Composite Steel and Concrete Structures

Innovative Solutions for Outstanding Buildings

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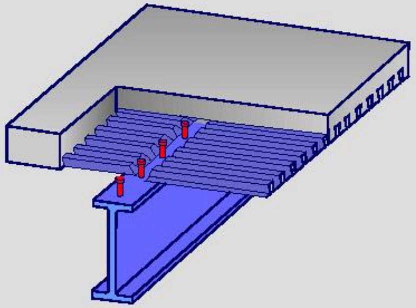

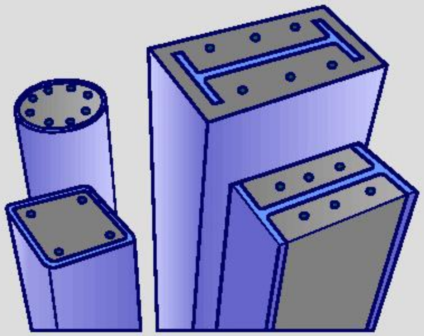

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Part I-1

Introduction

Typical composite members

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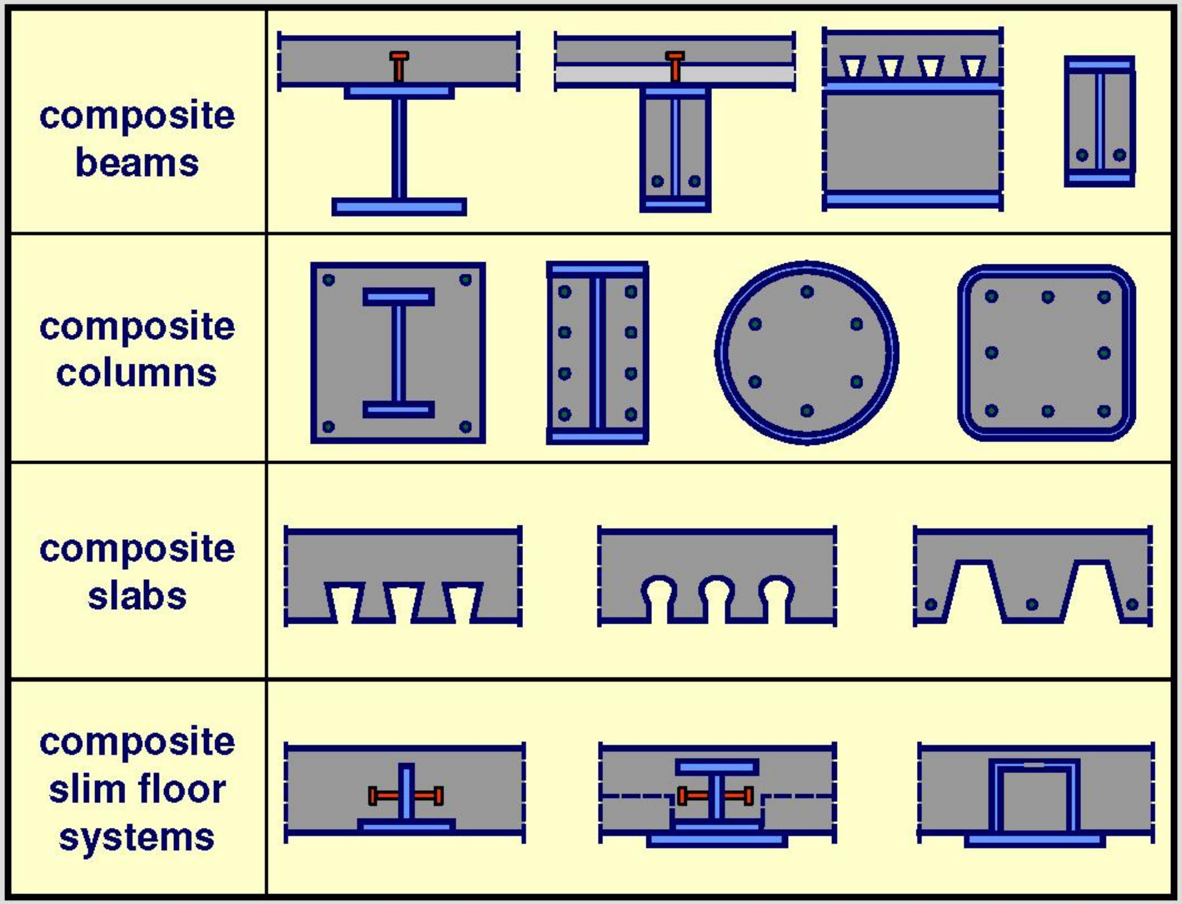

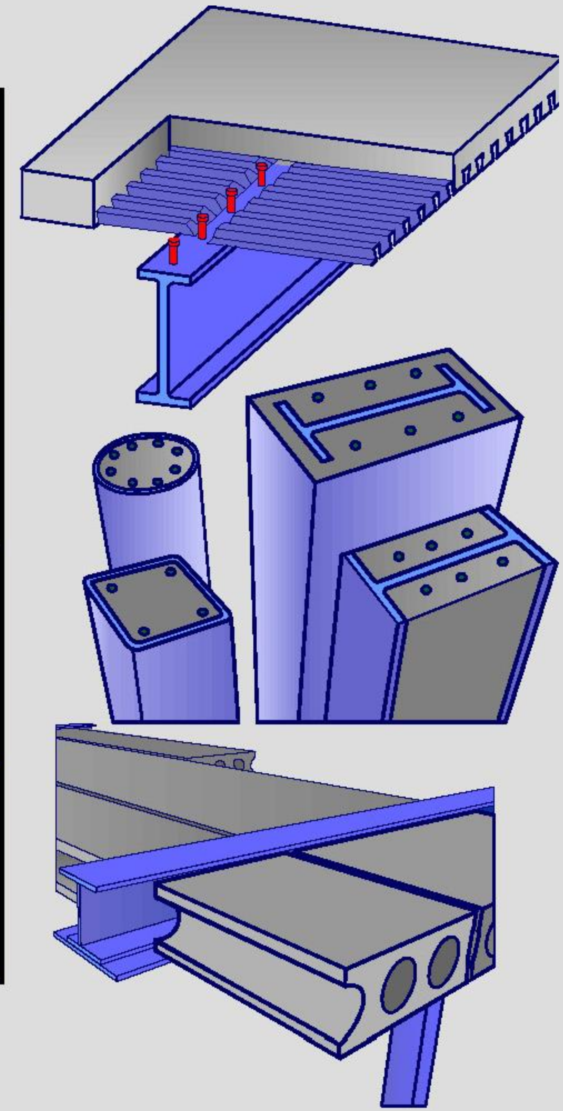

Typical application of composite structures for buildings

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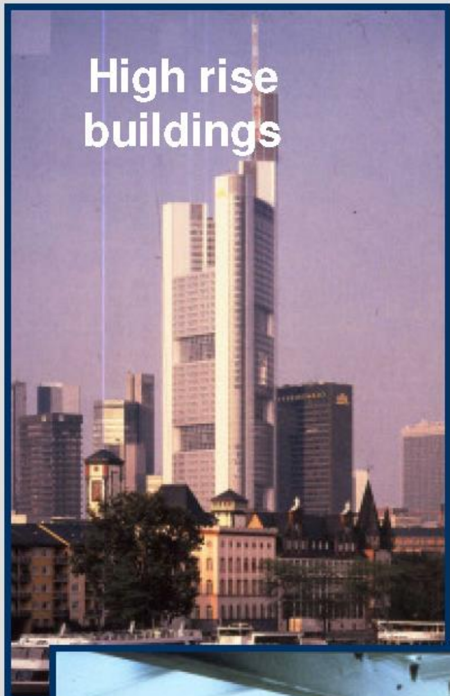

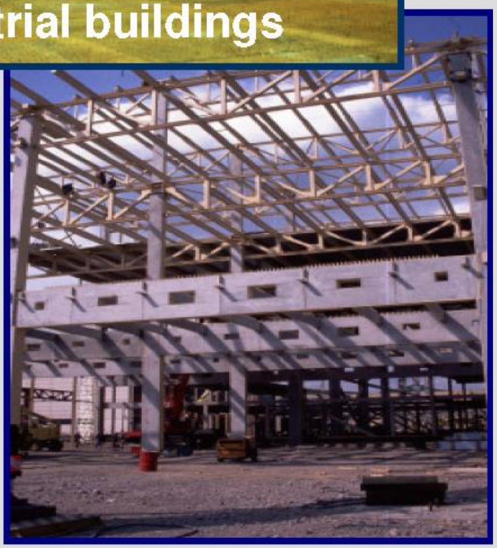

Typical application of composite structures for bridges

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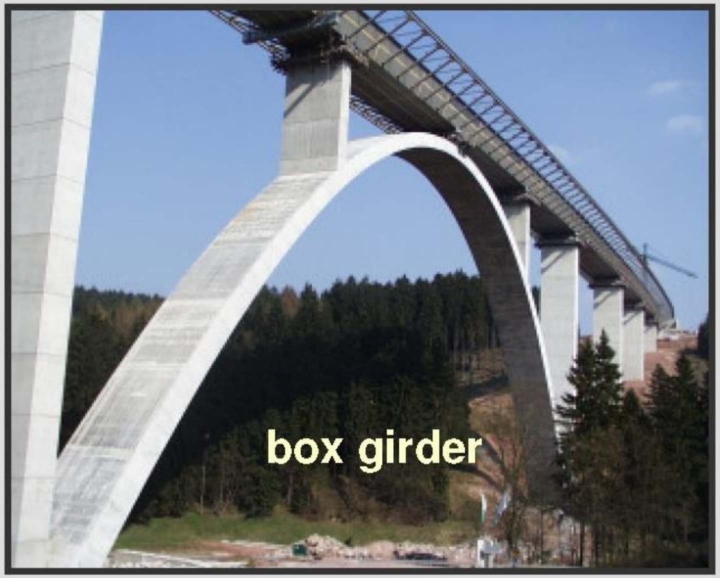

Advantages for the client and the building contractor

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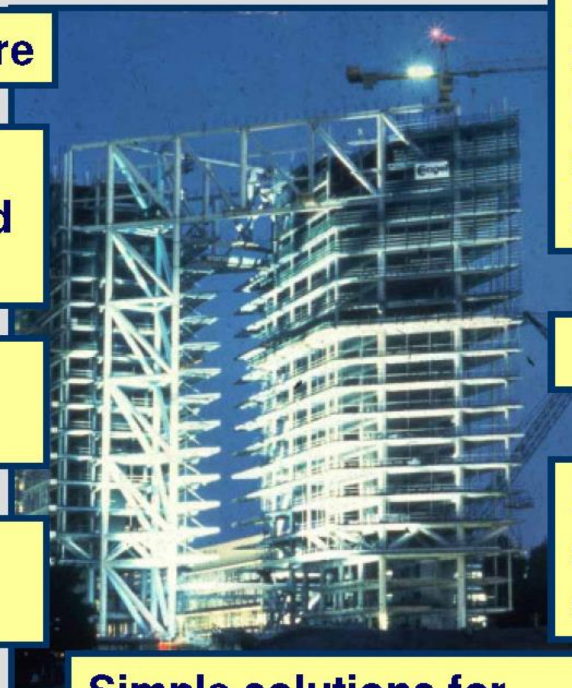
high degree of industrial prefabrication

Independence from exposure

Low area requirement for construction equipment and erection

Low construction time and reduction of building costs

High bearing capacity of beams and columns



high flexibility for the user due to longer span length of beams and small dimension of members

high fire resistance

high dimensional accuracy for finish and service work

Simple solutions for strengthening in case of later requirements for the use of the building

Historical overview

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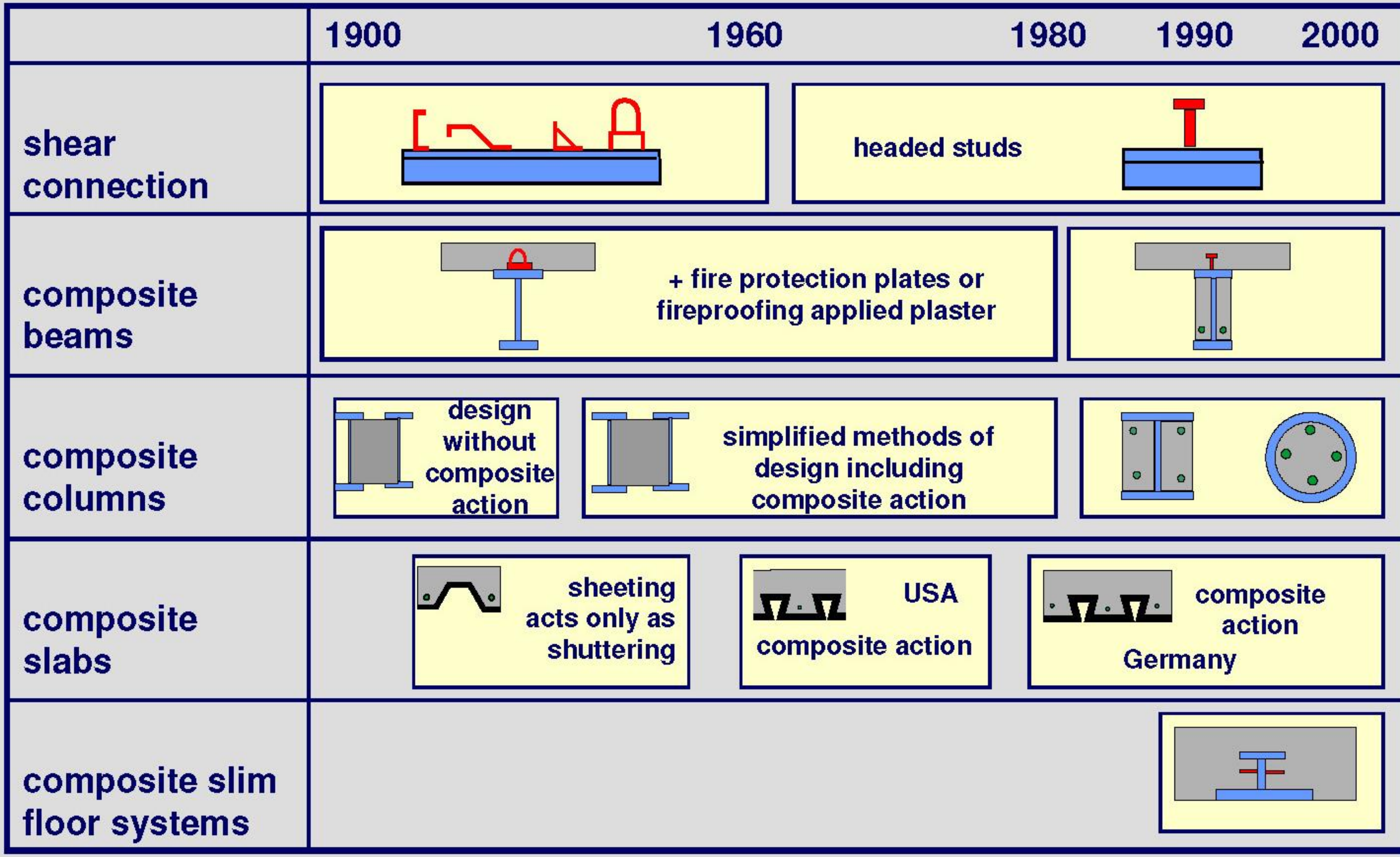
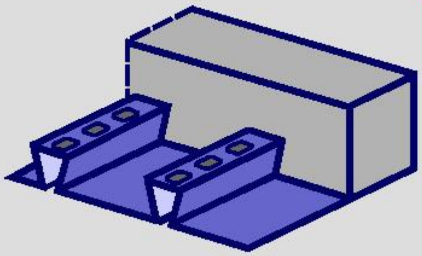


