



PART 5b
COMPLETED BUILDINGS

Illustration of completed buildings

Overview

No.	Project	City
1	Indoor Football Arena	Rauma, Finland
2	State Street Bank	Luxembourg, Luxembourg
3	Office Building of ProfilARBED	Esch/Alzette, Luxembourg
4	Köln-Arena	Cologne, Germany
5	Bilbao Exhibition Centre	Bilbao, Spain
6	City Gate Düsseldorf	Düsseldorf, Germany
7	Charles de Gaulle Airport	Paris, France
8	Shopping Centre Cactus	Esch/Alzette, Luxembourg
9	Shopping Centre Las Cañas	Viana, Spain
10	Airbus Hall	Toulouse, France
11	Rembrandt Tower (study)	Amsterdam, Netherlands

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Indoor Football Arena, Finland

General Information

Type: Sports hall

Inauguration: 2004

Height: 21 m

Hall floor
area: 7600 m²

Span of
trusses: 71 m



Indoor Football Arena, Finland Structure

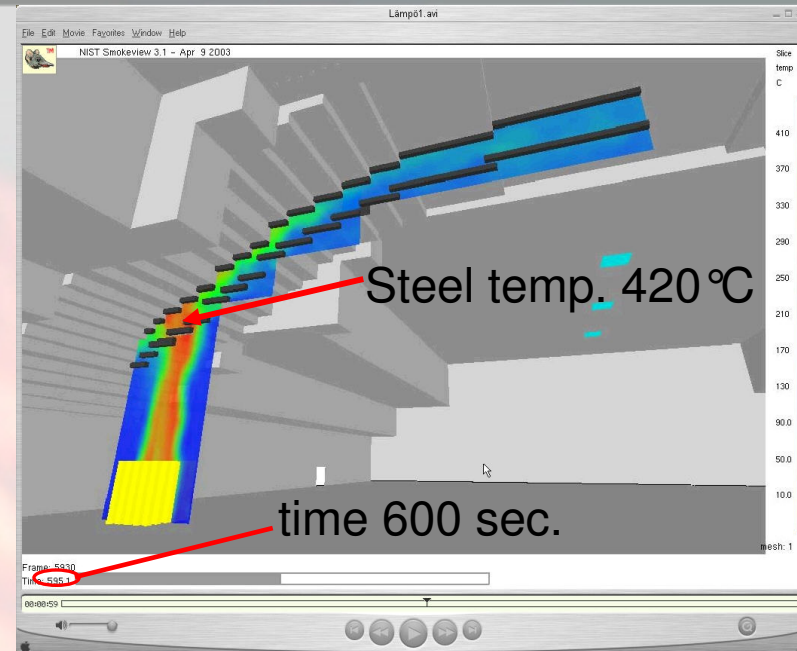


- Frames made of a tubular truss structure with a span of 71.2 m
- Distance between frames 13.5 m
- Steel grade S355

Indoor Football Arena, Finland

Fire safety concept

- Required fire resistance class: R 60
- Application of Natural Fire Safety Concept
- Active fire fighting measures
 - ✧ automatic alarm
 - ✧ transmission to fire brigade
 - ✧ smoke exhaust
- Fire load: 14 MW (one exhibition stand)



Air and steel temperatures were calculated by using FDS simulation

⇒ maximum steel temperature 420 °C

Indoor Football Arena, Finland

Fire safety concept

- The trusses were protected up to a height of 10 m to R 30 (intumescent painting), the upper structure was left unprotected (About 25 % of the steel structure was protected)
- The structural system still meets the functional requirement of a rescue time of 60 minutes
- Temperatures at the height of 2 meters were only 20 – 40 °C and the smoke-free zone after opening the smoke extraction hatches was at least 4 m ⇒ Safe evacuation

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State Street Bank, Luxembourg

