OPTIMISING FIRE PROTECTION IN A 10 STOREY AUTOMATED CAR PARK: A CASE STUDY IN FIRE ENGINEERING

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ABSTRACT

Car parking has developed differing technologies. Fire protection techniques have to develop accordingly to ensure the optimum levels of protection.

In the present case the parking technology allowed the design of a 10 storey high, enclosed car park with fire-resisting outer walls. Cars are parked in open-fronted (fire-resisting) concrete cells by automatic machinery which operates through an atrium-like space through the entire height of the building. Maintenance and fire service access is via routes outside this large, single fire compartment; opening via fire-resisting doors into the rear of each cell.

During normal operation, the entire multi-storey fire compartment is unoccupied. This means in turn that there is little difficulty in meeting the requirements under the Building Regulations.

Zone model methods are used to assess whether the initial fire cell is likely to flash over, increasing the size of the fire and developing a threat of fire spread to the cell immediately above. It is suggested that for cells larger than 3-car, there is a likelihood of "runaway ignition" leading to loss of the building.

For unsprinklered cells of 3 or fewer cars a smoke and heat exhaust ventilation system protecting fire-fighter access and/or minimising damage to cars on higher storeys, needs to be of an impractically large fan capacity of about 110 m^3/s to 150 m^3/s.

The same methods show that, with sprinklers to prevent flashover in a cell, the fan capacity needed to allow fire-fighter access with good visibility reduces to around 30 m^3/s or to about 38 m^3/s to prevent damage to cars on higher storeys.

Design fires, both sprinklered and unsprinklered, are based on the recently published BS 7346-7: 2006 which assumes sprinklers will allow the original vehicle to continue burning while preventing spread to adjacent vehicles.

KEYWORDS: Stacking car park, Sprinklers, Smoke control

INTRODUCTION

Car parking has developed differing technologies. Fire protection techniques have had to develop accordingly to ensure the optimum levels of protection.

In the present case the parking technology allowed the design of a 10 storey high, enclosed car park with fire-resisting outer walls. Cars are parked in open-fronted (otherwise fire-resisting) concrete cells by automatic machinery which operates through an atrium-like space through the entire height of the building. Maintenance and fire service access is via routes outside this large, single fire compartment; opening via fire-resisting doors into the rear of each cell.

During normal operation, the entire multi-storey fire compartment is unoccupied. This means in turn that there is no life threat to (non-existent) occupants, which in turn means that there is little difficulty in meeting the requirements under the Building Regulations. This allows the fire engineer to focus on giving protected access to fire-fighters while minimising the consequential losses in terms of damage to parked cars and/or to the structure due to heat generated in a fire.

OUTLINE DESCRIPTION OF BUILDING

The fire compartment is approximately 30 m long by 16 m wide and 10 storeys high. Individual storeys are either 1850 mm floor to ceiling, or are 2250 mm. Slab thickness at each storey is 400 mm and is fire resisting. The geometry is illustrated in Fig. 1a (plan) and Fig. 1b (atrium elevation).

Cars are parked in cells separated by fire-resisting walls, with each cell open to an atrium through which the car parking machinery (and the cars being transported) can move. Cells can have room for 2 cars side-by-side or 3 cars side-by-side. The atrium stretched the full length of the fire compartment, although a variation on this geometry was considered, where the floor slabs left a shorter atrium than the length of the car park compartment, such that the end of each storey was effectively a 6 car cell. Calculations have been done for 2, 3, and 6 car cells (although the 6-car cell was only studied in the unsprinklered case.).