Part I-2

Composite slabs and composite slim floor systems



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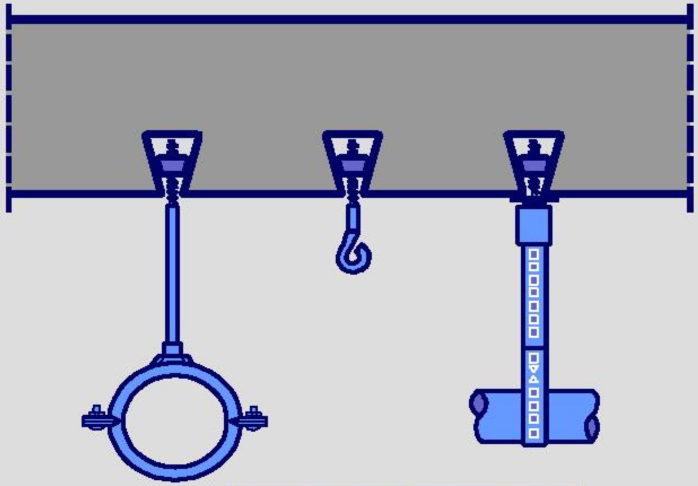
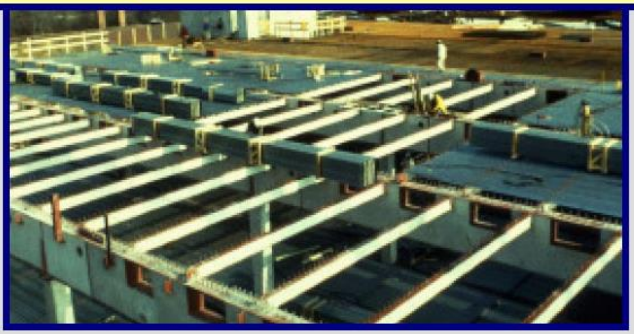
Composite slabs



- Steel sheeting can be assembled by hand.
- Steel sheeting can be used as work platform.
- Steel sheeting acts as formwork for casting of concrete.
- Steel sheeting acts together with concrete as a composite member in the final stage.
- Sheeting can be used to prevent lateral torsional buckling of the composite beam during erection.
- Steel sheeting allows simple solutions for fixing of service equipment
- High fire resistance



Composite slabs

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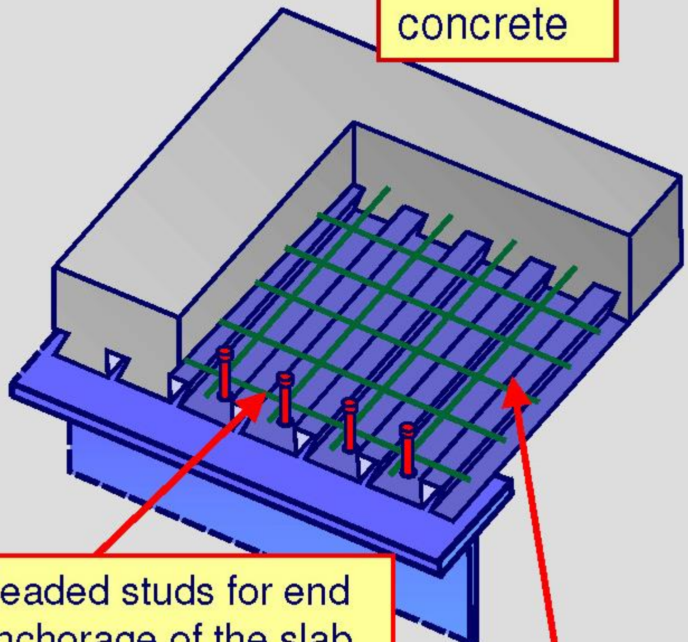
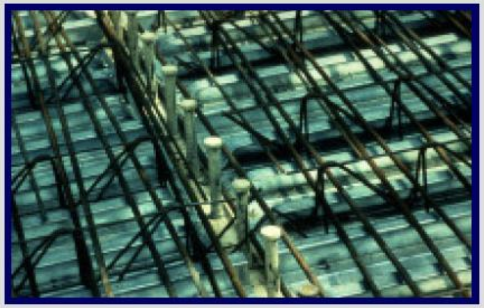
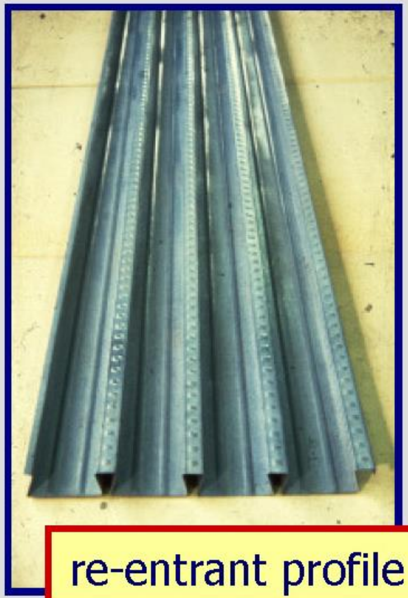


Composite slabs consist of thin profiled steel sheeting with zinc coating. For casting the sheeting is acting as formwork and after hardening of concrete the sheeting and the concrete act together as a composite member.





Composite slabs
Longitudinal shear resistance

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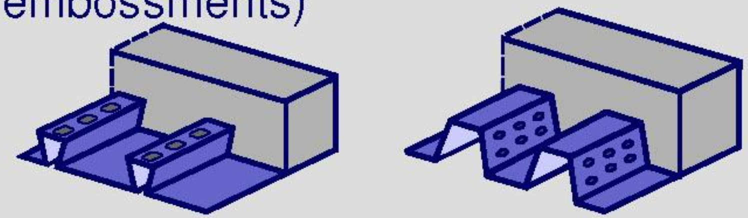
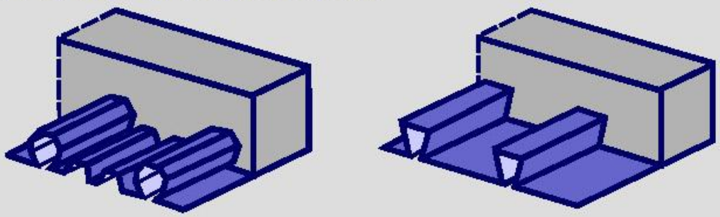
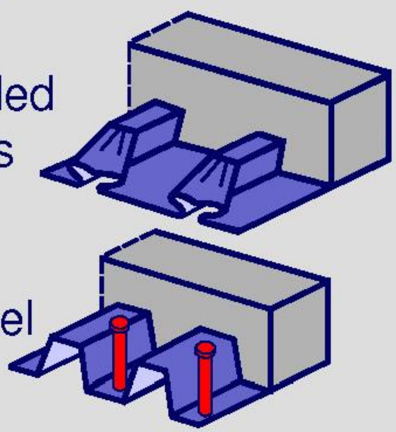
mechanical interlock provided by deformations in the profile (indentations or embossments)

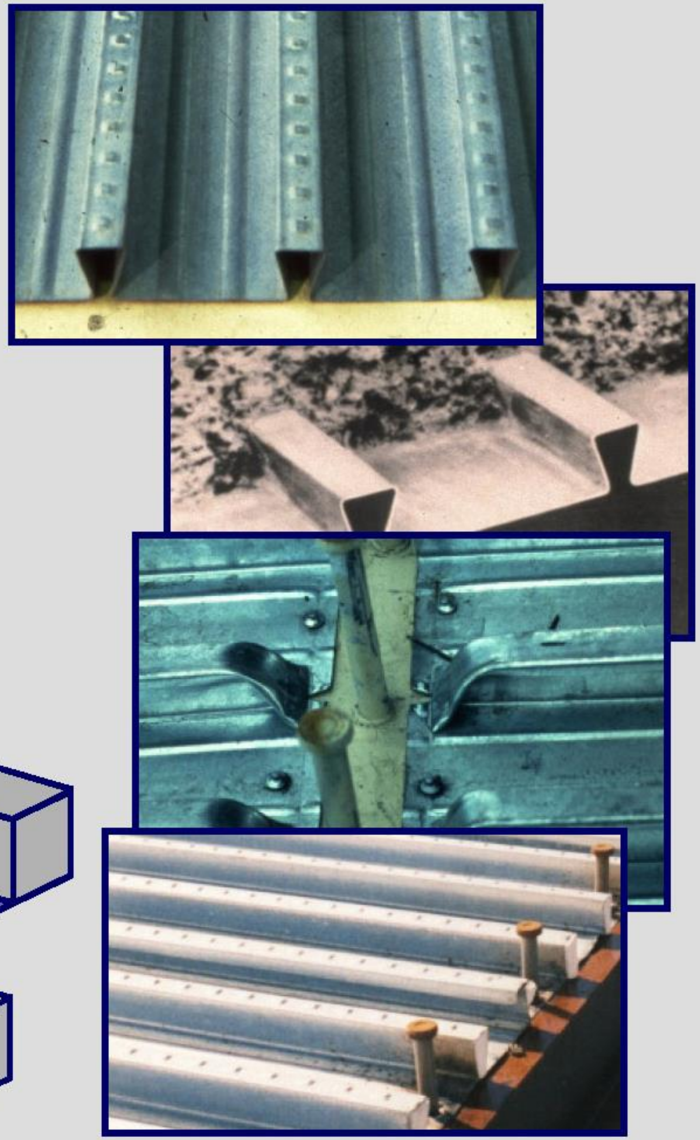


frictional interlock for profiles shaped in a re-entrant form



end anchorage provided by welded studs or by deformation of the ribs at the end of the sheeting or by another type of local connection between the concrete and the steel sheet





Composite action due to mechanical interlock and friction

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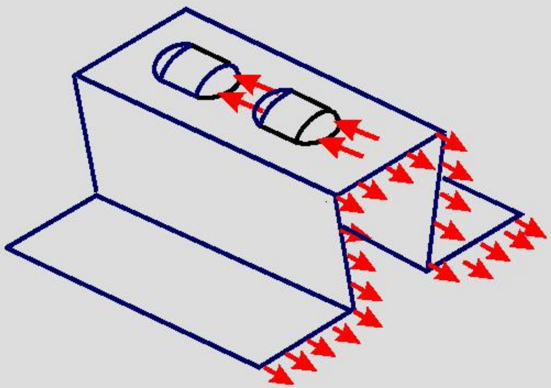
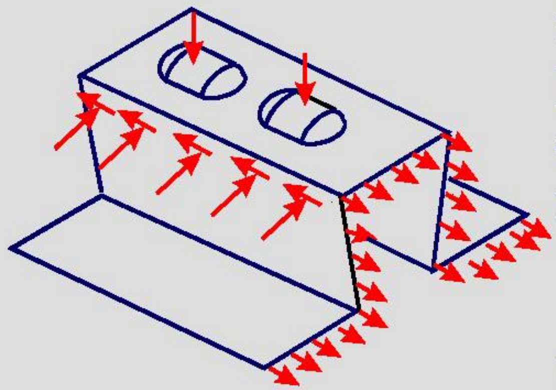
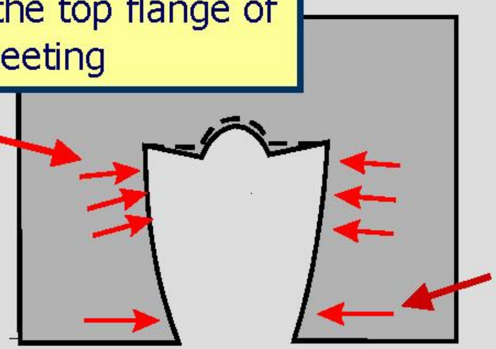
mechanical interlock + **frictional interlock**

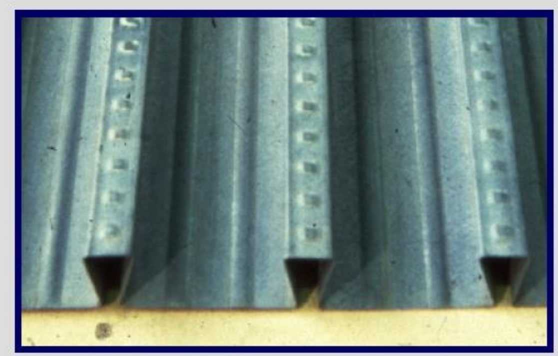




Indentations or embossments cause friction in the interface between steel and concrete in addition to the mechanical interlock.

Friction due to vertical deformation of the top flange of the sheeting





Friction due to lateral strain of the sheeting (effect of Poisson's ratio)

Temperature distribution in composite slabs in case of fire

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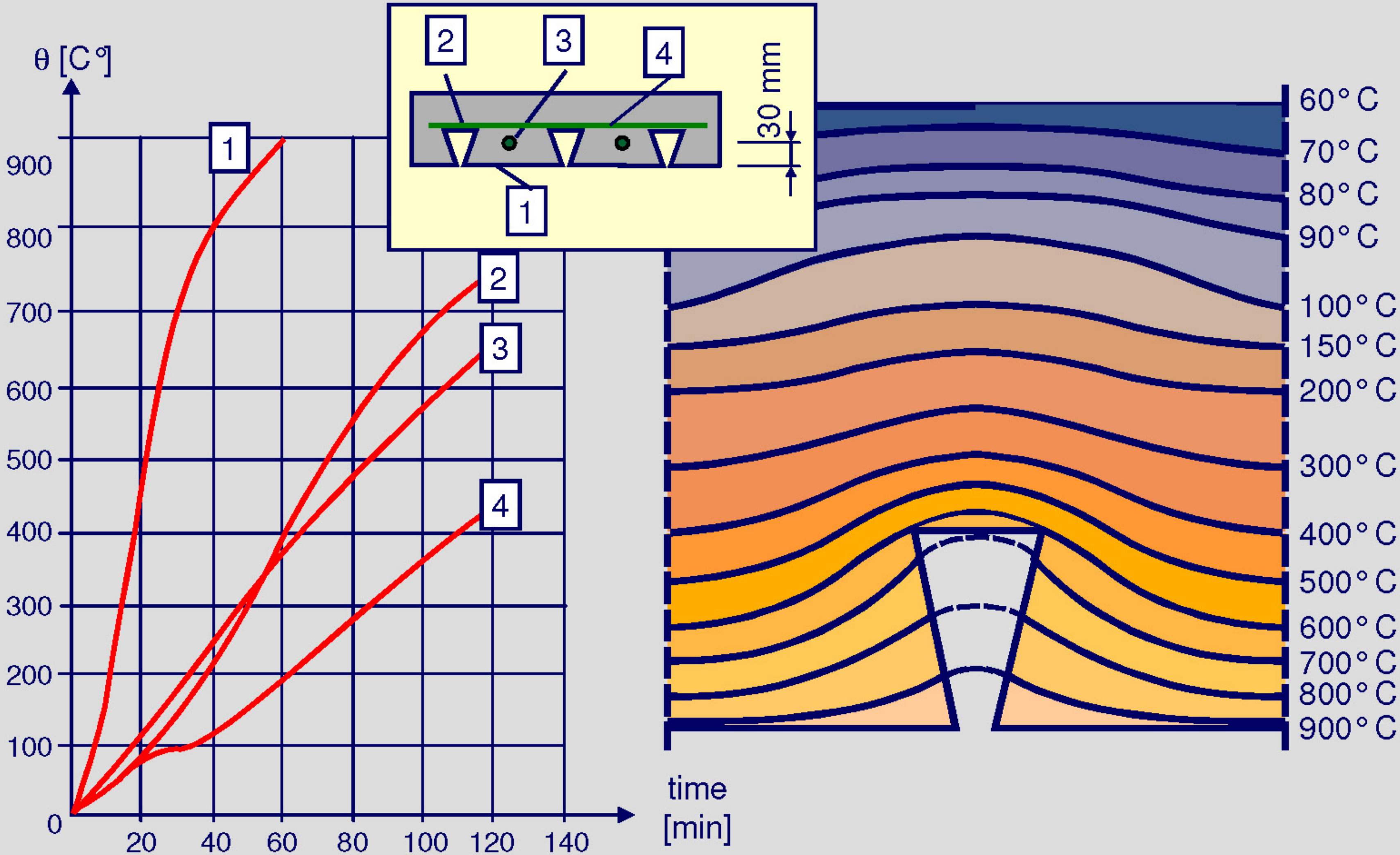