General Information

Type: Office building including an underground car park

Storeys: 4
+3 underground floors for car park

Processing
time: 2000 – 2001

Height: 21.6 m

Ground Plan: 63 m x 38.8 m



State Street Bank, Luxembourg Structure

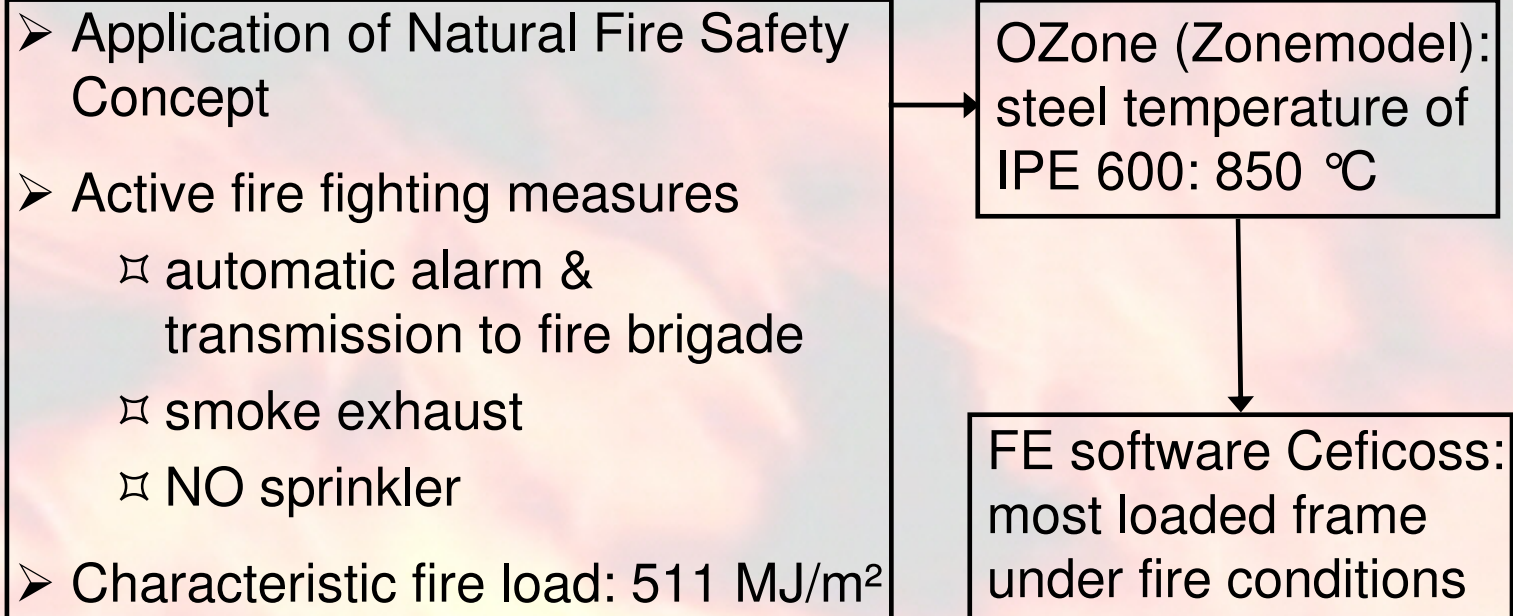
- Frames with 3 spans (15.15 m, 8.5 m, 15.15 m)
- Distance between adjacent frames is 4.5 m
- Height per storey is 4.2 m (except first 4.5 m)
- Slab with thickness of 36 cm (16 cm C30/37, 20 cm finishing)
- Composite beams are made of S355 (8.5 m) and S460 (15.15 m) and are partially encased with concrete in the underground car park



- Columns are made of S355 and are partially encased with concrete
- Concrete cores including stairs and elevators provide horizontal stability

State Street Bank, Luxembourg

Fire safety concept



State Street Bank, Luxembourg

Fire safety concept

Additional measures

- Extended endplate with one row in concrete slab \Rightarrow shear forces can be transmitted
- Additional rebars on middle support \Rightarrow negative bending moment can be activated

Passive fire protection measures

- Office building
 - ✧ Beams are unprotected
 - ✧ Columns are partially encased
- Underground car park
 - ✧ Beams and columns are partially encased



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Office building of ProfilARBED, Luxembourg

General Information

Type: Office building

Processing
time: 1992 – 1993

Storeys: 8

Total
Surface: 15,000 m²



Office building of ProfilARBED, Luxembourg Structure

- four atria provide natural illumination
- steel structure without concrete bracing
- horizontal loads are carried off by a truss structure
- truss structure is integrated in the atria
- columns are made of HE-profiles
- grid of the columns is 6.0 m x 7.2 m
- slabs are made of IFB system



Office building of ProfilARBED, Luxembourg

Fire safety concept

- Short ways to staircases
- Staircases separated from main structure
- Optimal ventilation by heat and smoke exhausts
- Sprinkler system



Low temperatures in the steel structure



Execution of steel structure without any use of fire protection material



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KölnArena, Germany

General information

Type: General purpose hall

Processing
time: 1996 – 1998

Total Height: 76 m

Surface Area: 83,700 m²

Seats: 18,000

Investment: 150 million of Euro



KölnArena, Germany

Structure

Load transfer of the structure:
Supporting ring → 36 columns



Load transfer of the roof:
28 truss beams → hangers → arc

KölnArena, Germany

Fire safety concept

Roof structure

Following fire scenarios were analysed:

- fire in the event area
- fire in the loge
- fire on the top level of the tribunes



- | | | |
|--|---|-------------|
| ➤ lower part of the arc (up to 3.0 m above the roof) | } | R 90 |
| ➤ horizontal bracing of arc | | |
| ➤ truss beams | } | Unprotected |
| ➤ round pipes | | |

KölnArena, Germany

Fire safety concept

Foyer

Foyer and staircases are
escape routes

⇒ Smoke free zone!!!



Fire in Foyer → unmanageable → has to stay free of fire loads

Fire in adjacent site → automatic closing of
fire resistant doors → escape route stays
free of smoke

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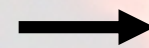
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Bilbao Exhibition Centre, Spain

General information



Type: Exhibition Centre



- 6 halls
- Underground car park
- Conference centre
- Offices
- Atrium
- Restaurants