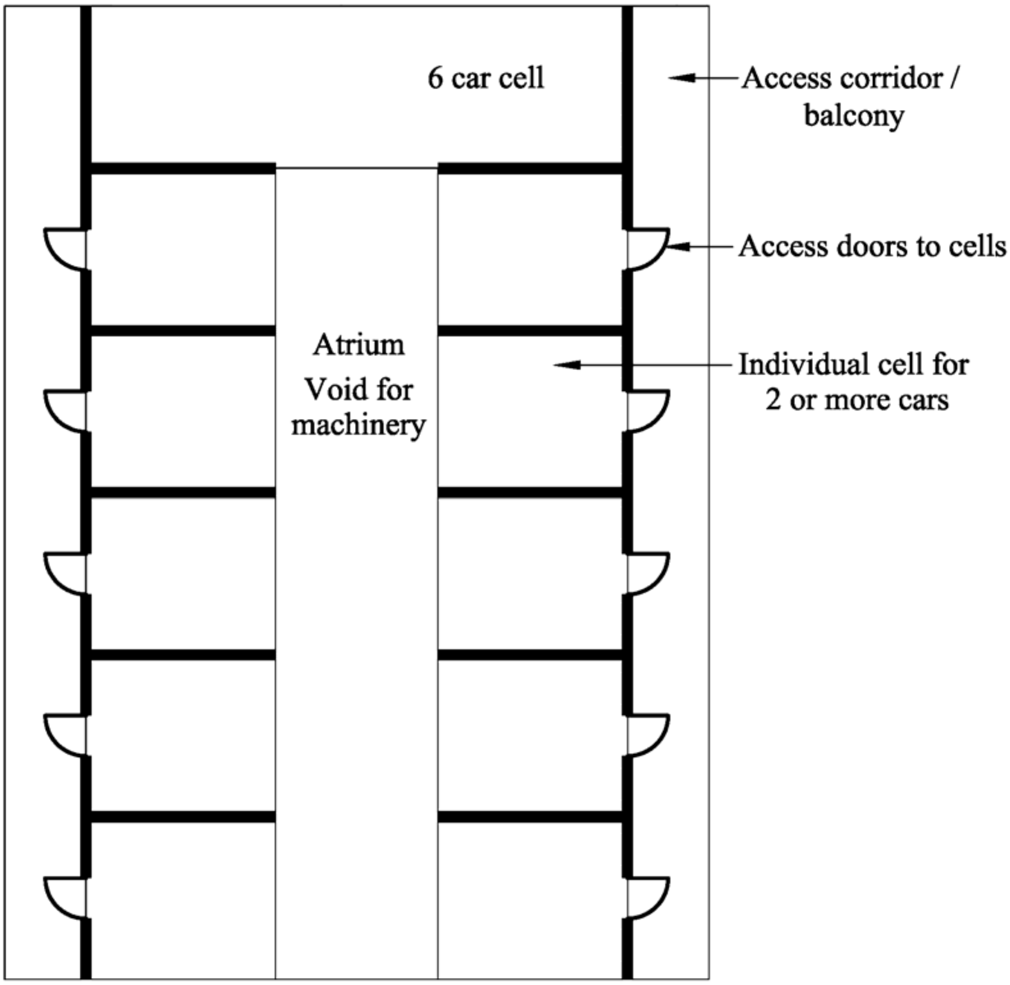

FIGURE 1a. Schematic plan view of typical storey

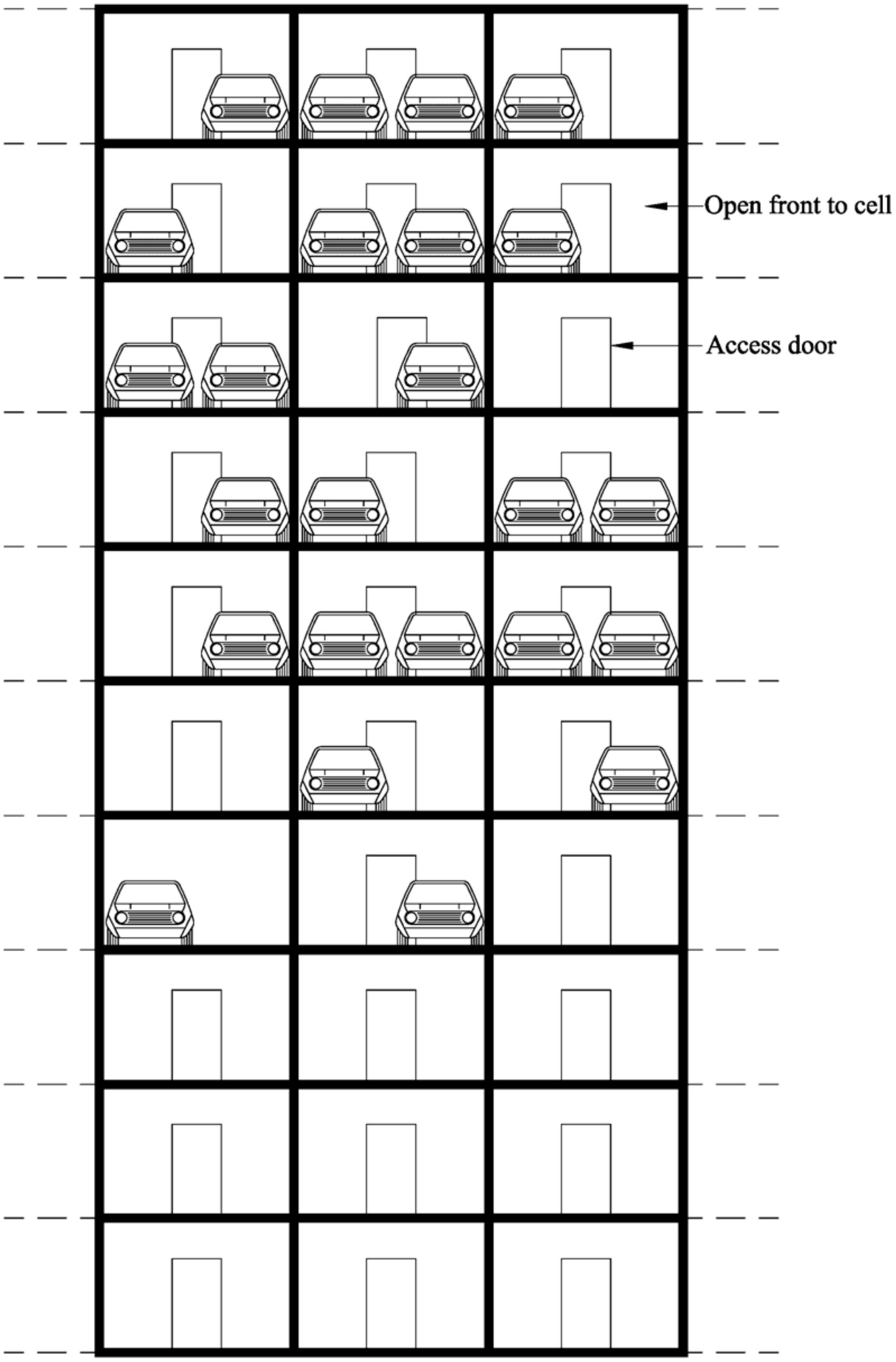

FIGURE 1b. Partial elevation, schematic view across atrium

Fire-fighters will have access to any fire location by open external stair and maintenance walkway on the exterior of the building with access to each cell via a door in the external wall. It would appear to be just as acceptable to specify both a fire-fighting stair and protected corridor within neighbouring fire compartments where a car park fire compartment forms part of a larger multi-purpose building. One would expect to have each rear-entry to each cell to be protected by a simple lobby in such a case.

CAR FIRE HEAT RELEASE RATES – A BRIEF HISTORY

The burning behaviour of cars is best described for calculation purposes in terms of heat release rate. Research fires in a simulated open-sided car park at the then Fire Research Station in the early 1960s [1], reassessed in terms of convective heat flux under the storey's ceiling close to the fire in the early 1970s, led to the conclusion that a severe value of convective heat flux was 2,500 kW. It was also concluded that fires would not spread from a car to its neighbour at "normal" car park spacing – although even in the 1960s [1] there was a cautionary note that this may not be valid for plastic-bodied cars.

The 2,500 kW design fire became widely accepted, see for example BR 186 [2]. The idea that fires would not spread between neighbouring cars is currently still found in Approved Document B to the Building Regulations [3], and in the LDSA Guide to Section 20 Buildings under the London Building Acts [4].

By 1999 there was a growing concern that car construction was changing, with a much higher proportion of plastics, and with more plastics used in the outside shell of the car. Consequently and rather arbitrarily the design fire for a car fire was increased to a convective 3,000kW in BR 368 (1999). At about the same time there became available a new generation of experiments where cars were burned under large calorimeters, using oxygen depletion measurements to measure the heat release rate as a function of time. The clearest such evidence came from Schleich et al. [5] in a paper delivered at Eurofire '98, which showed that a car fire could remain under 4,000kW for typically the first 15 to 20 minutes, then rising to 8,000 kW leading to fire spread to a neighbouring car. Note that one can multiply these heat release rates by 2/3 to obtain a convective value equivalent to the older design fires.

