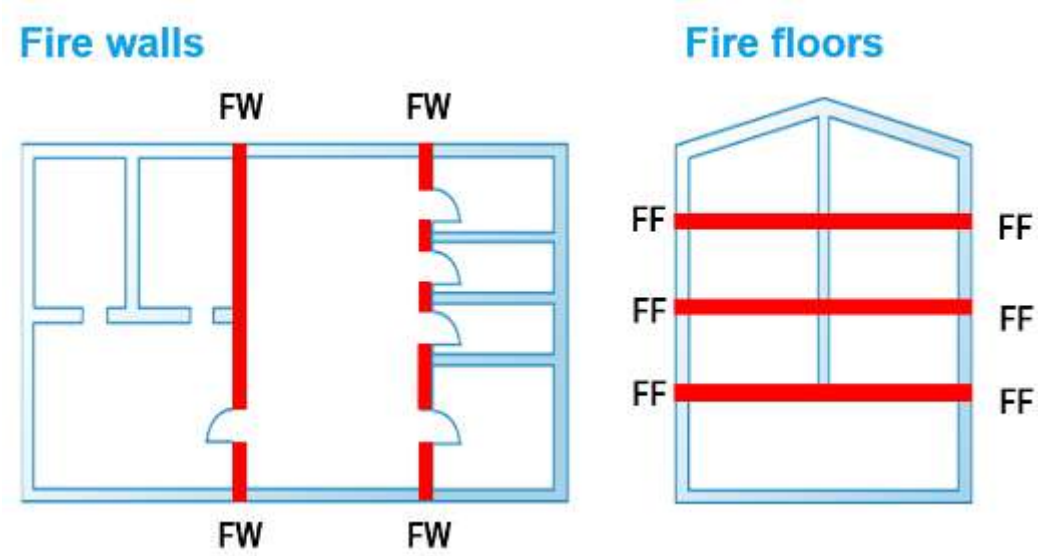
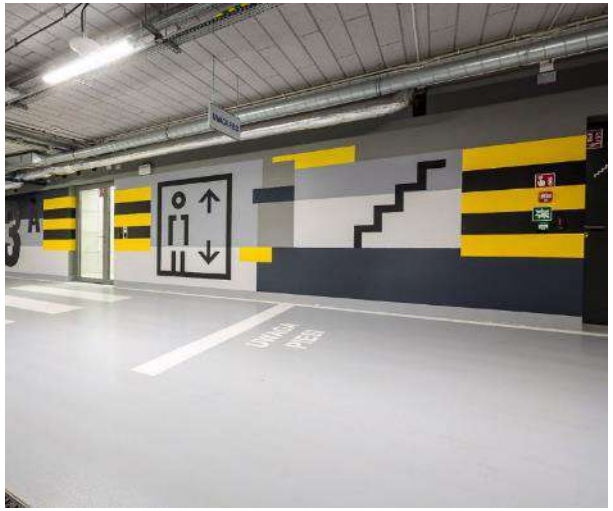
The spaces in the building are **divided into smaller compartments** for fire safety management reasons to:

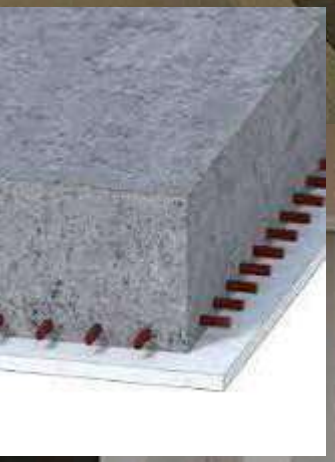
- **Limit the spread of fire.**
- **Restrict the movement of smoke.**
- **Optimize evacuation routes during fire.**

Mobility and passages between compartments thanks to **fire doors.**






ELECTRIC
VEHICLE
PARKING
ONLY



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Smoke in underground car parks

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Smoke is the most dangerous element for people in a confined spaces such as an underground car park

- Asphyxiating, narcotizing substances, reduced visibility and slowed down rescue operations.
- Hot gases and solid particles transport thermal energy.
- Can causes economic damages (post-fire cleaning is extremely expensive).

Smoke must be managed or removed

- **In small car parks/ garages for apartment blocks**, openings are sufficient (i.e. the way in and out for vehicles)
- **In large car parks or multi-story car parks**, smoke must be managed with mechanical systems.

