Steel framed car parks

- Characteristics of steel framed car parks
- Fire safety engineering for car parks
- Design example
- Applications of steel framed car parks
Characteristics of steel framed car parks

Customer friendly car parks shall have no columns in the parking spaces!

Better solution!
Characteristics of steel framed car parks

Basis of lay-out
Characteristics of steel framed car parks
Characteristics of steel framed car parks

Cross section through split level car park
Finish fire tests in 1991
French tests to analyse fire spread
Statistical overview of cars involved fire events

- **Number of cars**
  - 1: 80% superstructure, 90% infrastructure
  - 2: 10% superstructure, 0% infrastructure
  - 3: 0% superstructure, 0% infrastructure

- **Percentage of cases (%)**
  - 1: 80%
  - 2: 10%
  - 3: 0%
Derivation of RHR curve

- Scenario of 1, 3 or 4 car burning
- Spread is taken as 12 or 15min

![Graph showing RHR curve for different cars over time](image)
Carparks
New fire engineering model

Determination of the fire scenario

Development and spread of the fire

Heating of the structural elements

Mechanical behaviour of the structure
Possible Fire Scenarios

1 car burning in the middle of the span

Bridge approach
Possible Fire Scenarios

3 car burning near column (spread 12-15min)
In case of sprinklers scenario reduced to 1 car
Possible Fire Scenarios

3 car burning in mid span (spread 12-15min)
Rather unusual geometry but severe scenario
Possible Fire Scenarios

4 car burning in mid span (spread 12-15min)
Typical scenario for columns
Open Car Park fire tests in VERNON 2000
Open Car Park fire tests

2,5m

5,0m

2,33m
Open Car Park fire tests

Test arrangement

Direction of wind

Perimeter columns: HEA 180  
Inner columns: HEB200
Open Car Park fire tests

1 min
Design Example

Underground Car Park
“Auchan”
Closed Car Park: Commercial Centre Auchan

Main data

- **Owner:** Stadtteilzentrum Kirchberg S.A.
- **Location:** Kirchberg, Luxembourg City
- **Erection:** 1999-2001 (Extension of Car park)
- **Architect:** Arkitektbyran AB, Atelier A+U
- **Designer:** Schroeder & Associés, TR-Engineering
- **Contractor:** HOCHTIEF Luxemburg S.A.
- **Building:** Extension of 4 Storey underground car park
- **Dimensions:** $L \times W = 67.2 \times 50.4$ m
- **Structure:** Composite structure
Close Car Park: Commercial Centre Auchan
Description of Structural System

Structure:

- Composite Beams IPE 550 in S460 (full shear connected)
- Beam span 16.8 m
- Slab of 16 cm in C30/37 (Pre-cast slab 4 cm)
- Floor Span 4.2 m
- Partially encased columns HD 400x 237(187) in S355
- Simply supported beam to column connections
- Horizontal stiffness trough concrete core (Staircases)
Close Car Park: Commercial Centre Auchan
Fire Safety Concept

Active fire fighting measures:
- Smoke exhaust System
- Sprinklers
- Automatic alarm detection
- Automatic alarm transmission to the fire brigade

Natural Fire Approach resulted in:
- Partial encased Columns
- Unprotected composite Beams

Constructive changes in the structure to reach this:
- Some additional rebars have been put on middle support in order to activate a hogging moment in case of fire.
- Beam to Column connection using an extended end plate with additional row of bolds in the slab

Natural Fire Concept accepted by the Authorities
Close Car Park: Commercial Centre Auchan Situation
Most severe fire scenario in this project

8.4 m

CAR

x
Localised Fire: HASEMI Method

Annex C of EN 1991-1-2:
• Flame is impacting the ceiling ($L_f > H$)

$Y = \text{Height of the free zone}$

$\theta_g$ = Air Temperature at Beam Level

Calculated by CaPaFi
Excel Macro CaPaFi
(based on Hasemi Method)

This Excel Macro is based on EN 1991-1-2, prEN 1993-1-2, and the ECSC projects "Large Compartment" & "Closed car parks"

- EN 1991-1-2 Annex C: Calculation of heat flux
- prEN1993-1-2: Calculation of steel temperatures
- Development of design rules for steel structures subjected to natural fires in LARGE COMPARTMENT
- CEC Agreements 7210-SA/210/317/517/619/932: Calibration of the method (The beam height is taken into account)
- Development of design rules for steel structures subjected to natural fires in CLOSED CAR PARKS
  CEC Agreements 7210-SA/211/318/518/620/933: Validation of the method & Measured rate of heat release of burning

It has been created in order to calculate the temperature in a steel member heated up by 1 to 5 local fire sources.

The aim of this tool is to simulate the temperature distribution in open car parks as well as huge closed car parks (walls are far enough from the fire in order to avoid any influence on the heat distribution).

The method gives the temperatures under the ceiling at different horizontal distances and is only valid in cases, in which the fire is impacting the ceiling.

The given rates of heat releases are calibrated on cars and are based on real measurements.
**Excel Macro CaPaFi Input**

![Excel Macro CaPaFi Input](image)

<table>
<thead>
<tr>
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<th>B</th>
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<th>D</th>
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<th>P</th>
<th>Q</th>
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<tbody>
<tr>
<td>Beam position (horizontal)</td>
<td>X [m]</td>
<td>Y [m]</td>
<td>CAR position</td>
<td>X [m]</td>
<td>Y [m]</td>
<td>CAR 1</td>
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<td>CAR 3</td>
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<td>CAR 5</td>
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<td>Coefficient beam</td>
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To obtain estimated gas temperatures set Am/V to: 9999
Excel Macro CaPaFi
Rate of Heat Release

Rate of heat release of the localised fire sources

![Graph showing rate of heat release over time for different cars](image-url)
Calculation of Gas Temperatures with CaPaFi

![Diagram showing temperature over time for different curves labeled C1 to C6.](image)
Simulation of the Structure With the FE Software Ceficoss
Temperature in section on support

Gas temperatures from HASEMI Curve C6
Temperature in section on mid span

Gas temperatures from HASEMI Curve C1
Ceficoss results

TIEFGARAGE AUCHAN IPE550 SCENARIO A
VALEUR PROPRED MINIMALE

NPV fire/cold

30.0
60.0
90.0

1.0
0.5

120.0

t (min)

ARBED-RECHERCHES / SERVICE RPS

ANALYSE CEFICOS / CEF13.0

titre du projet
AUCHAN

numero de projet
99-06-02

ESCH/ALZETTE : 6-AUG-1999 FEUILLE 13
Maximum displacement of the structure
Vertical displacement at mid span
Visible steel beams thanks to NFSC concept
Picture of the structure
Picture of a connection
Application: steel framed open car parks

Carpark Bouillon- Luxembourg
Application: steel framed open car parks

Car park Airport Dresden (D)
Application: steel framed open car parks

Car park
Airport Dresden (D)
Application: steel framed open car parks

Amershan car park (UK)
Application: steel framed open car parks

Car park for shopping mall
Aix-en-Provence (F)