Processing

time: 2001 – 2004

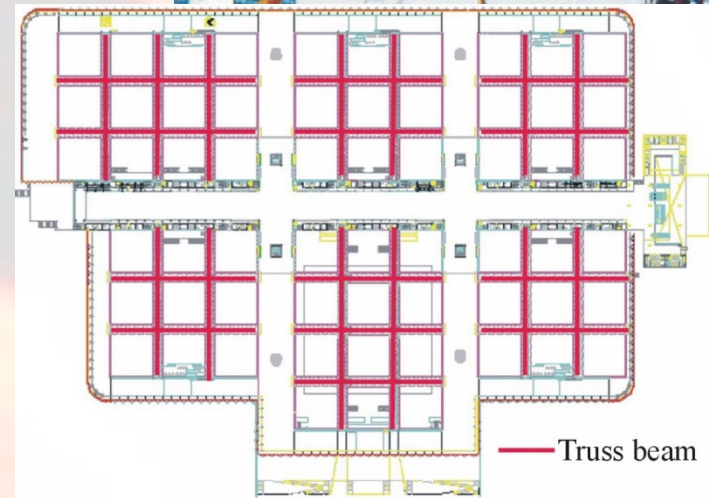
Surface area: 117,700 m²

Investment: 420 million of Euro

Bilbao Exhibition Centre, Spain

Structure

- Truss beams are made of structural steel
- Lengths of truss beams 125 m – 167 m
- Roof tubular spatial structure consists of 60 panels
- Columns are made of reinforced concrete



Bilbao Exhibition Centre, Spain

Fire safety concept

Necessary characteristics for alternative study:

- Low fire load
- Good ventilation
- Large diaphanous spaces with high thermal dissipation
- Presence of active protection measures (i.e. automatic sprinklers)
- Smoke control allows safe evacuation of the building



Alternative study: Determination, whether a lower protection than specified in the regulations gives the same level of security.

Bilbao Exhibition Centre, Spain

Fire safety concept

Conclusions of alternative study:

- Smoke curtains and smoke vents allows save evacuation
- Columns in the restaurant and lattice behind it remain unprotected
- Lattice supporting the mezzanine in the halls has to be protected
- Truss beams of the halls have to be protected



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City Gate Düsseldorf, Germany

General information

Type: High-rise building with
19 storeys

Processing
time: 1995 – 1997

Total Height: 72.55 m

Ground Plan: 51 m × 68 m (rhomboid)

Foundation: on the tunnel walls of the
Rheinuferstrasse



City Gate Düsseldorf, Germany Structure

Vertical loads:

- Concrete slabs of 15 cm thickness and spans from 2.5 m to 4.6 m
- Composite beams with spans from 7.5 m to 7.6 m
- Concrete filled steel tubes with diameters of 40 cm, 55 cm and 90 cm
- Highly subjected columns are supported by a rolled profile inside the tube



City Gate Düsseldorf, Germany Structure

Horizontal loads:

- 3-storey truss beams arranged in Z-shape
- Truss towers with height of approx. 70 m
- Two u-shaped staircases connected to truss frames



City Gate Düsseldorf, Germany

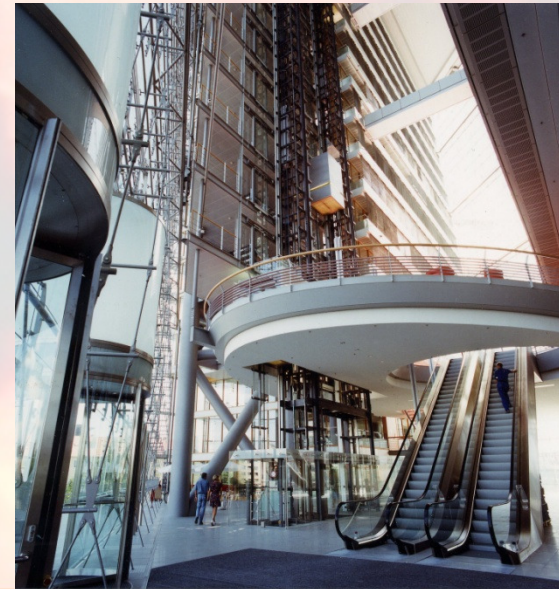
Fire safety concept

- 3 redundant sprinkler systems
- Concentrated placement of sprinklers near the facade
- Short ways to the escape staircases
- Fail-safe smoke exhaust system

⇒ Fire resistance class R 90

Unprotected Members:

- Balconies leading to the elevators
- Lobby level
- 19th floor (includes only machines)



City Gate Düsseldorf, Germany

Fire safety concept

Fire protection:

- Hollow sections of columns are filled with concrete
- Beams are partially encased
- Small beams are protected by contour encasement or hollow encasement
- Vertical tubes of truss frames are filled with concrete
- Horizontal and diagonal tubes up to the 3rd floor are filled with concrete



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Charles de Gaulle Airport, Paris

General information

Type: Airport

Inauguration: 1998

Total length: 520 m

Ground Plan: 130 000 m²



Charles de Gaulle Airport, Paris

Structure of Central Core

Roof structure:

Data:

Span: 57 m

Height: 21 m

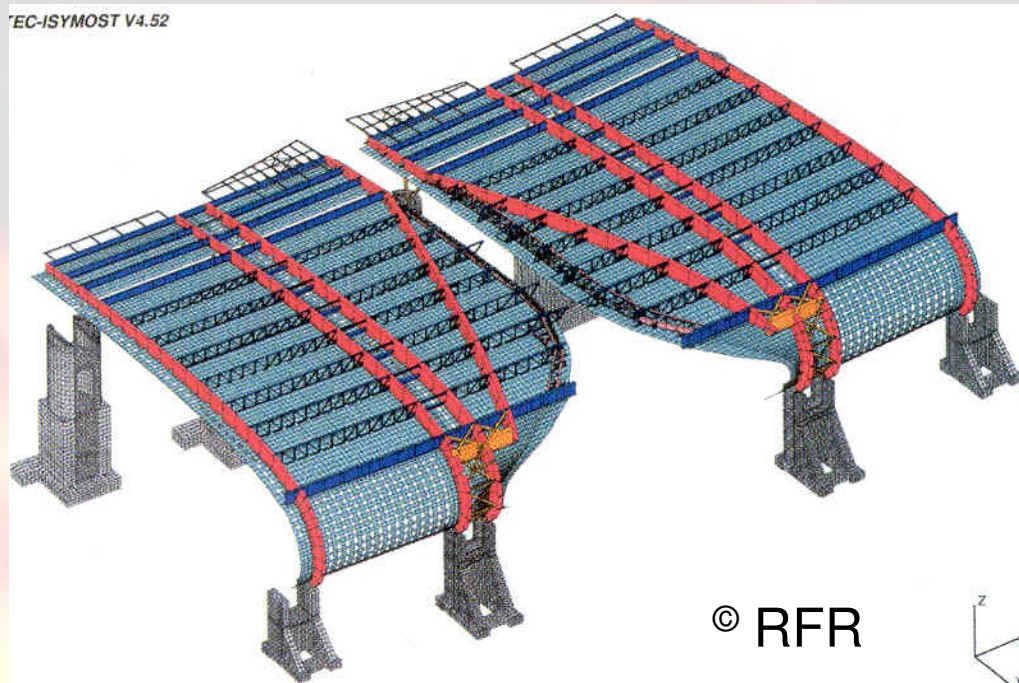
Steel: 5600 t

Assembly:

Zinc roofing structure

Steel structure

Concrete shell



Charles de Gaulle Airport, Paris

Structure of Peninsulas

Roof structure:

Data:

Span: 13 ÷ 48 m

Height: 8 ÷ 22 m

Steel: 650 t

Assembly:

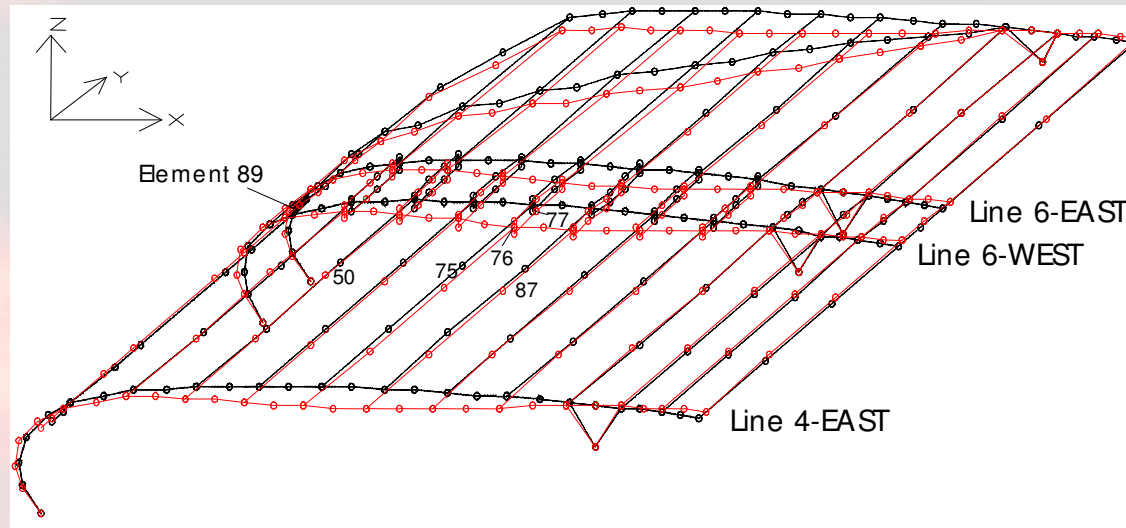
Virendeel beams



© Viry

Charles de Gaulle Airport, Paris

Fire safety concept (Central Core)



- Normative required fire resistance: R30
- Fire protection offered by the concrete shell
- Various openings for natural light and smoke extraction
⇒ local heating of the steel structure
- Exigency of global structural analysis

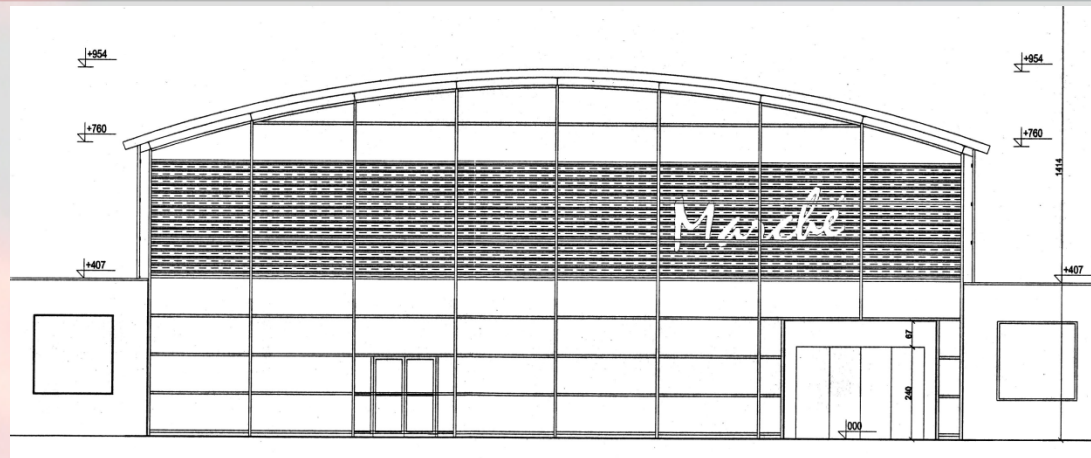
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Shopping Centre Cactus, Luxembourg