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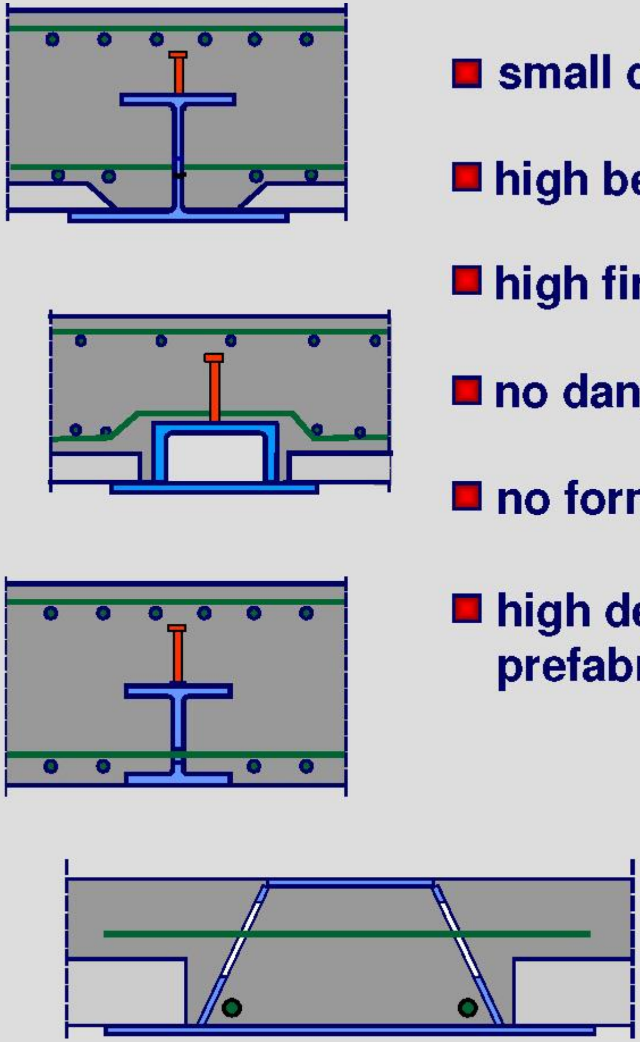
Composite slim floor systems



- small depth of the cross-section
- high bending resistance
- high fire resistance
- no danger of punching shear
- no formwork
- high degree of industrial prefabrication

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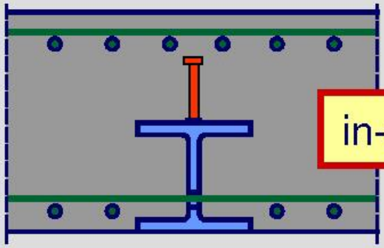
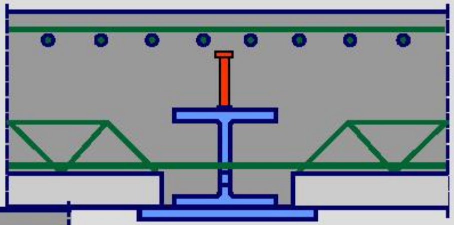
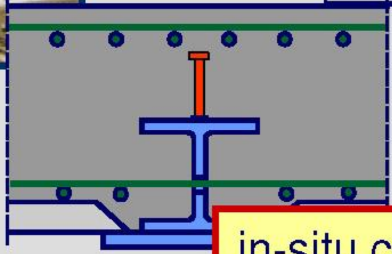
Composite slim floor systems



in-situ concrete



in-situ concrete in combination with partially prefabricated concrete elements



in-situ concrete in combination with profiled steel sheeting

Composite slim floor systems

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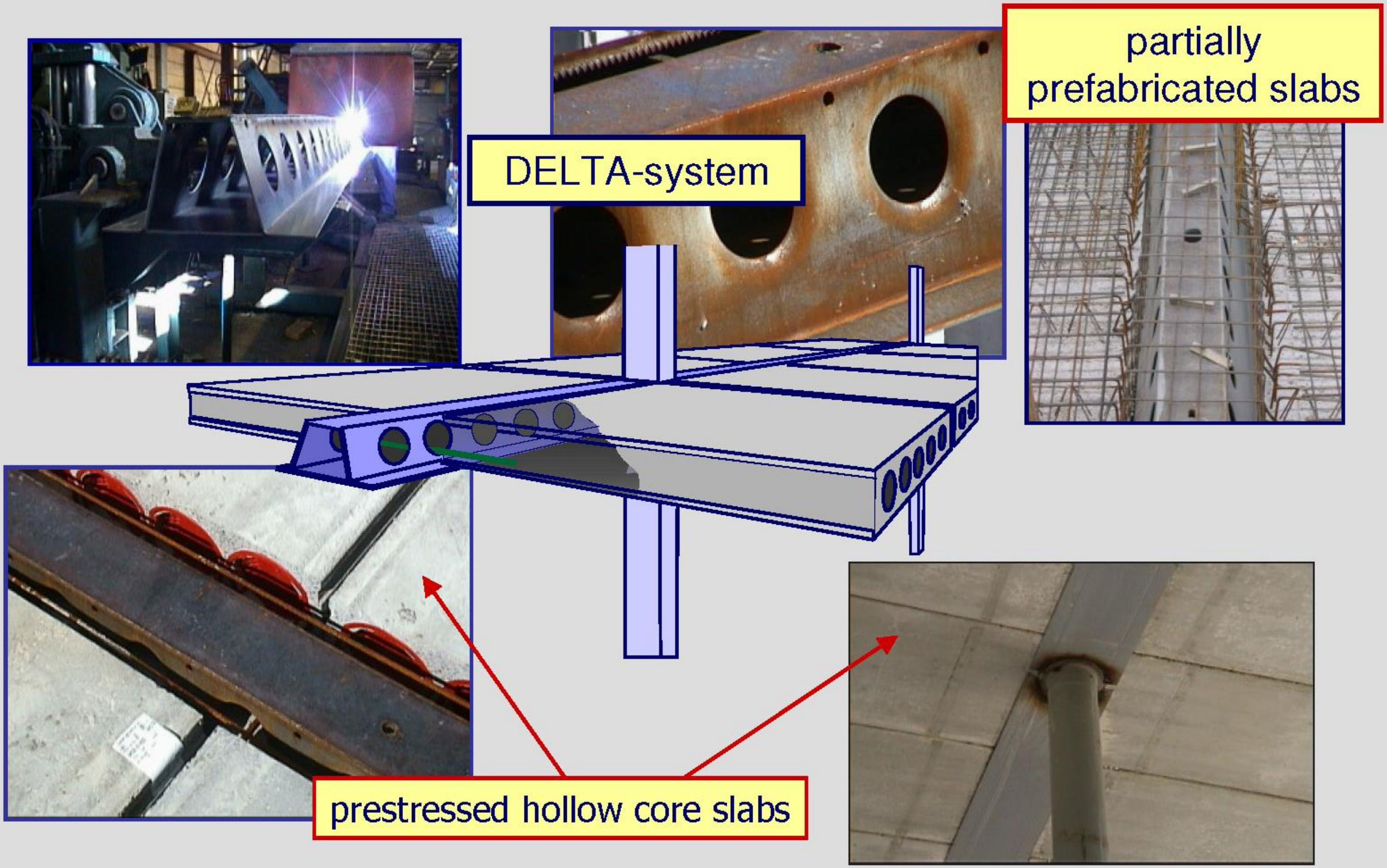

Composite slabs with high steel profiles

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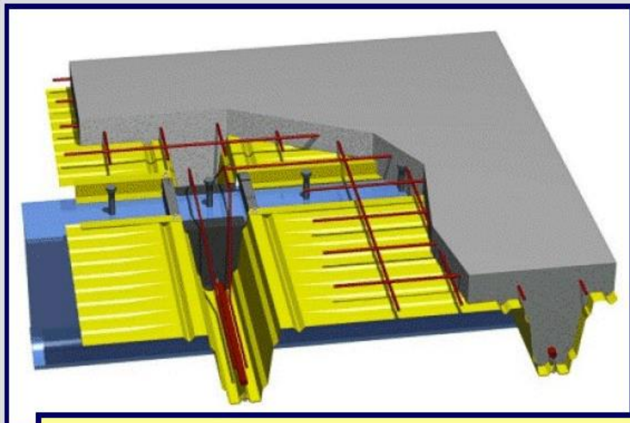
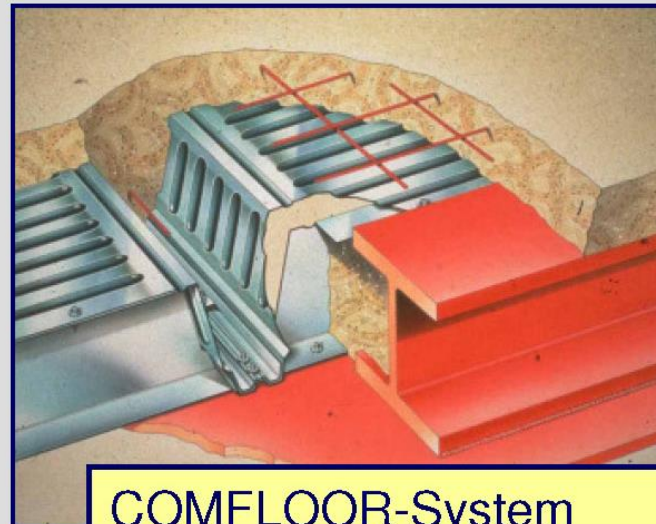


Hoesch - Additiv - System



COMFLOOR-System

Systems to increase the punching shear resistance of concrete slim floors

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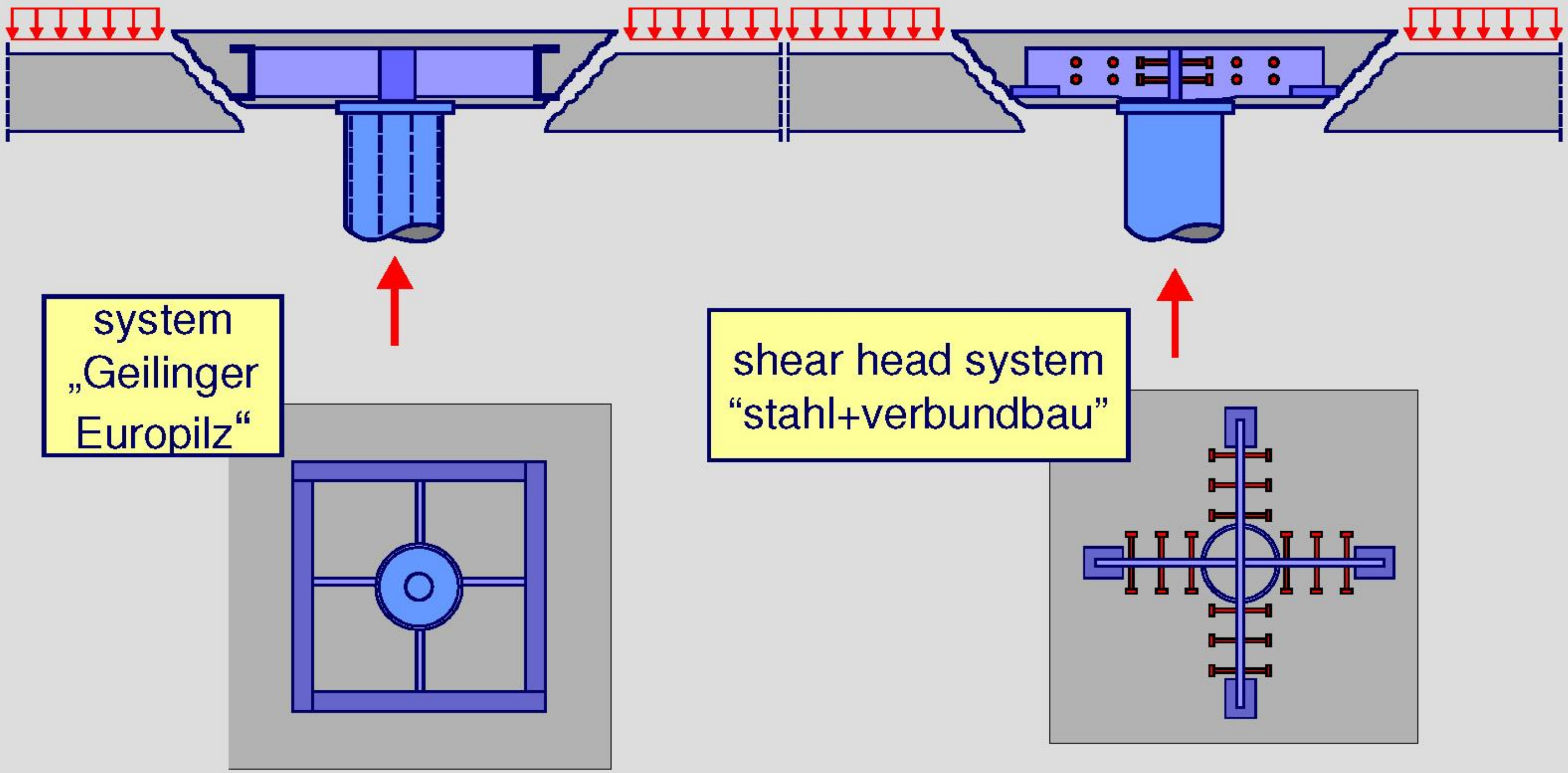

Shear head system “Geilinger Europilz”

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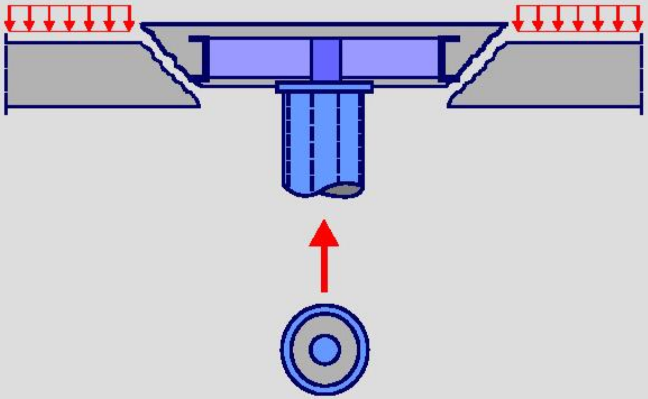

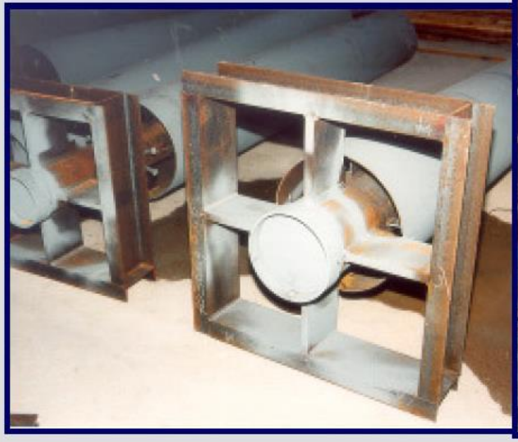

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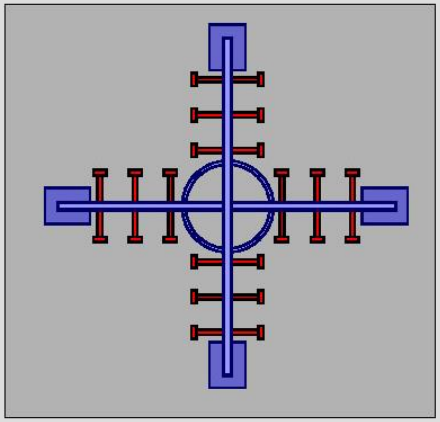
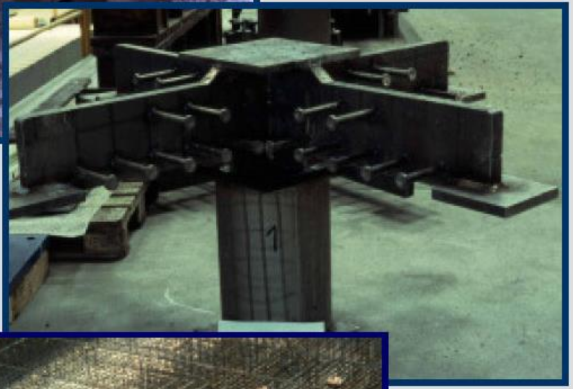
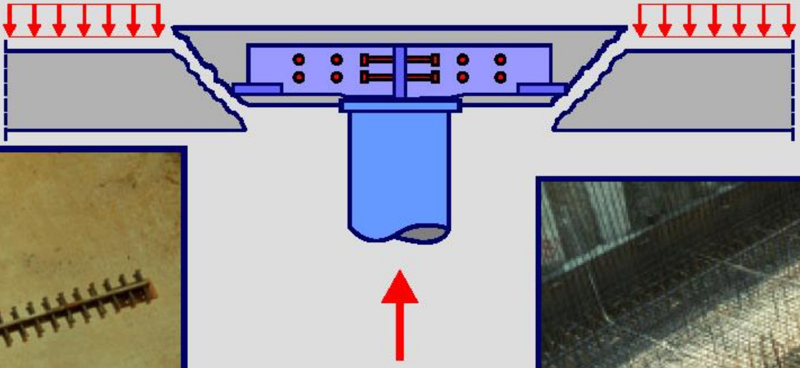
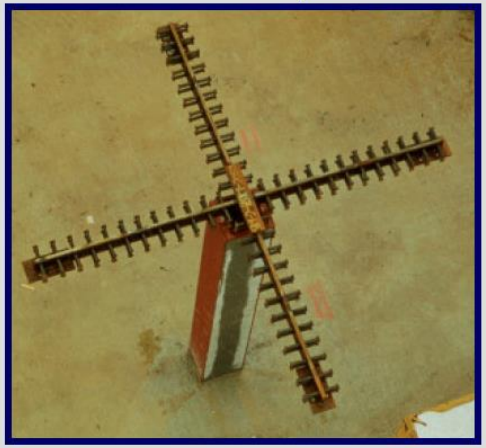
Shear head system "stahl+verbundbau"