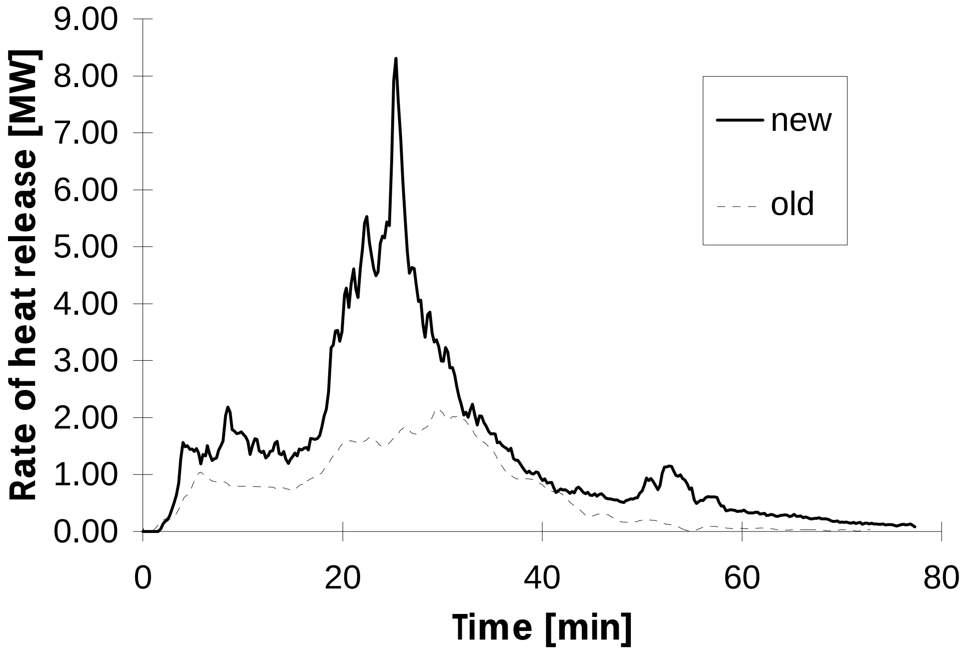

FIGURE 2. Heat Release Rate vs time for a category 3 car from Schleich et al. (Ref. 5)

Put simply, the new data shows that after the first quarter hour of the car fire, the old guidance becomes invalid. Firefighters able to attack the fire within the first 15 to 20 minutes will have a less arduous task than at a later time. For the purposes of the present paper, the contribution of the fire-fighters to controlling and extinguishing the fire is ignored, although this is likely to be a very real contribution; especially if the built-in fire protection measures make the fire-fighters task easier and quicker.

This and other information has been considered in the production of a Standard for smoke control in car parks (BS 7346-7 [6]). Note that the document recommends that the values in Table 1 should be the basis of design fires for car parks:

TABLE 1. Steady-state design fires

Fire Parameters	**Indoor car park without sprinkler system**	**Indoor car park with sprinkler system**
Dimensions	5 m x 5 m	2 m x 5 m
Perimeter	20 m	14 m
Heat release rate	8,000 kW	4,000 kW

Throughout the past 40 years it has been believed that sprinklers will have little effect on a one-car fire because cars are designed to keep out rain, but sprinklers would prevent the spread of fire to neighbouring cars by maintaining a film of water over the neighbouring cars. This remains the current doctrine.

OUTLINE OF CALCULATION METHOD

A fire is assumed to have started in a car in a cell, and to be burning at the rate specified in the Table above.

The mass flow rate of hot gases entering the atrium from the cell, and the temperature of those gases, is calculated using section 5.2 and 5.4 of BR 368 (1999) [7], expressed as an in-house IFC spreadsheet. It is generally recognised that a layer hotter than 500^{o}C to 600^{o}C will radiate sufficient heat to ignite other materials, and so any predicted temperature in or above this range leads to the conclusion that in the absence of sprinklers we need to amend the design fire to include every car in the cell e.g. a 2-car cell design fire would become 16,000 kW heat release rate.

The smoke movement and location of the main heat radiation threat to higher storeys is illustrated schematically in Fig. 3.

This hot gas will spill into the atrium and will rise. CIBSE Guide Volume E Fire Safety Engineering (2003) [8] tells us that the axial temperature of a spill plume is twice the mass-weighted gas temperature at the same height above the spill edge (the top of the opening of the cell).

We can use the recent simplification of spill plume entrainment by Harrison and Spearpoint [9,10] to calculate the mass flow rate at any specified height. This has been incorporated in an IFC in-house spreadsheet.

From this and the convective heat flux we obtain the mass-weighted temperature for that height, and hence the axial temperature. We can note that the axial temperature of 550^{o}C is often taken as defining the flame height. Where the spill plume has a flame height similar to the height of the cell directly above the fire cell, we can expect the heat radiation to ignite cars in the higher cell, leading to a “runaway ignition” and probable loss of the building.