General information



Type: Shopping Centre

Inauguration: 2003

max. Height: 9.13 m

Ground Plan: 28.51 m x 48.16 m

Shopping Centre Cactus, Luxembourg Structure

- Portal frame with a span of 20 m
- Frames are connected by purlins (IPE 200)
- Steel columns (HE 500 B) made of S235
- Cambered cellular beams (final height 590 mm) made of S235
- Diameter of openings is 400 mm with distances between opening axes of 600 mm
- Horizontal stability is given by the frames and a bracing system on each side of the building



Shopping Centre Cactus, Luxembourg

Fire safety concept

Required fire resistance class: **R 90**

- Application of Natural Fire Safety Concept
- Active fire fighting measures
 - ✧ automatic alarm & transmission to fire brigade
 - ✧ smoke exhaust
 - ✧ NO sprinkler
- Characteristic fire load: 730 MJ/m²

OZone (Zonemodel):
steel temperature in
columns: 880 °C

FE software SAFIR:
➤ Complete 3D model
➤ Beam for local
phenomena

Shopping Centre Cactus, Luxembourg

Fire safety concept

Passive fire protection measures

- Beams and Columns will stay free of passive fire protection materials
- The fillet welds of the cellular beams were increased from 3 mm to 5 mm



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“Las Cañas” Shopping Centre, Spain

General information



Type: Shopping Centre → ➤ 80 shops

Inauguration: 2003

max. Height: 20.00 m

Ground Plan: L-shape

➤ 12 cinemas

➤ 1 discotheque

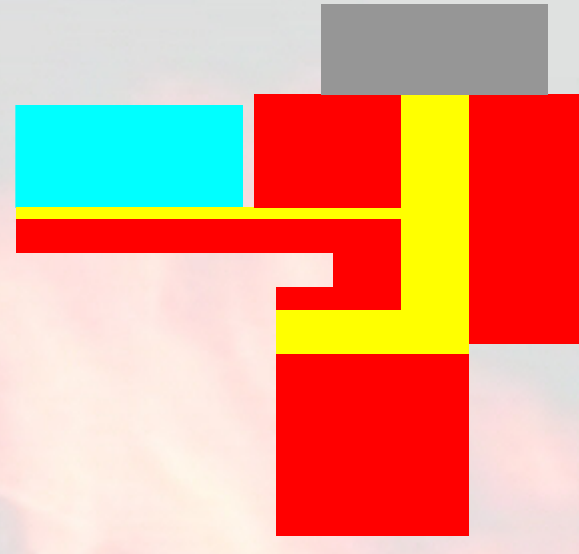
➤ 1 bowling centre

➤ 1 hotel

“Las Cañas” Shopping Centre, Spain

Structure

- Structure is completely made of steel
- Main corridor (yellow):
 - ✧ Columns (IPE)
 - ✧ Truss-structure (HEB)
- Supermarket (blue):
 - ✧ Roof is supported by timber beams resting on steel columns
- Retail area (red):
 - ✧ Continuous beams (IPE) on steel columns
- Cinemas (grey):
 - ✧ Steel columns



“Las Cañas” Shopping Centre, Spain

Fire safety concept

- Isolated building
 - Lower than 28 m
 - Lightweight roof ($< 100 \text{ kg/m}^2$)
- } \Rightarrow Fire resistance class R 30

Fire safety goals for the studied fire scenarios:

- Structural stability of the shops adjacent to the main corridor.
- Structural stability of the supporting elements of the corridor.
- Verification of the smoke control system formed by smoke vents and draft curtains.

“Las Cañas” Shopping Centre, Spain

Fire safety concept

- The supporting structure of the corridor were designed without passive fire protection.
- The beams inside the shops adjacent to the corridor remained unprotected.
- Some columns embedded in masonry walls were recommended not to be protected.
- The size and number of smoke curtains in the main corridor were increased.

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Airbus Hall Toulouse, France