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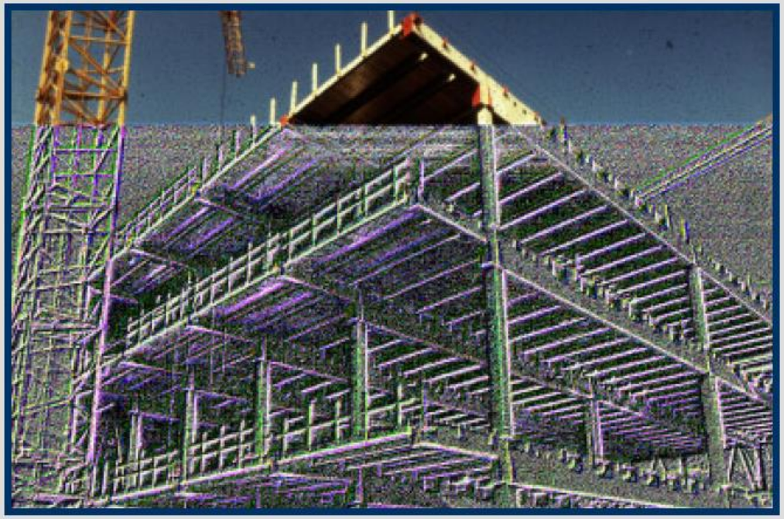
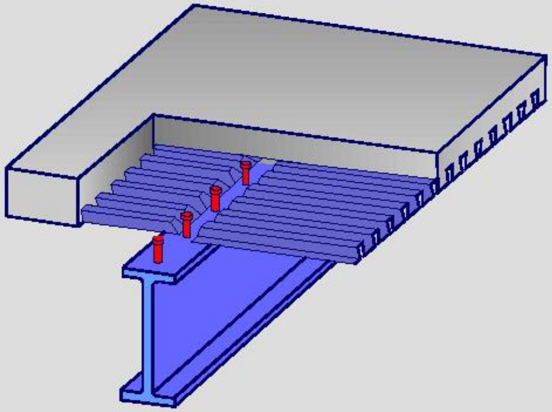


Part I-3



Composite beams

Typical composite beams

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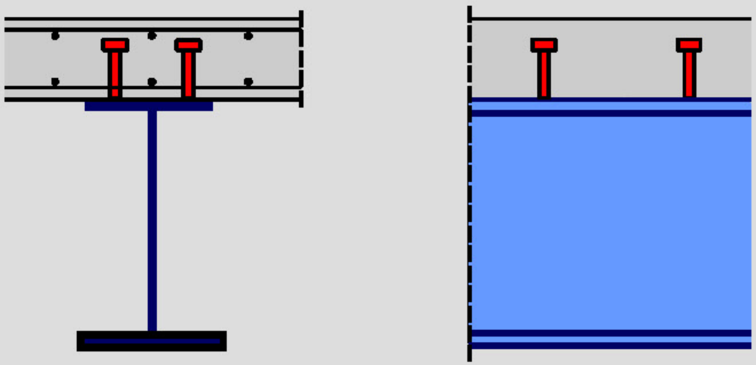
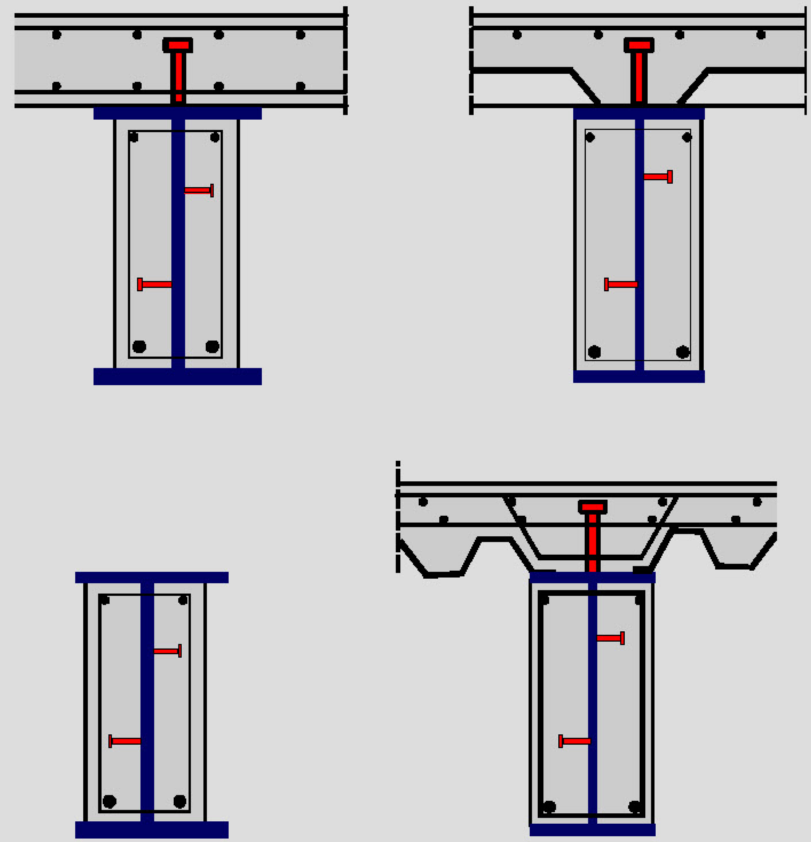
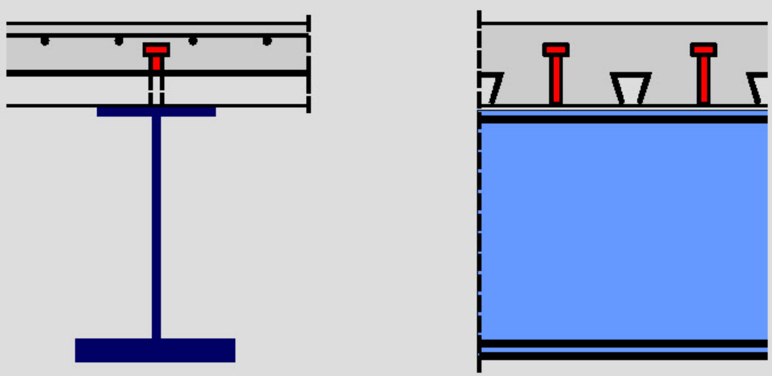
composite beam with solid slab



partially concrete encased beams



composite beam with composite slab



structural steel sections are rolled or welded

Typical composite beams in buildings

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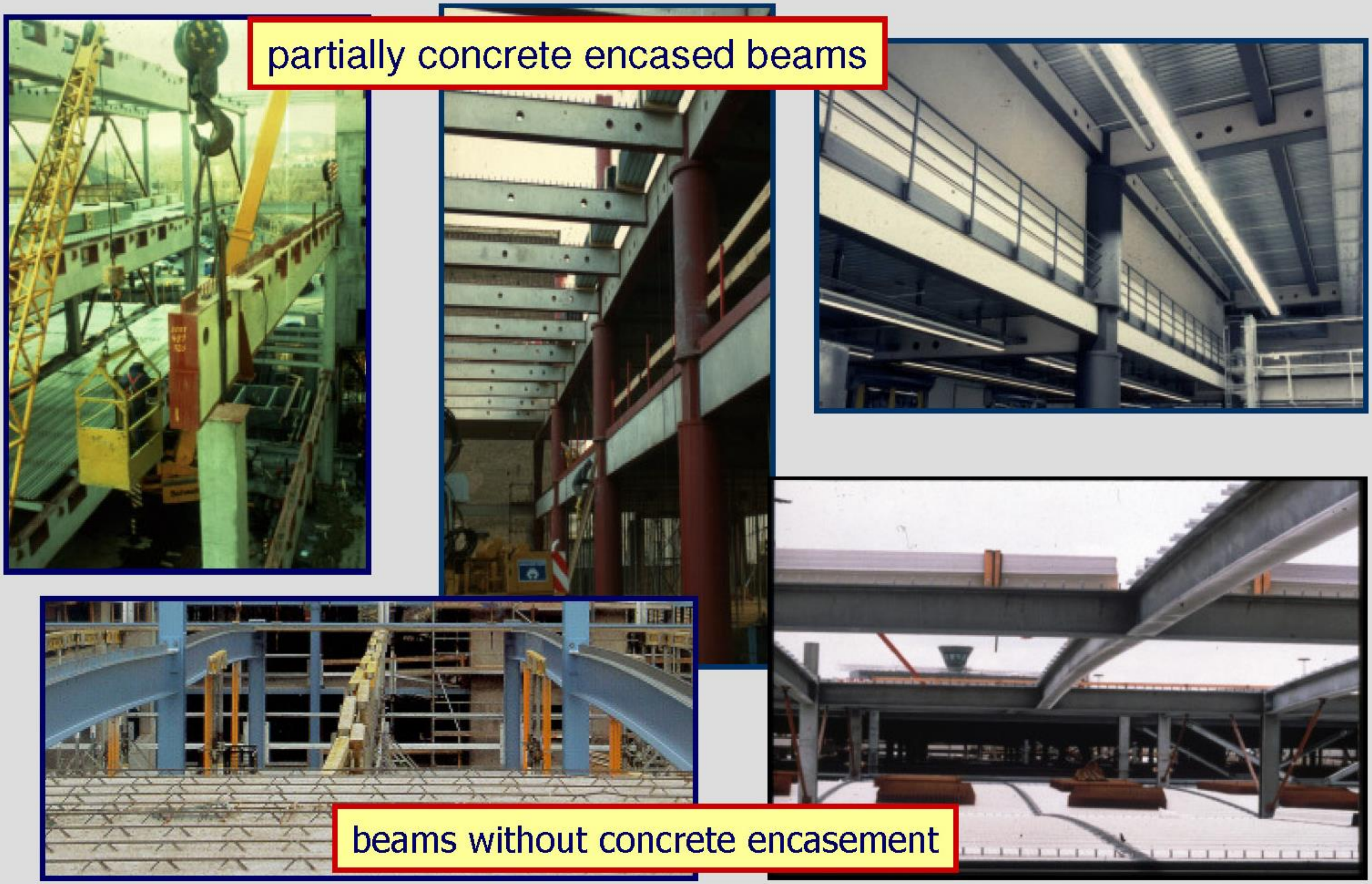

Composite beams with web openings

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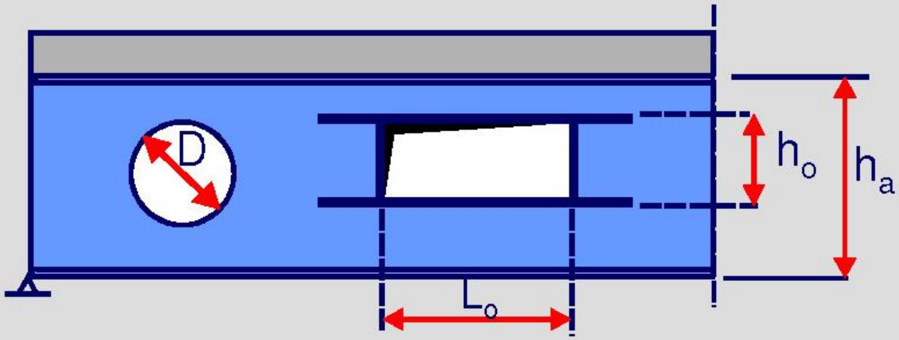
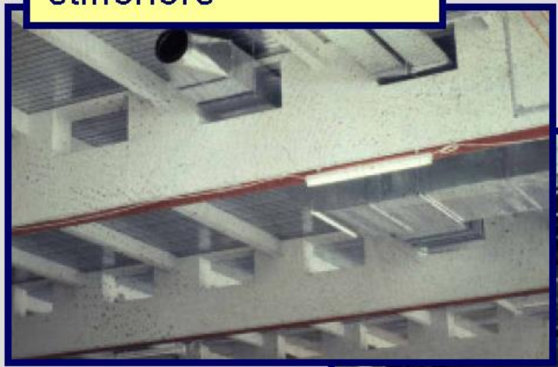
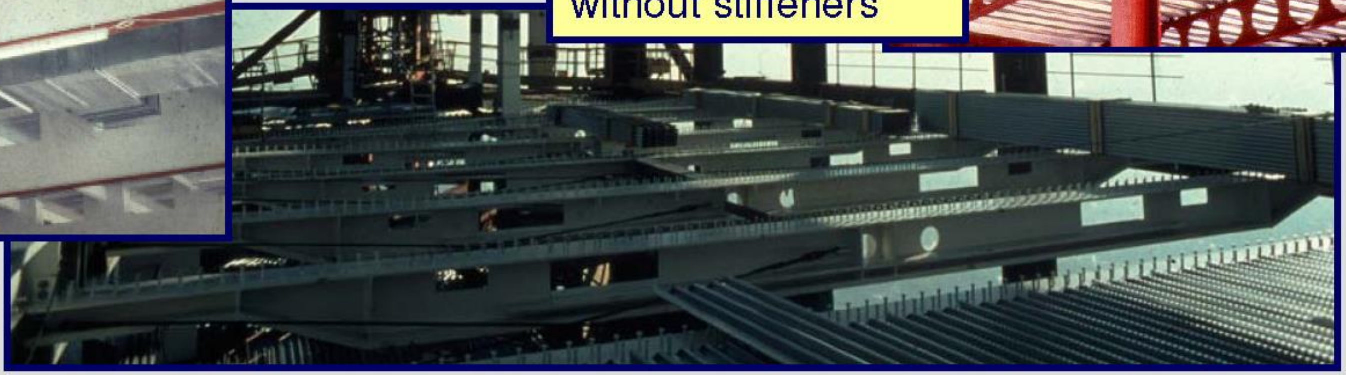