The exhaust fan capacity needed to maintain a smoke layer above the storey immediately above the fire cell (i.e. to maintain clear fire-fighter access on the fire storey and on the storey above – to check for secondary fires) has been calculated using equation 5.16 of BR 368 [7].

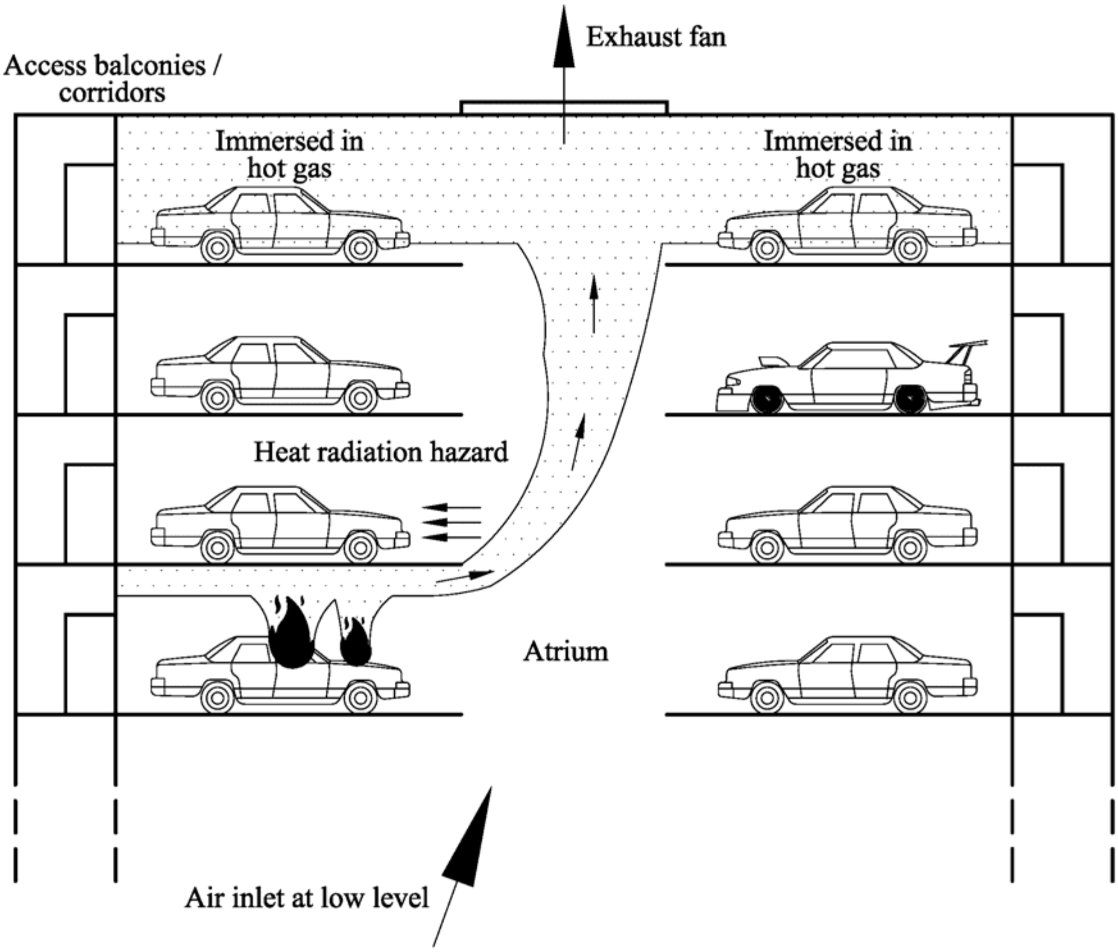

FIGURE 3. Schematic showing smoke movement and location of maximum heat radiation hazard to higher cell

As an alternative basis for smoke control design, we can note that most plastics including PVC will not be harmed by a gas temperature of about 70°C. The fan capacity needed to maintain this as a temperature-control system has also been calculated. For a main atrium layer temperature < 70°C we can expect minimal damage to vehicles in further cells, even if they are immersed in the smoke.

PRACTICAL IMPLICATIONS

Unsprinklered cells larger than a 3-car cell can expect vertical fire spread from cell to cell, leading to a runaway fire growth unless the fire is extinguished within the first 15 minutes or so.

It is a common design principle to limit the air inlet velocity to 5 m/s in order to avoid inconvenience to people opening final exit doors. This tells us that the larger exhaust rates in Table 2 would need to have unreasonably large areas for incoming replacement air.