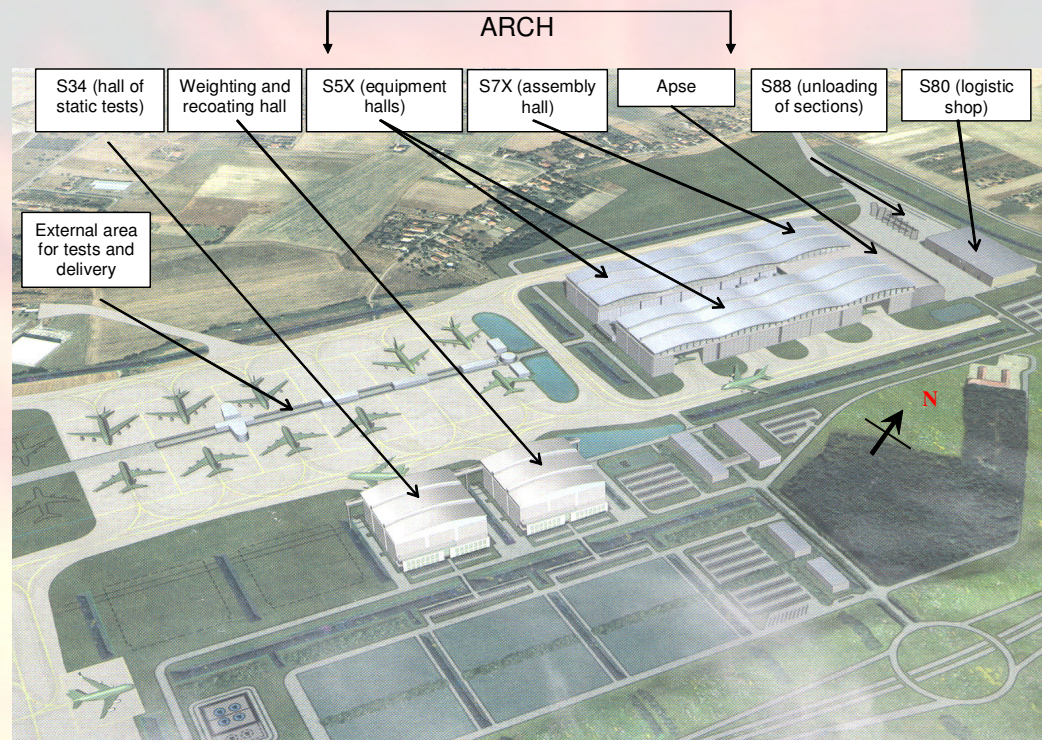
General information

Type: Assembly plant of Airbus A380

First
Airbus
delivery: 2006

Average
Height: 45.00 m

Ground
Plan: 200 000 m²



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Airbus Hall Toulouse, France

Structure

- Structure is completely made of steel
- For example:
Assembly hall S7X

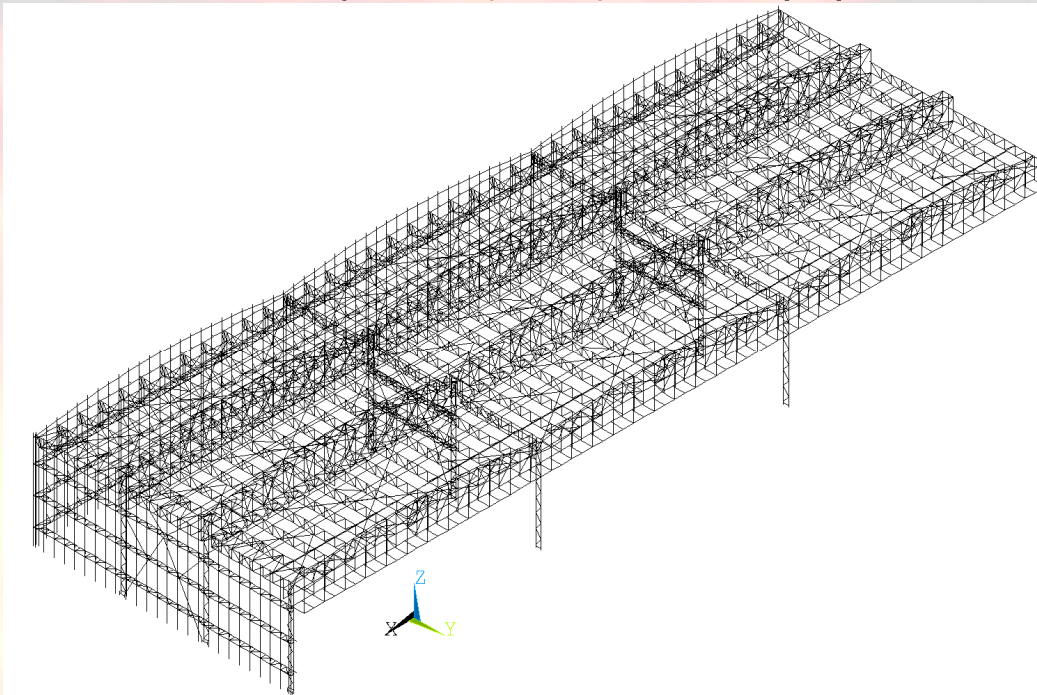
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Airbus Hall Toulouse, France

Fire safety concept

- ordinary fire safety requirement is not applicable
 - ⇒ experiences from similar works
 - ⇒ discussion with fire brigade
- partition wall between assembly hall (S7X) and equipment halls (S5X)
- Global structural analysis



Airbus Hall Toulouse, France

Fire safety concept

Fire safety study for three different fire scenarios:

- Fire of delivery truck near the column
- Fire of aircraft without fuel and various working tools
- Fire of aircraft full of fuel

Result of fire safety study:

- Danger of column collapse
- dynamic impact of steel truss beam on concrete partition wall leading to its damage

Consequence of fire safety study:

- Increasing the intensity of sprinklers for columns

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Rembrandt Tower (study), Netherlands