web openings with stiffeners





web openings without stiffeners

Partially concrete encased beams

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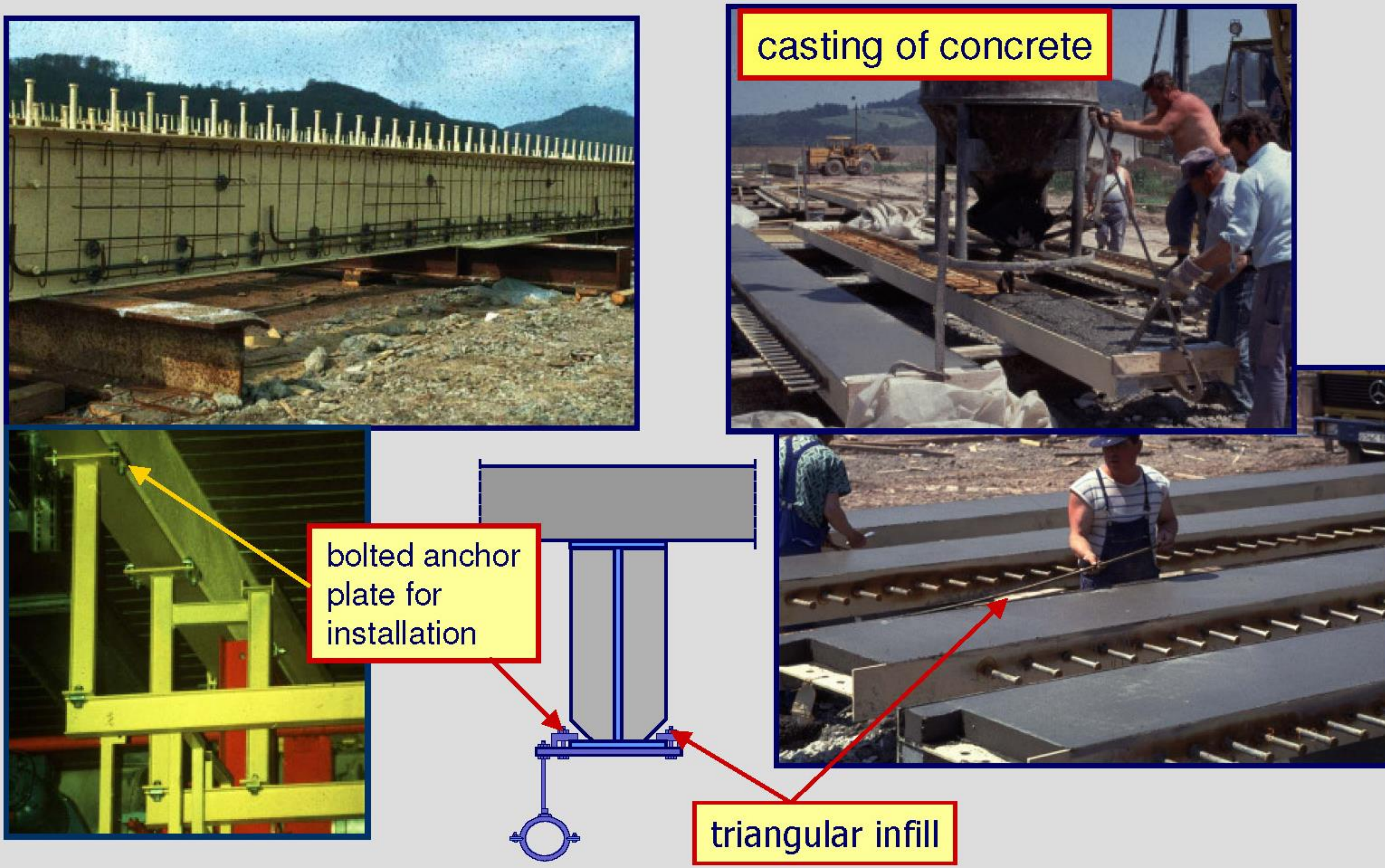

Advantages of partially concrete encased beams

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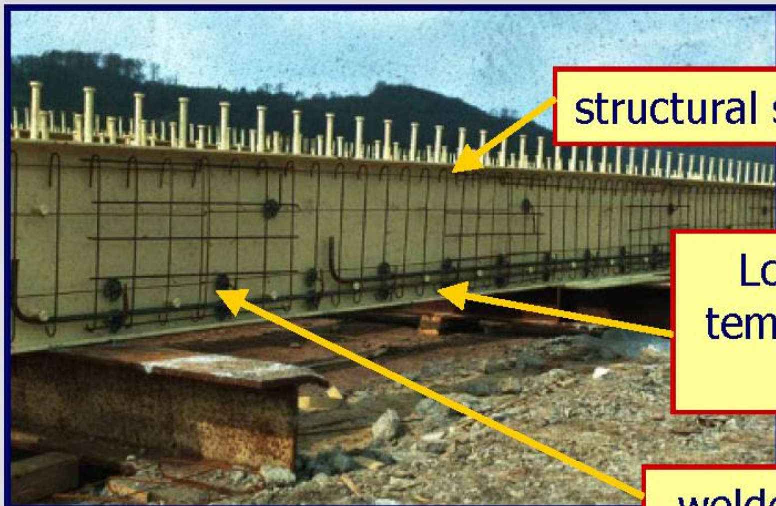
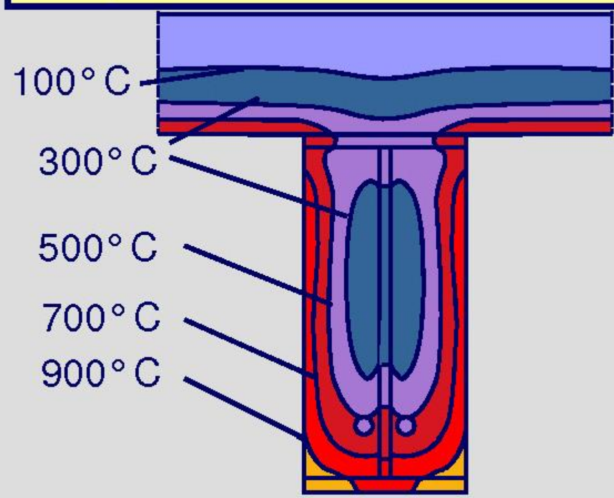


Temperature distribution in case of fire



Advantages:

- high flexural stiffness
- high fire resistance (classes R30 – R120)
- longitudinal reinforcement can be used instead of additional flange plates or altering flange thickness

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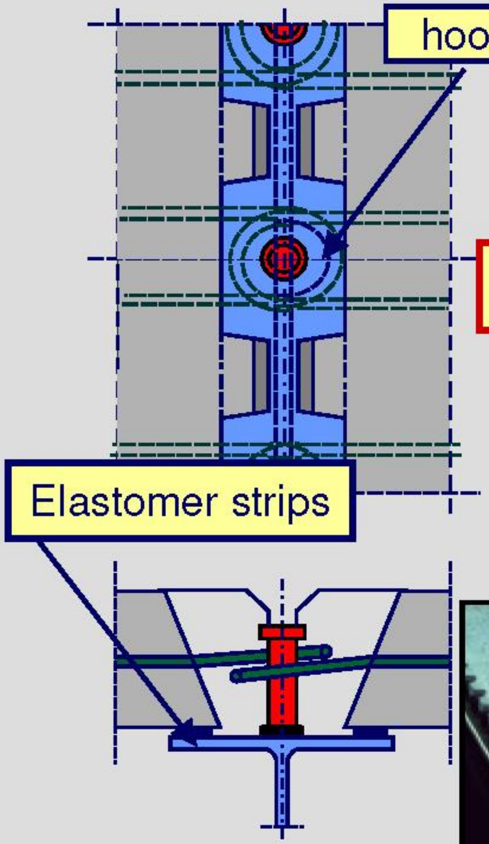

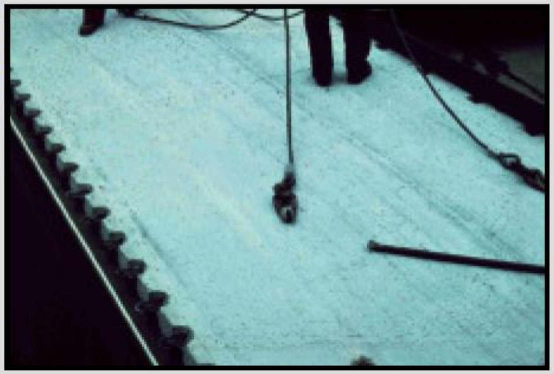

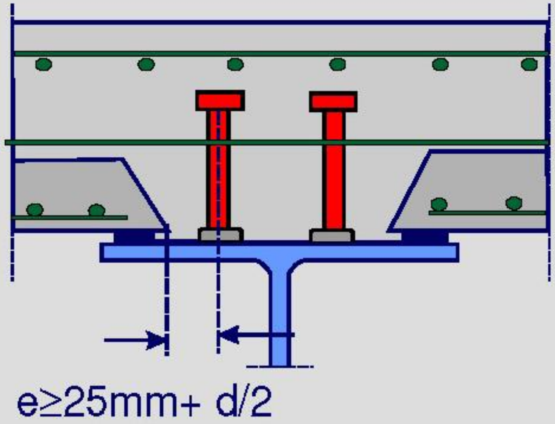

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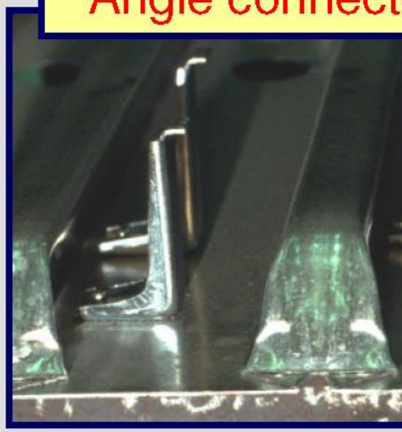
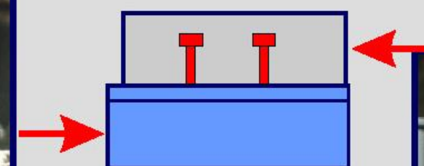
Nails

Angle connectors

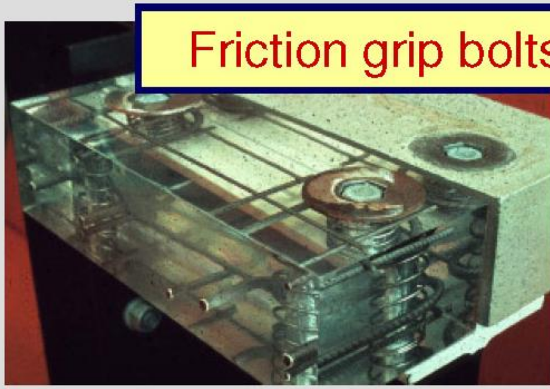




Perfobond

Headed studs

Friction grip bolts



Block-connectors

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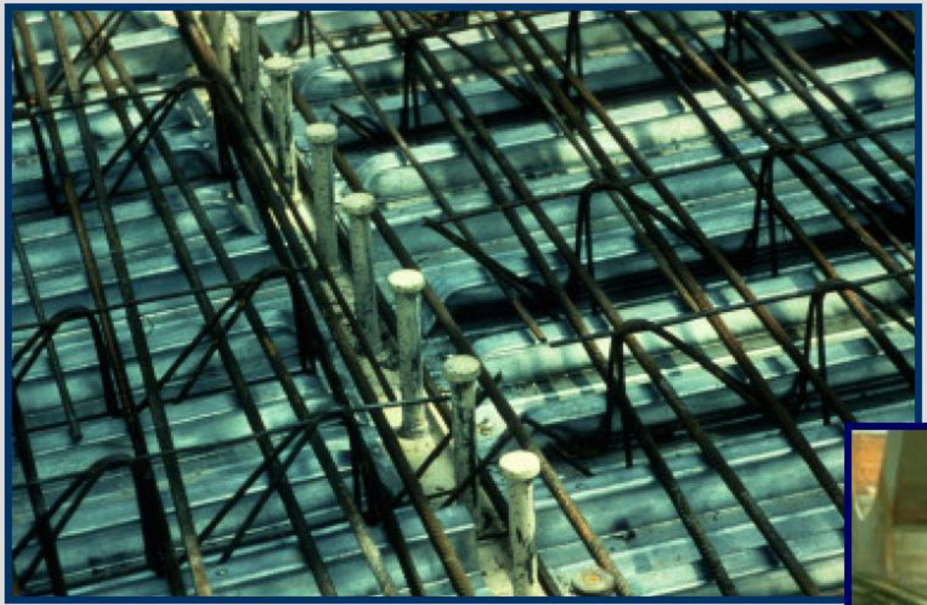
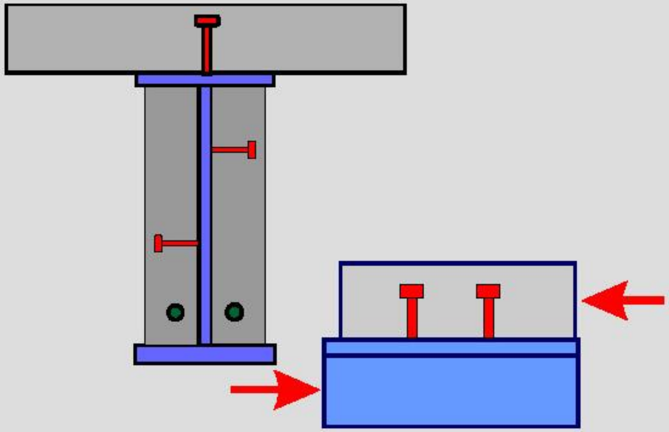
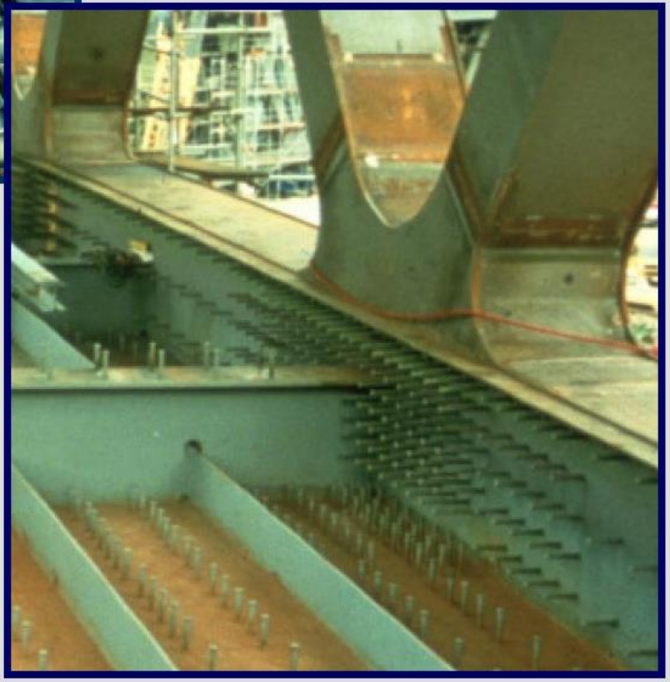
Headed stud shear connectors







Resistance of headed studs

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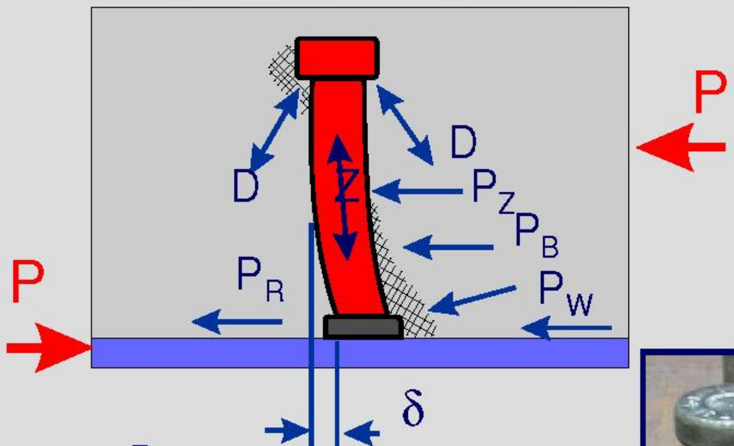