A new challenges for smoke extraction in car parks

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Electric vehicles (and even more hybrid) release a quantity of energy similar to ICEV, but…

- **Temperature can be higher** in the first minutes, so the production of smoke and hot gases can be quicker.
- When burn, EV batteries emit more than **100 dangerous substances** (including hydrogen fluoride, sulphur dioxide, heavy metals).

Smoke management is crucial both for the **evacuation of people** and for the **safety of the rescue teams**.

Smoke management: solutions

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Duct systems

Passive, low-maintenance systems (single and multiple compartments)

Adaptable to any geometry and size, ideal for large /multi-storey car parks

Create best condition for evacuation

Jet fans

Suitable for large compartments

Customisable system in case of layout changes

Can create a smoke-free zone that helps rescue teams

If not fire rated, duct systems can be useless or even dangerous

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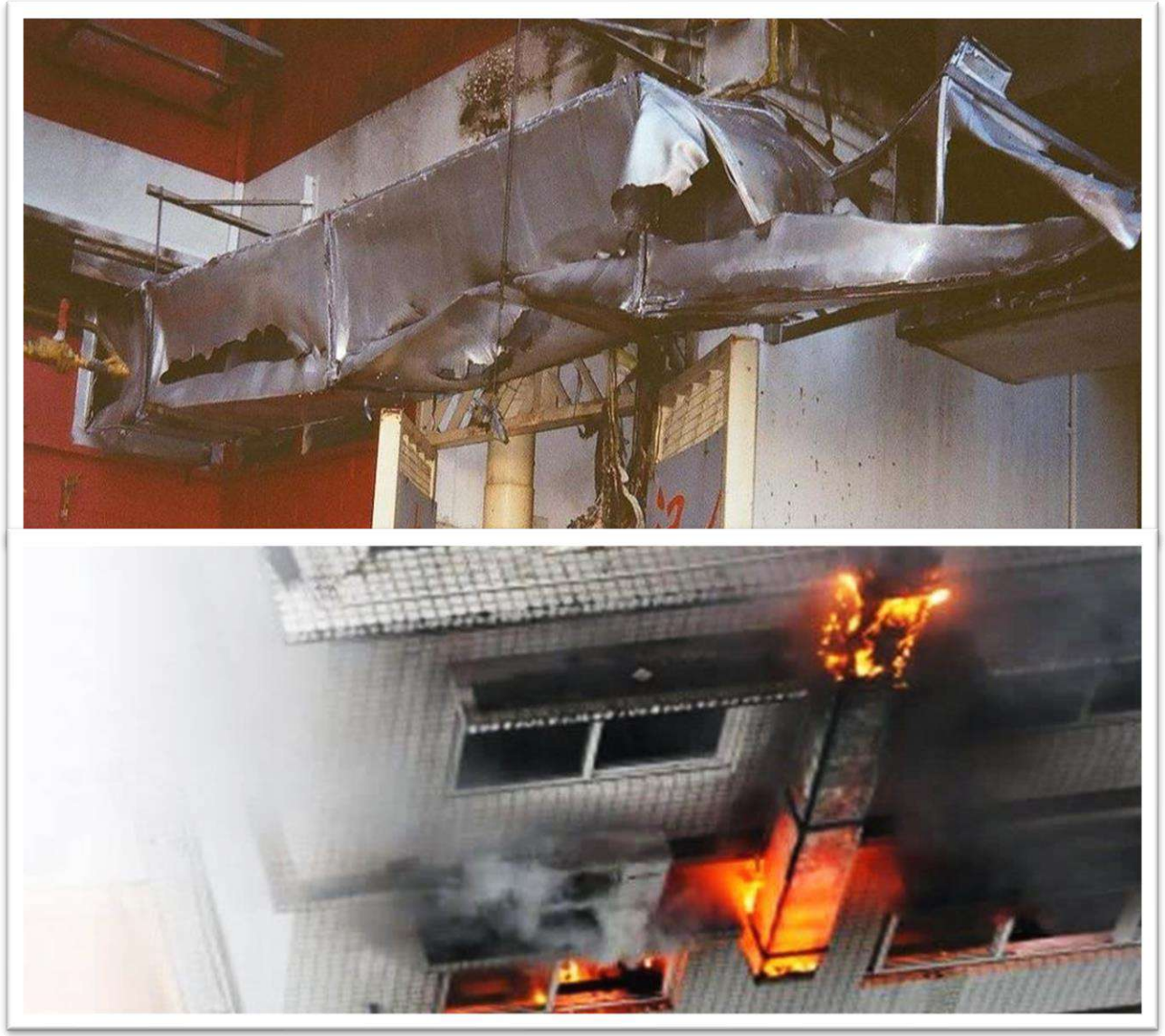


Non-insulated steel ducts cannot be used when multi-compartmenting is required (they **transmit heat** to other compartments and **deform** so much to damage the walls they pass through, especially lightweight walls and partitions).