General information

Type: Office building

Inauguration: 1996

Height: 135 m

gross floor area: 52 000 m²

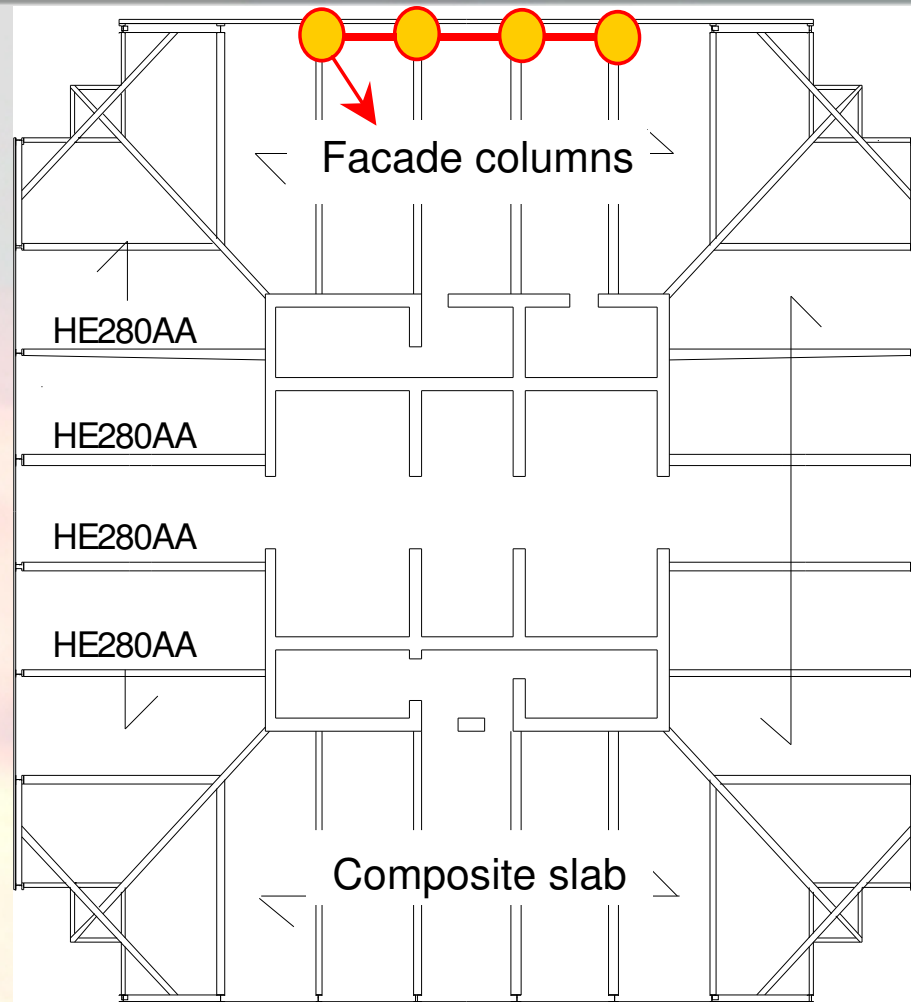
Tallest building in Amsterdam



Rembrandt Tower (study), Netherlands Structure

First tower in the Netherlands with a concrete core and a steel frame

The foundation required piles 56 meters long and two meters in diameter



Rembrandt Tower (study), Netherlands

Fire safety concept

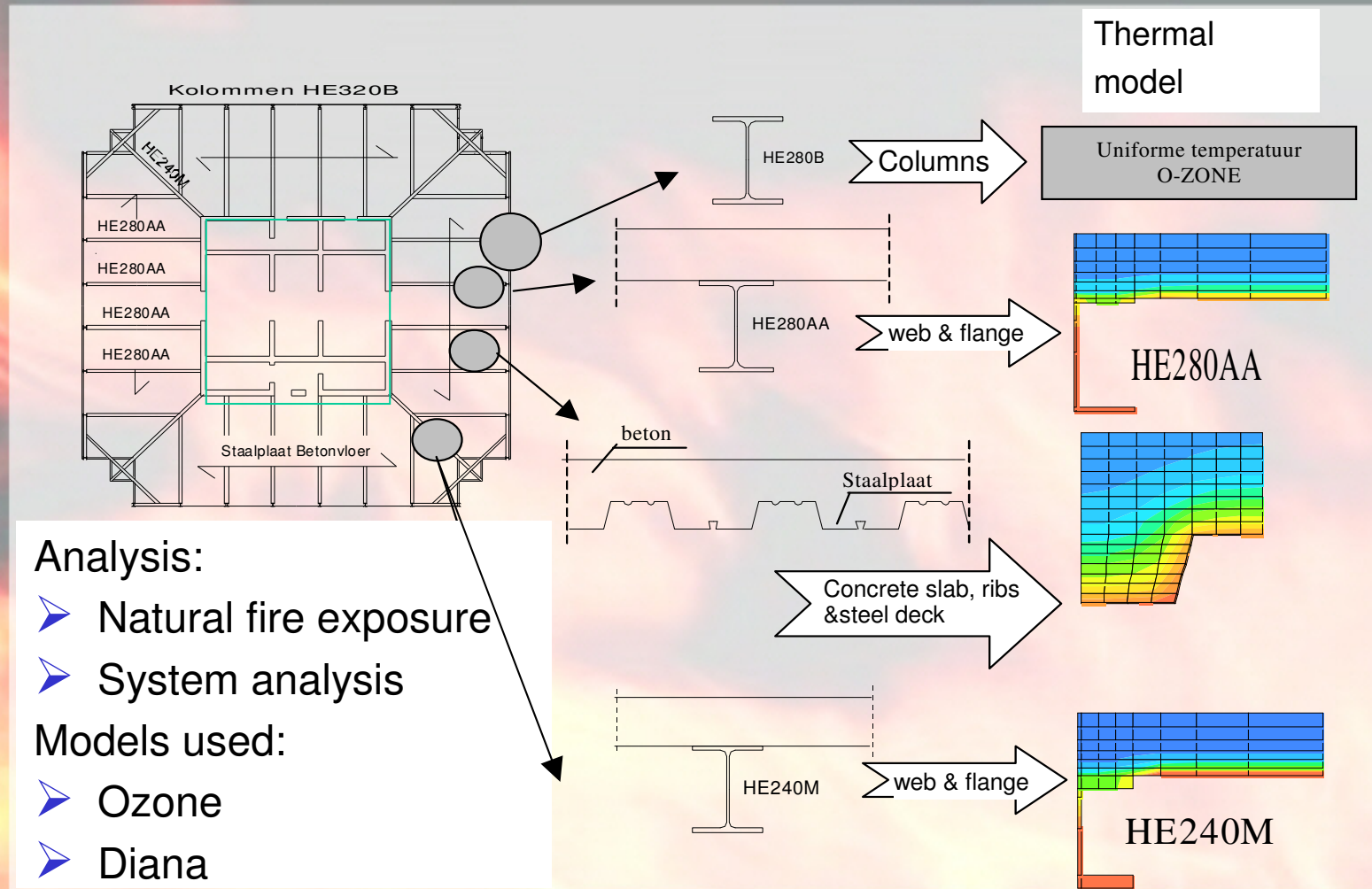
Building height > 70 m:

- Functional requirement: no collapse
- performance requirement: not in NL regulations
- Classification: R120 (beams, columns, floors) & sprinkler
- Alternative: FSE analysis



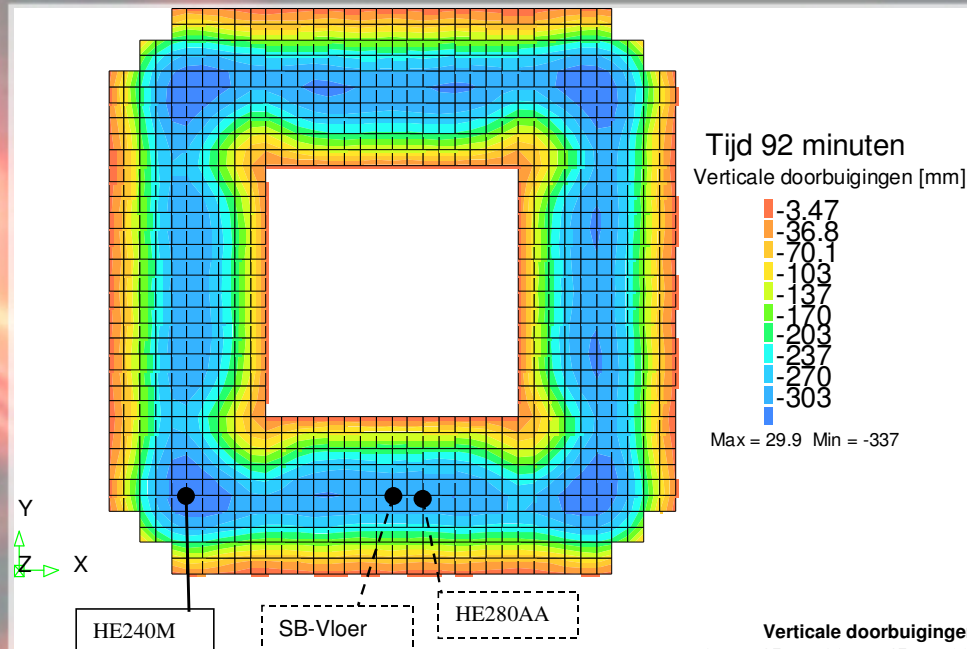
Rembrandt Tower (study), Netherlands

Fire safety concept



Rembrandt Tower (study), Netherlands

Fire safety concept

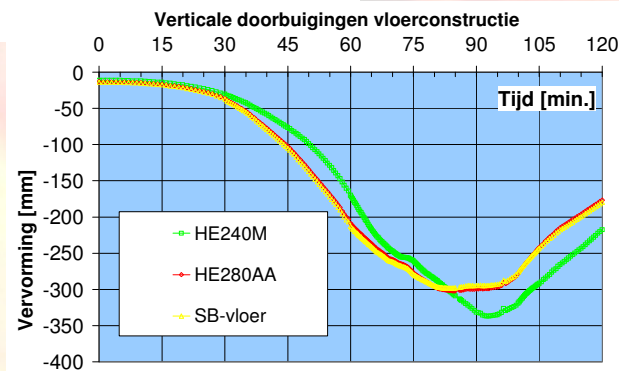


Result FEM analysis

For:

- Columns: protected (Promatect, 20 mm)
- Beams: unprotected

⇒ NO COLLAPSE!



Rembrandt Tower (study), Netherlands

Conclusions

- Functional requirement is met (i. e. no collapse)
- Significant cost reduction compared to actual solution (≈ 540 kEURO)
- Complementary measures found to be necessary (reinforcement connections)

Rembrandt Tower (study), Netherlands

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