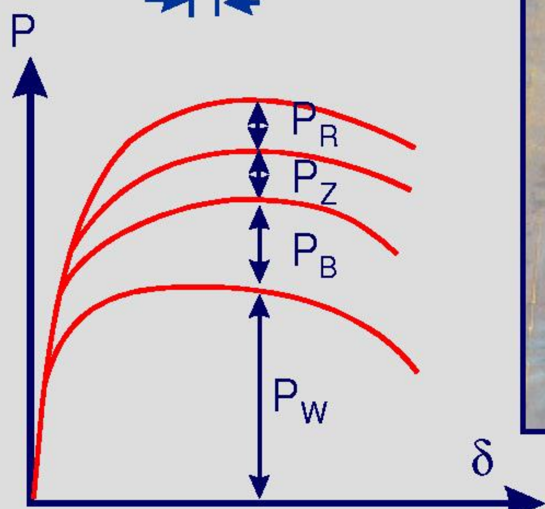

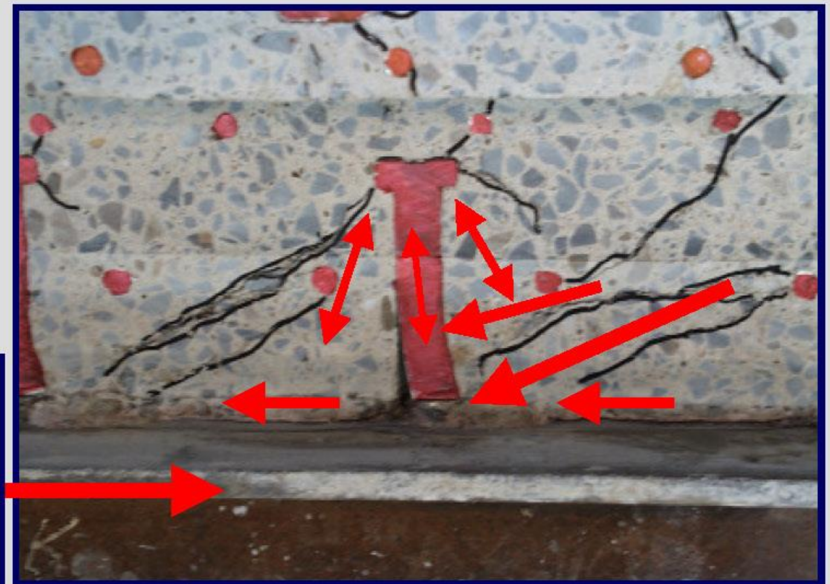

weld collar

Load transfer by

P_w – weld collar

P_B – bending of the shank

P_Z - inclination of the stud

P_R - friction

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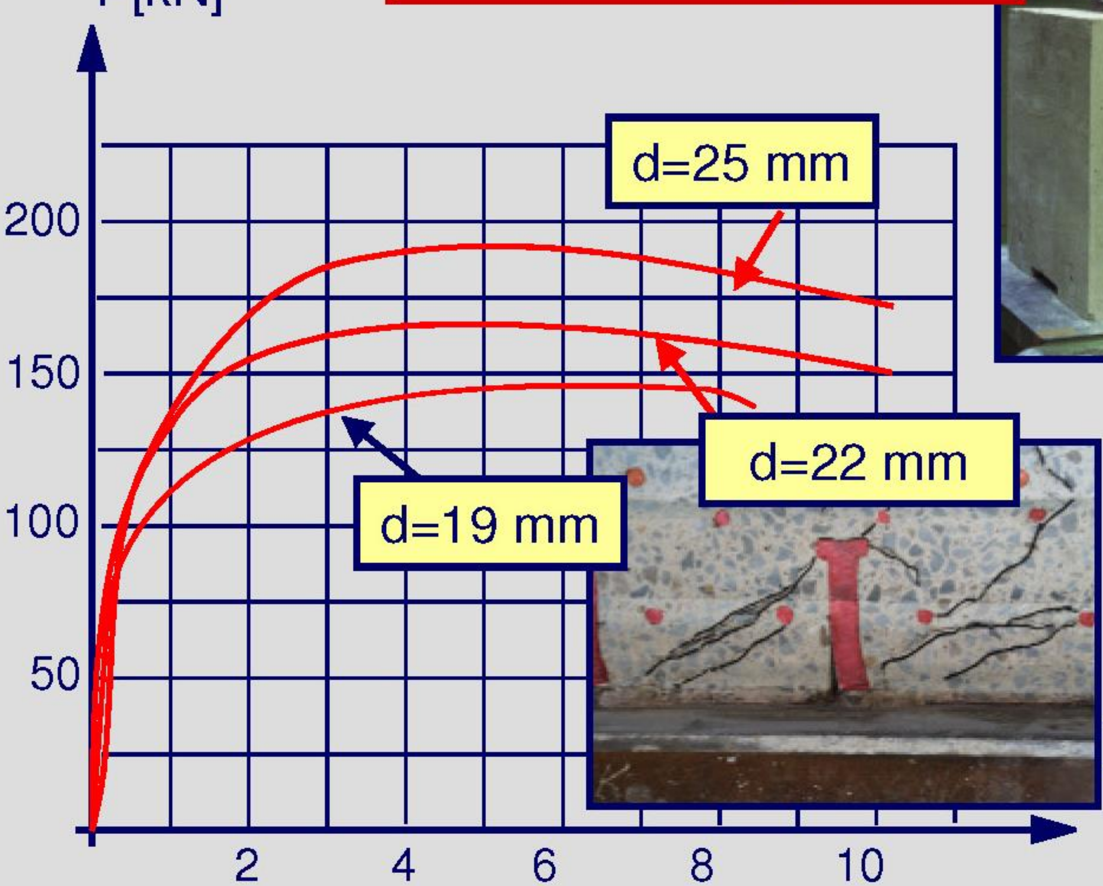
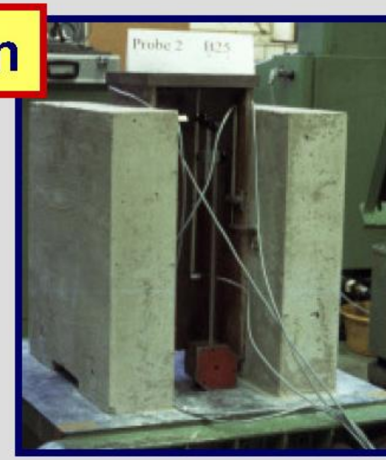
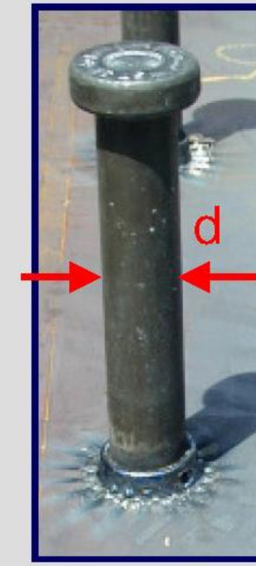
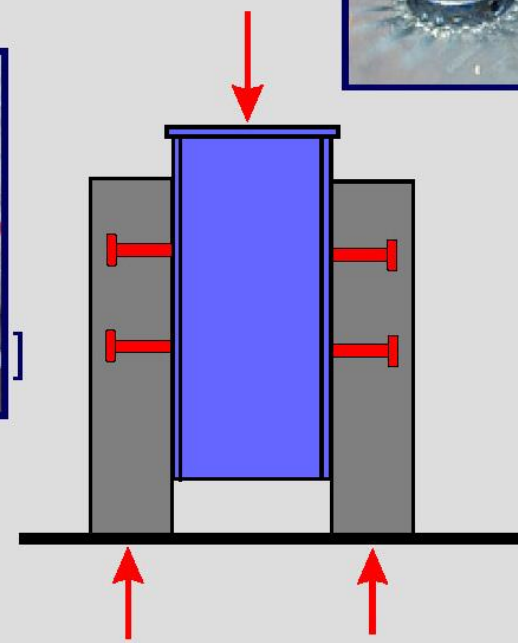
Load – deformation behaviour

Push-out test specimen









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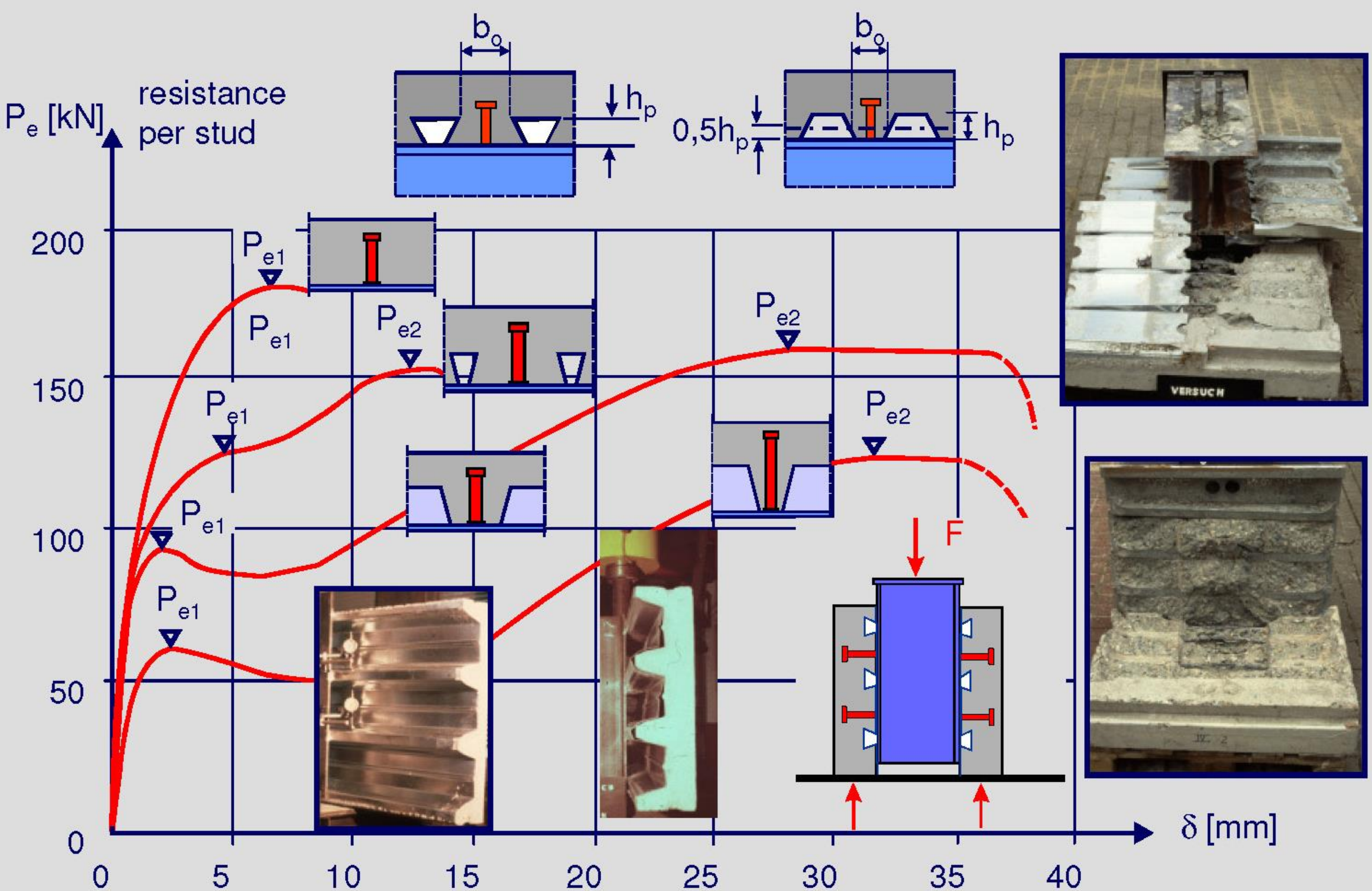
Headed studs in combination with profiled steel sheeting



Fire resistance – Design concept

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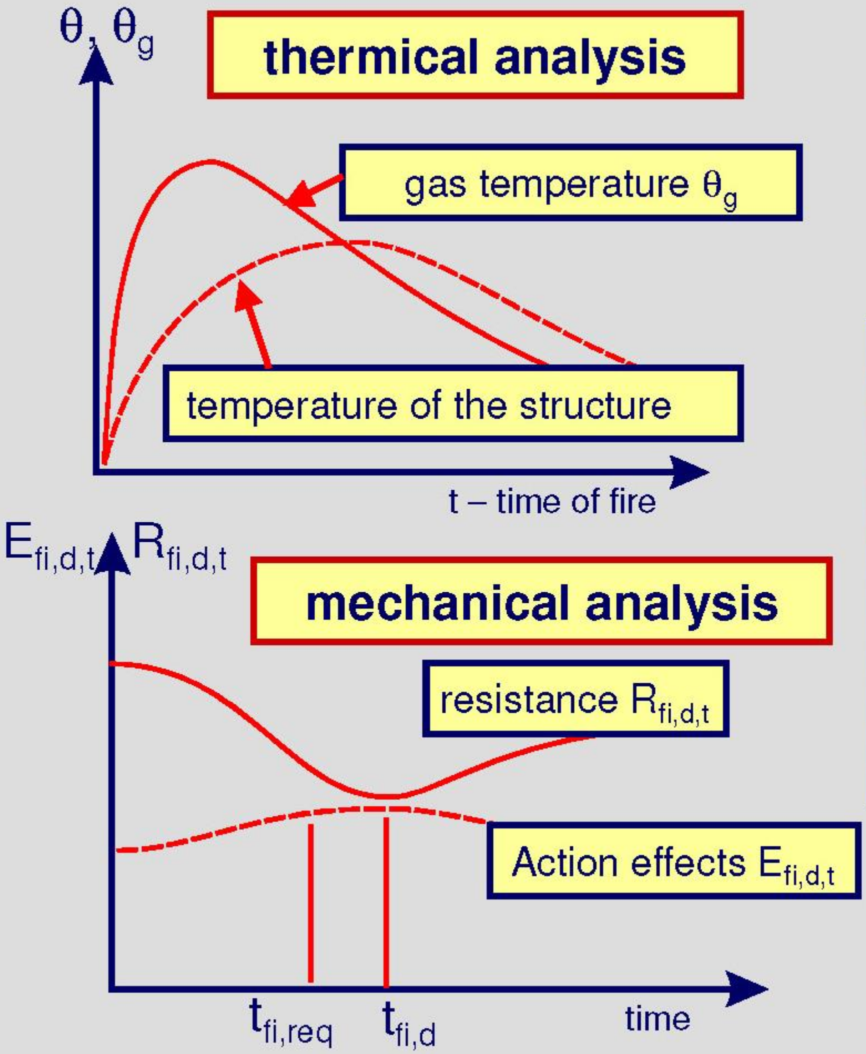

Verification

$E_{fi,d,t} \leq R_{fi,d,t}$

Strength and modulus of elasticity of structural steel due to high temperatures

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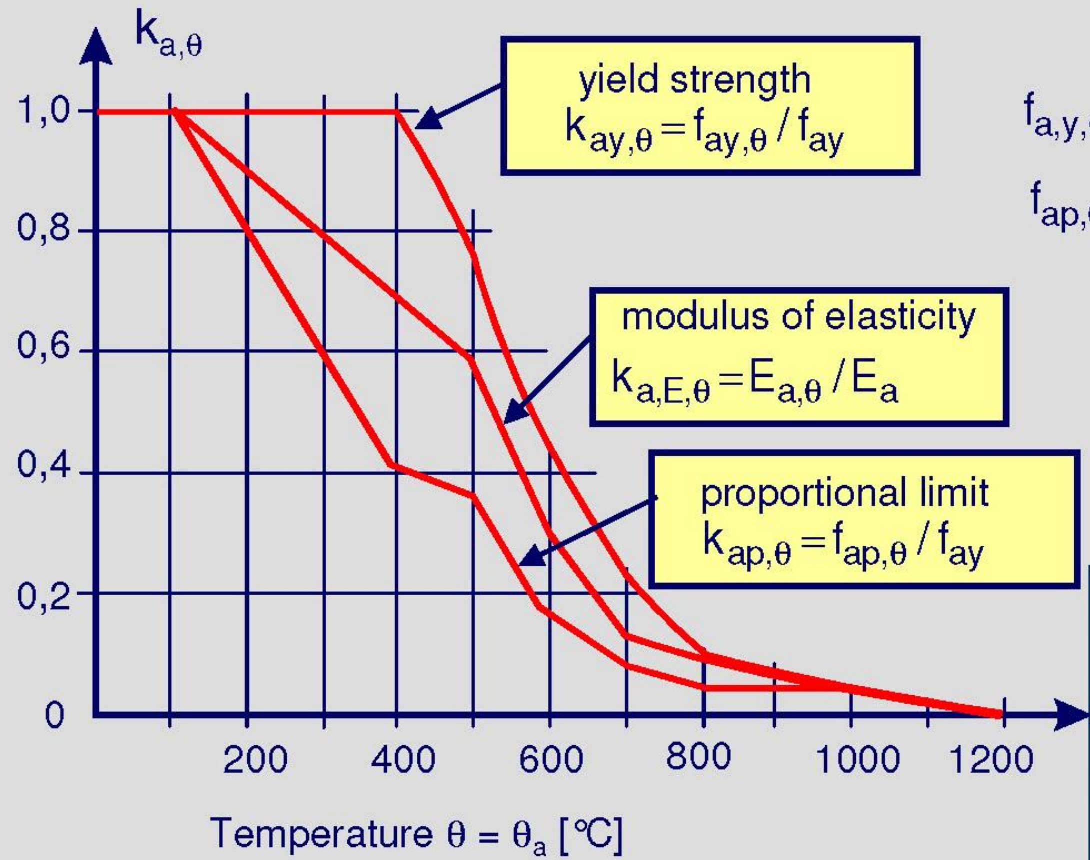