Steel ducts can be used in single compartment, provided that a **localised fire in their proximity does not lead to deformations** or collapse.

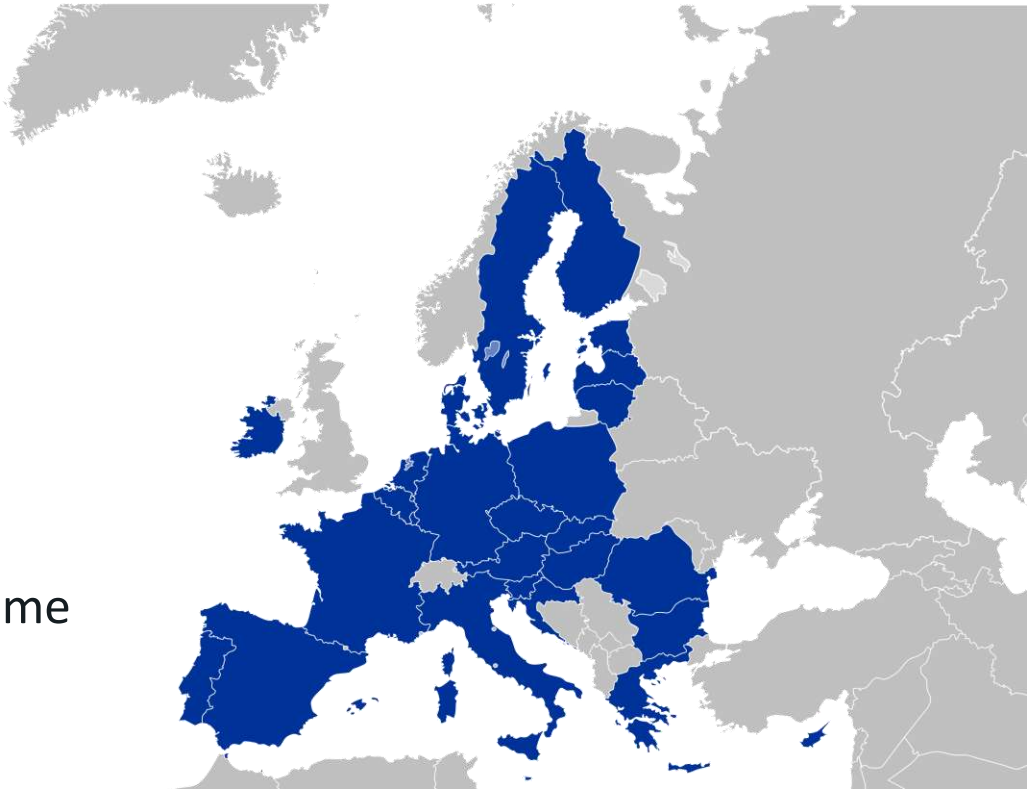
Regulations in Europe

How to prove the performance of smoke extraction ducts in **almost all Europe?**

- Test report **EN 1366-1/8** + Classification Report **EN 13501-4**
- (+ DoP of the boards EAD EAD 350142-00-1106)

OR

- Certificate **EN 12101-7** (CE marking of section ducts)



How to prove the performance of smoke extraction ducts in some countries, such as the **Baltics?**

Fire rated smoke extraction ductworks

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The geometry of the ducts can vary, while maintaining the same flow rate.

The ducts can be rectangular, to save space in height.

It is always necessary to use smoke dampers, which must be tested together with the ducts.

Ductworks must have the longest durability, with limited maintenance.

Complex shapes: ducts can be adapted to the needs of the car park.

It’s important that the connections between the multi-compartment and single compartment is suitable to resist to fire and deformations.


It's not our talents that
make us safe or
dangerous, it's our choices.
Josephine Angelini

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Thank you for your attention!

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