2 and 3 car cells can be controlled even without sprinklers, provided there can be a smoke and heat exhaust ventilation system of a relatively large capacity.

TABLE 2. Summary of results of calculation

No Sprinklers	6 car cell	Runaway fire growth after 15-20 minutes
	3 car cell	Flashover in cell. Go to 3 car fire.
		Spill flame plume c. 0.8 m high. Probable damage to parts of cars near open edge in cell above fire
		Fan exhaust for firefighter access – 113 m^3/s
		Fan exhaust for minimal damage – 228 m^3/s
	2 car cell	Flashover in cell. Go to 2 car fire
		Spill flame height 0.65, minor chance of fire spread to cell above.
		Fan exhaust for firefighter access – 76 m^3/s
		Fan exhaust for minimal damage – 152 m^3/s
With Sprinklers	3 car cell	No flashover
		No flames in atrium
		Fan exhaust for firefighter access – 37 m^3/s
		Fan exhaust for minimal damage – 38 m^3/s
	2 car cell	No flashover
		No flames in atrium
		Fan exhaust for firefighter access – 32 m^3/s
		Fan exhaust for minimal damage – 38 m^3/s

Sprinklers prevent flashover, allowing smoke and heat exhaust capacities (and inlet areas for replacement air) to become much smaller and more practical.

The gain in terms of minimising damage to immersed cars may be attractive to Insurers, especially when sprinklers and fire-fighting are both considered.

In view of the automated machinery, and the corresponding absence of regular occupants, there is no Means of Escape issue within the stacked areas, except for maintenance personnel who can use a “permitted entry” system of tickets to prevent operation while they are in the stack.

The lack of a Means of Escape problem effectively removes the issue from Building Regulations concern, and raises the possibility of accepting even a total loss of the building should this appear economically viable. It would of course be necessary to agree such a strategy with the fire service and with the Insurers.

This car storage building need not be designed on the basis of a total burn out.

A smoke control system should be installed to limit temperatures to below that where damage is likely to occur to other vehicles.

In order for the ventilation system to be practicable, the design fire needs to be restricted to no more than 2 cars.

This can be achieved by means of fire resisting construction (i.e. cells for a maximum of 2 cars each) or by the installation of a fire suppression system (e.g. sprinklers in each cell, which can include cells for more than 2 cars).

If a sprinkler system is installed the fire can be expected to be limited to a single vehicle and smoke temperatures will be cool enough to avoid damage to other cells in the fire compartment. There are savings in the size of the ventilation plant compared to the unsprinklered case.

REFERENCES

1. Butcher, E.G., Langdon-Thomas, G-J. and Bedford, G.K., "Fire and Car-Park Buildings", Fire Note No. 10, The Fire Research Station (Later a part of the Building Research Establishment) 1968.
2. Morgan, H.P. and Gardner, J.P., "Design Principles for Smoke Ventilation in Enclosed Shopping Centres", BRE Report BR 186, Garston, CRC, 1990.
3. The Building Regulations 2000, Fire Safety, Approved Document B, amended 2002, Department for Communities and Local Government, London, 2000.
4. London District Surveyors Association Fire Safety Guide No. 1, Fire Safety in Section 20 Buildings, LDSA Publications, London, 1997.
5. Schleich, J.B., Cajot, L.G. and Joyeux, D., "Natural Fires in Closed Car Parks", Eurofire 98, Belgium, 1998.
6. British Standards Institution BS 7346-7: 2006. "Components for Smoke and Heat Control Systems: Part 7: Code of Practice on Functional Recommendations and Calculation Methods for Smoke and Heat Control Systems for Covered Car Parks, BSI, 2006.
7. Morgan, H.P., Ghosh, B.K., Garrad, G., Pamlitschka, R., De Smedt, J-C, and Schoonbaert, L.R., Design Methodologies for Smoke and Heat Exhaust Ventilation, BR 368, CRC, London 1999.
8. Chartered Institute of Building Services Engineers, CIBSE Guide Volume E: "Fire Engineering", London, CIBSE, 2003.
9. Harrison, R. and Spearpoint, M., "Spill Over", Fire Engineers Journal, 65:258, 33-35, 2005.
10. Harrison, R., "Smoke Control in Atrium Buildings: A Study of the Thermal Spill Plume", Fire Engineering Research Report 04/01, Department of Civil Engineering, University of Canterbury, New Zealand, 2004.