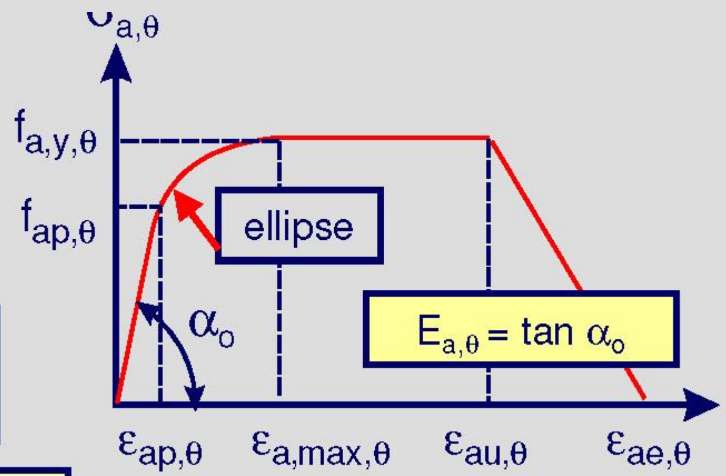

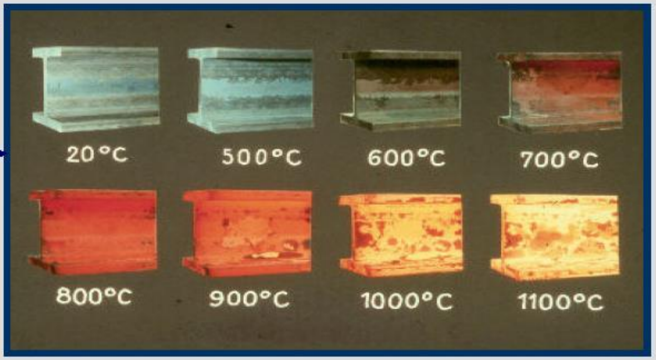

Fire resistance of composite beams

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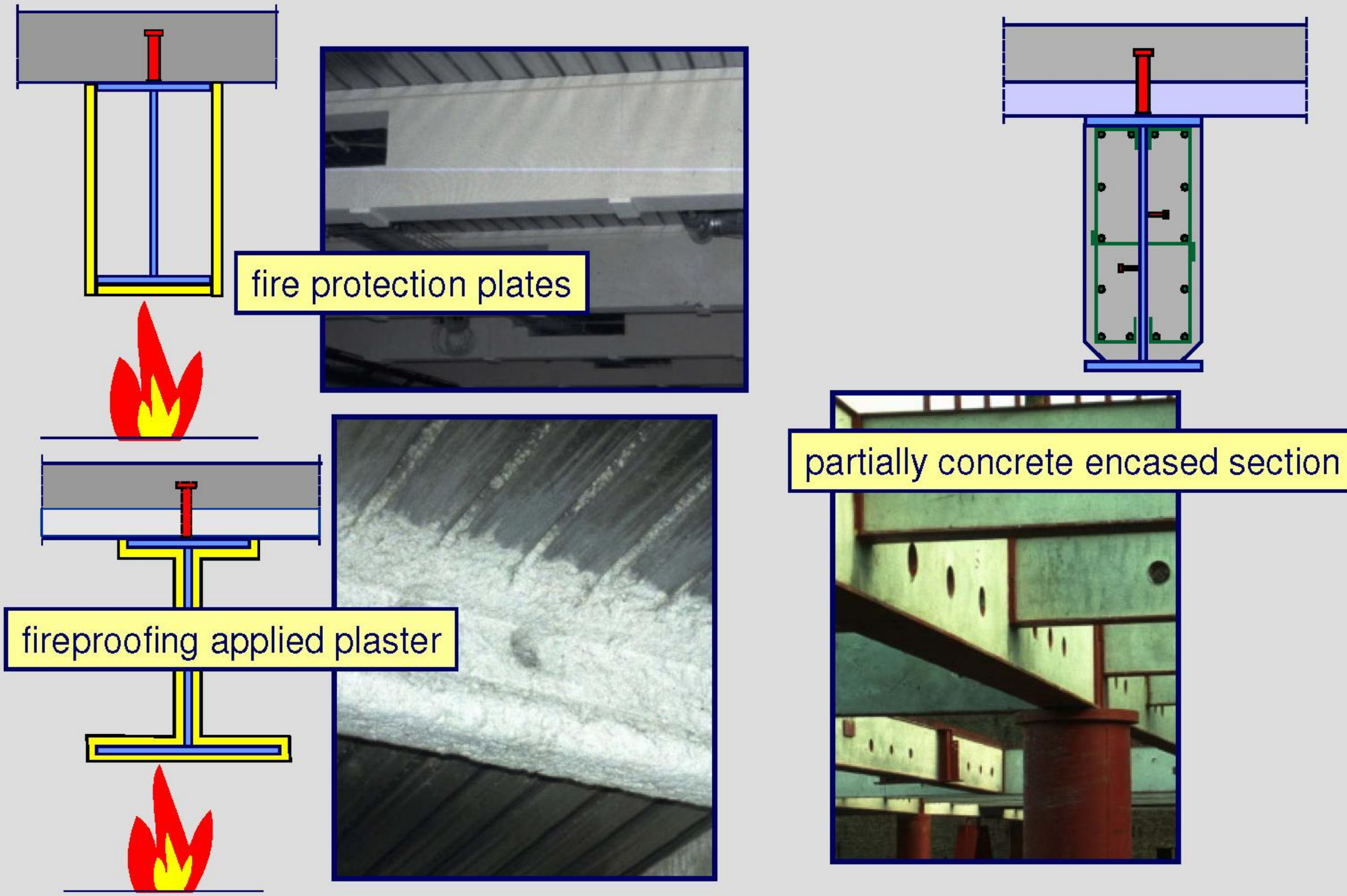

Fire resistance of partially concrete encased beams

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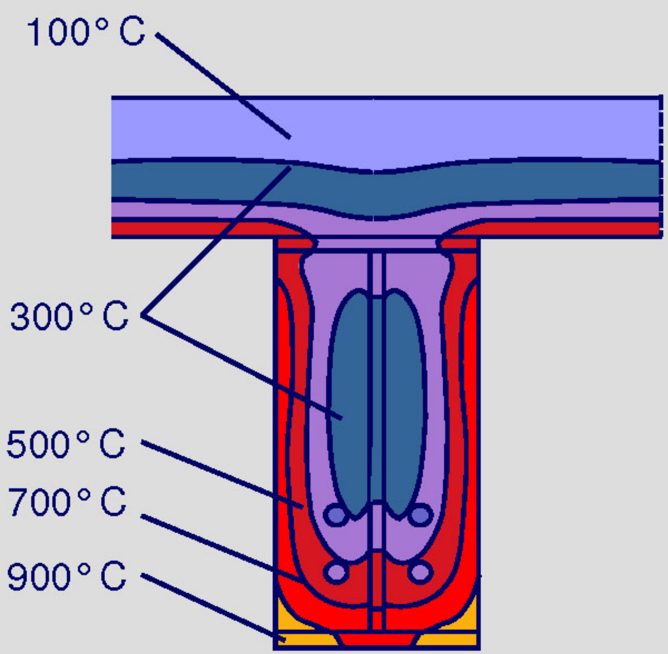
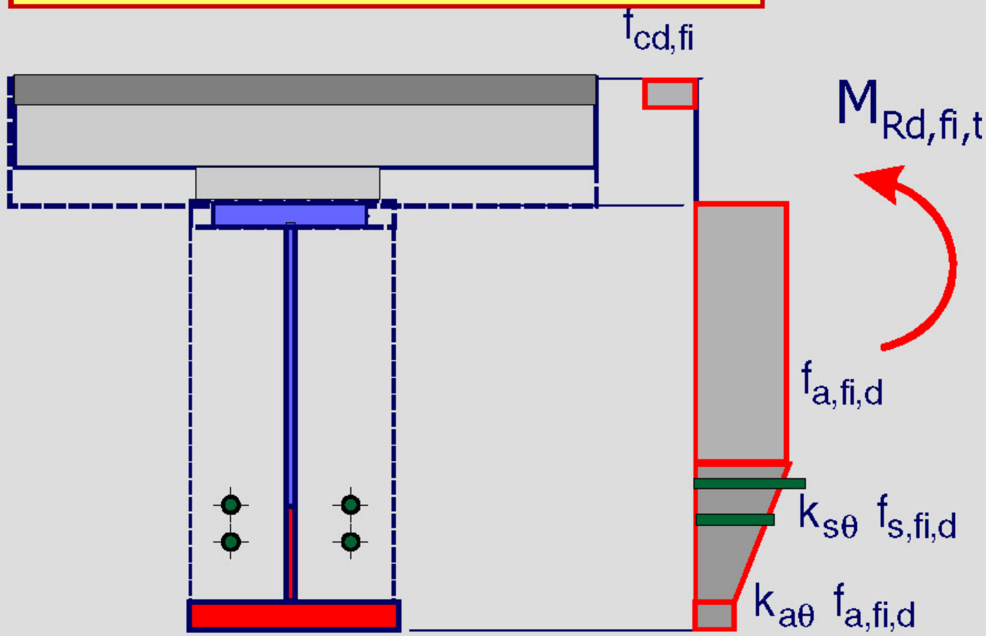
temperature distribution



effective cross section and reduced strength of steel and concrete



Design strength for fire resistance

$$f_{c,fi,d} = \frac{f_{ck}}{\gamma_{c,fi}} \qquad f_{ay,fi,d} = \frac{f_{yk}}{\gamma_{a,fi}} \qquad f_{s,fi,d} = \frac{f_{sk}}{\gamma_{s,fi}}$$

Part I-4
Composite columns

Composite columns

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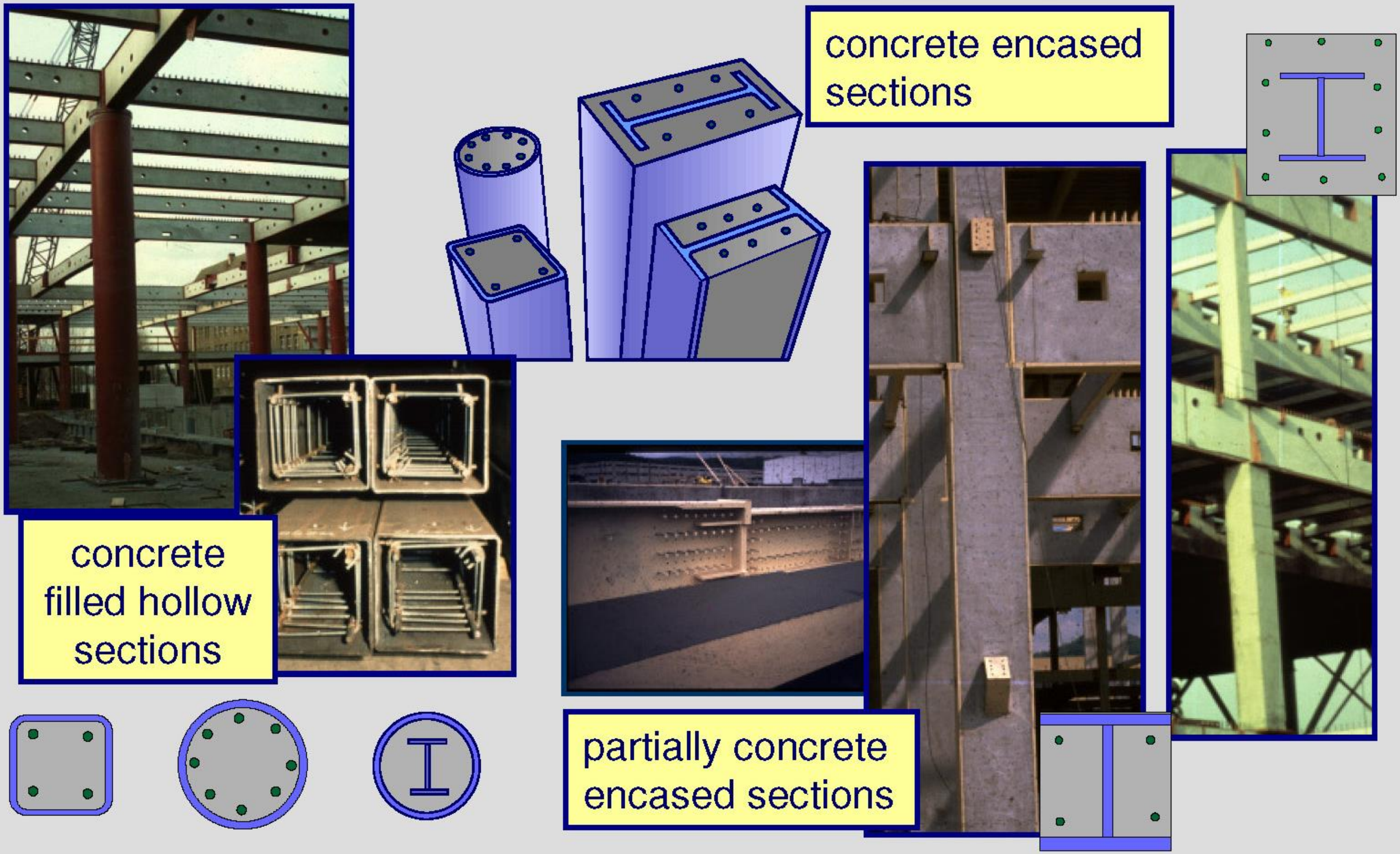

Special cross-sections

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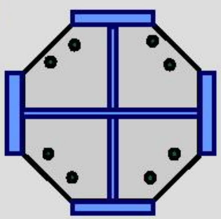
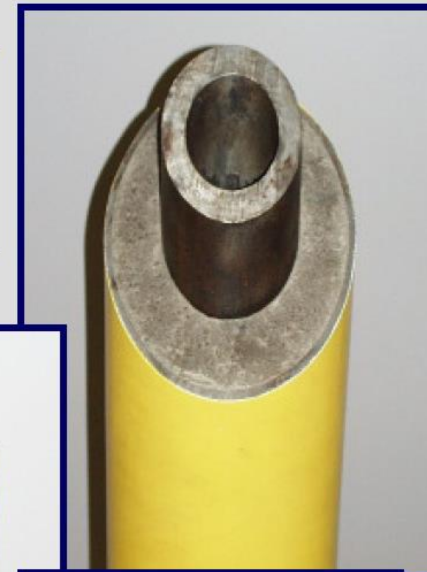
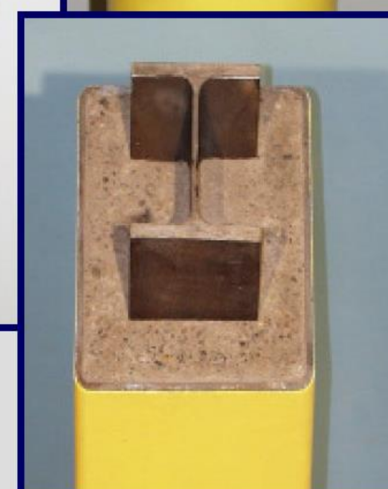
partially concrete encased sections



hollow sections with additional inner profiles





Composite columns with hollow sections and additional inner profiles

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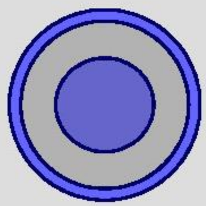
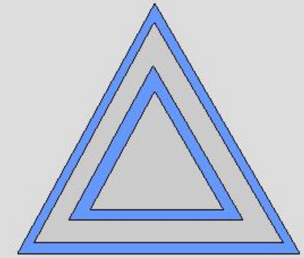
Post-Tower Bonn





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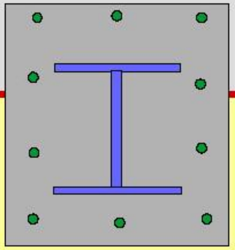
Concrete encased sections



advantages:

- high bearing resistance
- high fire resistance
- economical solution with regard to material costs

disadvantages:

- high costs for formwork
- difficult solutions for connections with beams
- difficulties in case of later strengthening of the column
- in special case edge protection is necessary

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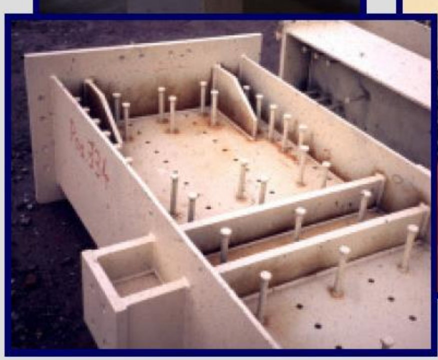
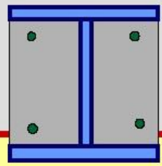
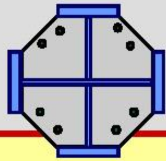
Partially concrete encased sections







advantages:

- high bearing resistance, especially in case of welded steel sections
- no formwork
- simple solution for joints and load introduction
- easy solution for later strengthening and additional later joints
- no edge protection

disadvantages:

- lower fire resistance in comparison with concrete encased sections.

Casting of partially concrete encased sections

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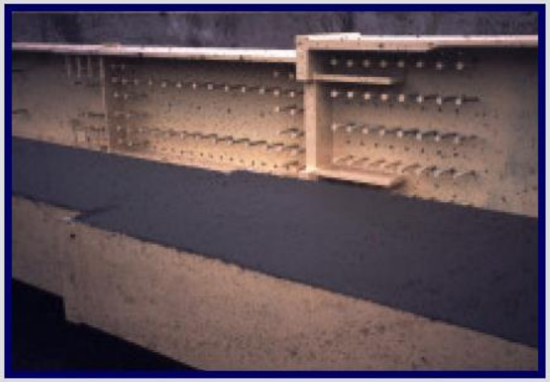
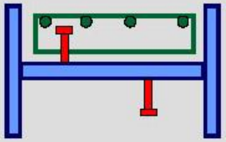
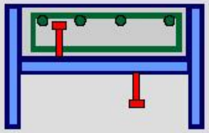
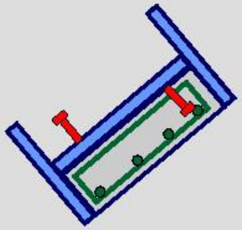




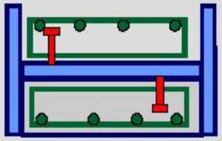
reinforcing pocket 1



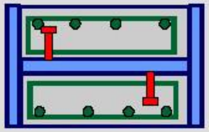
casting pocket 1



turning the steel profile



reinforcing pocket 2



casting pocket 2

Concrete filled hollow sections

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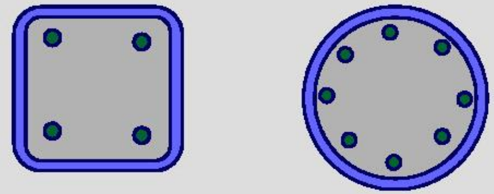

advantages:

- high resistance and slender columns
- advantages in case of biaxial bending
- no edge protection

disadvantages :

- high material costs for profiles
- difficult casting
- additional reinforcement is needed for fire resistance

Casting of concrete in case of concrete filled hollow sections

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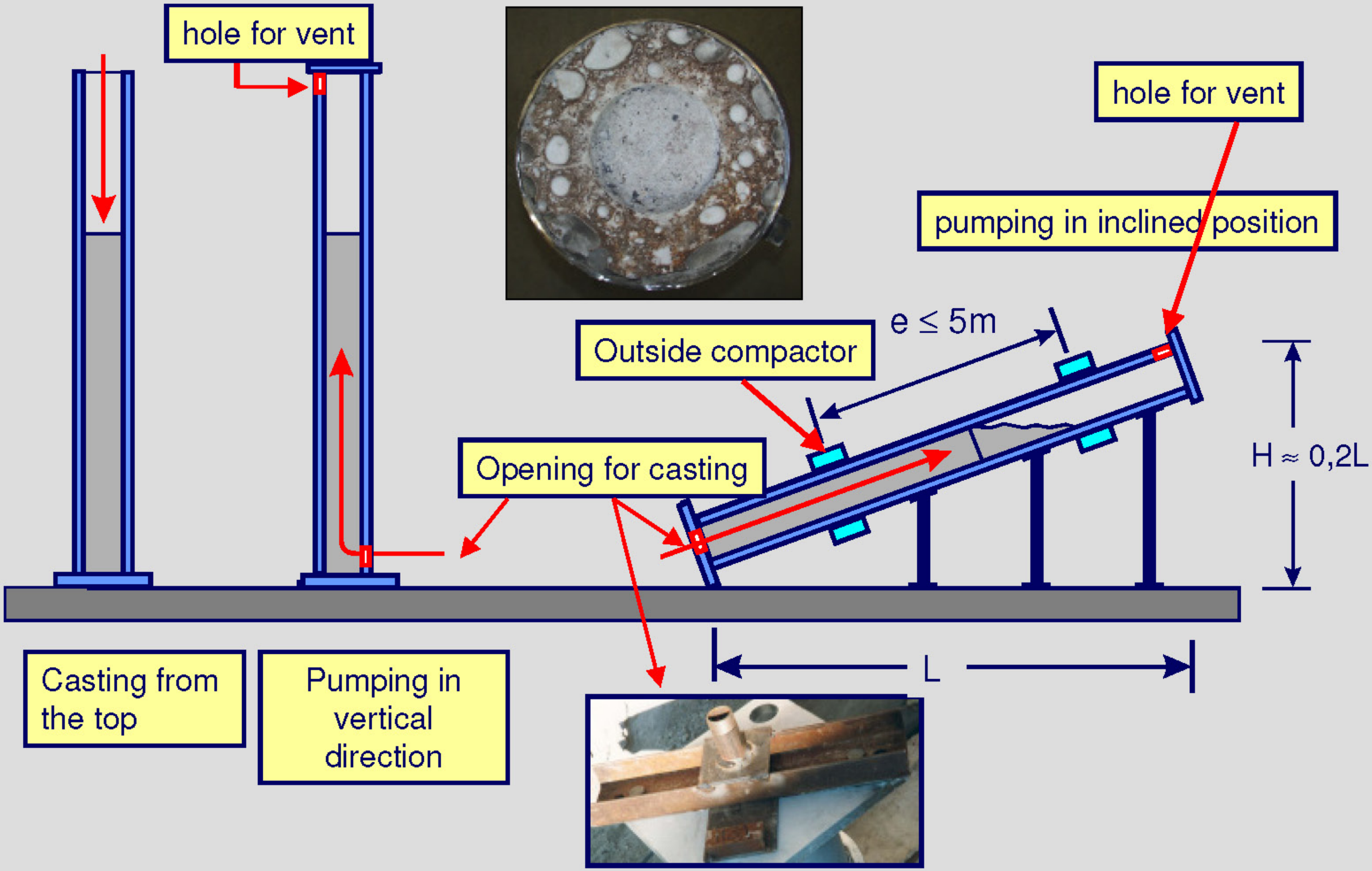

Concrete filled hollow sections with additional inner profiles

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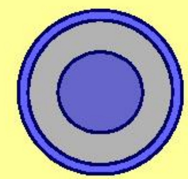
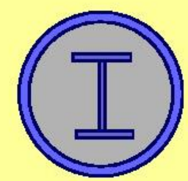
advantages:

- extreme high bearing resistance in combination with slender columns
- constant cross section for all stories is possible in high rise buildings
- high fire resistance and no additional reinforcement
- no edge protection



disadvantages:

- high material costs
- difficult casting



HILTI – shear connection with nails

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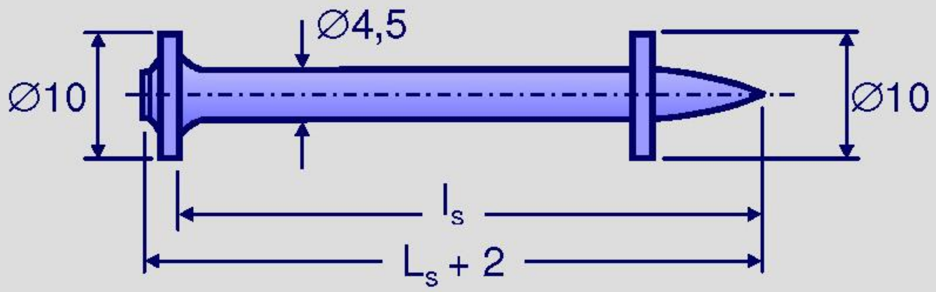

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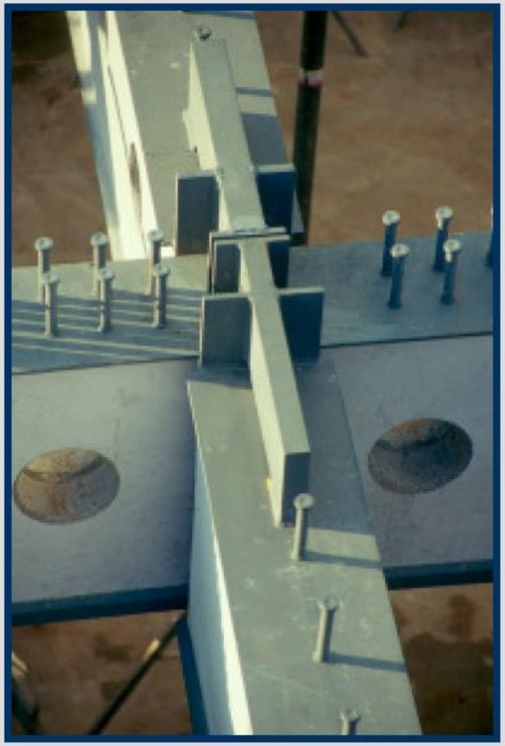

Part I-5

Connections for composite structures

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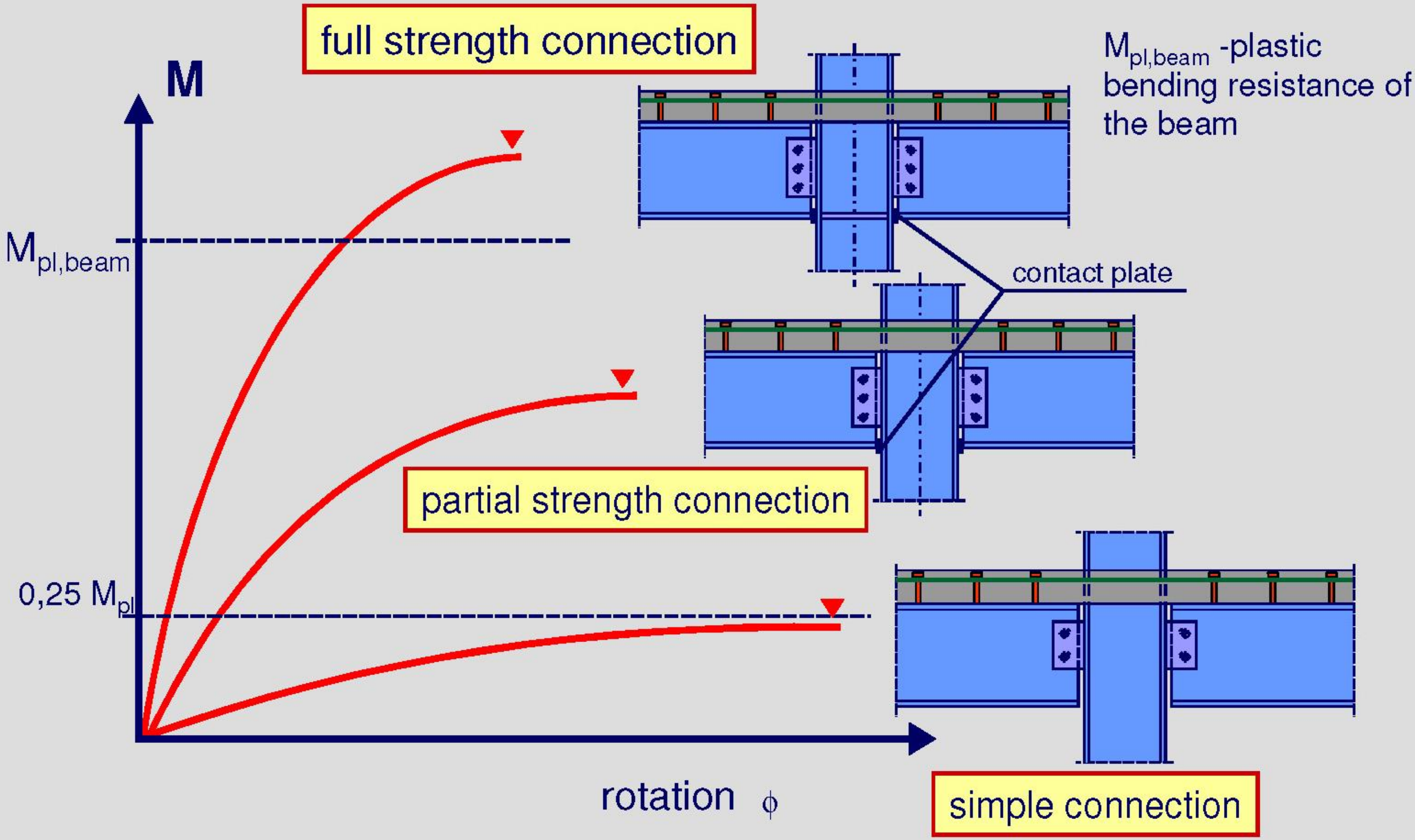
Classification of joints



Simple joints for composite beams with concrete encasement

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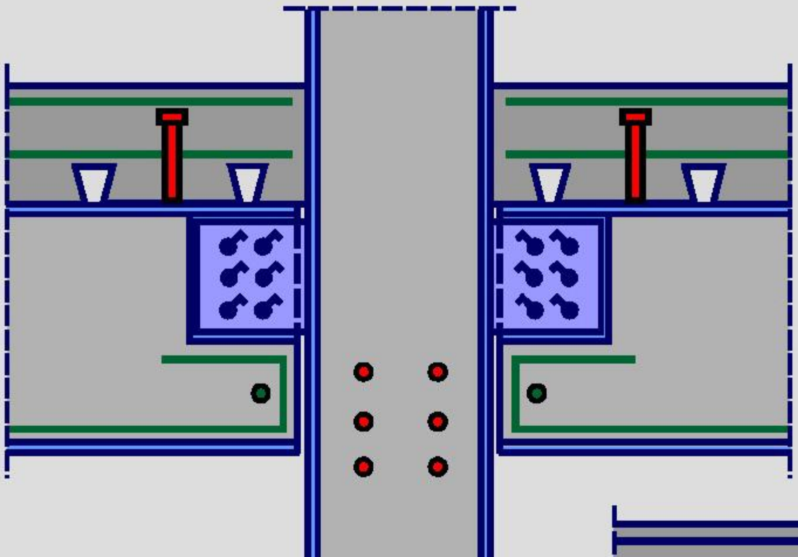
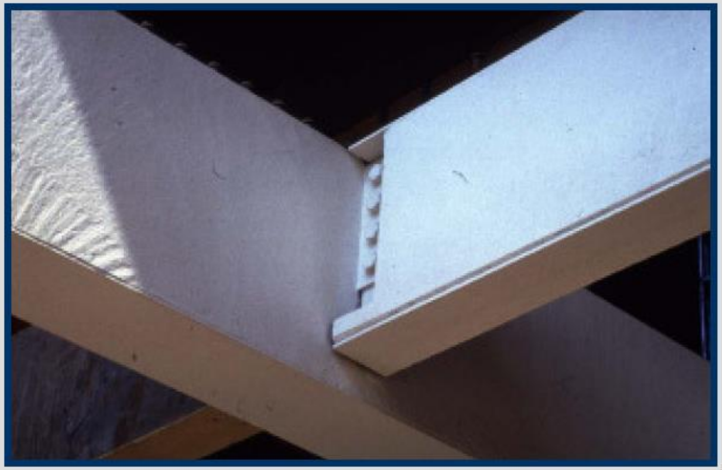
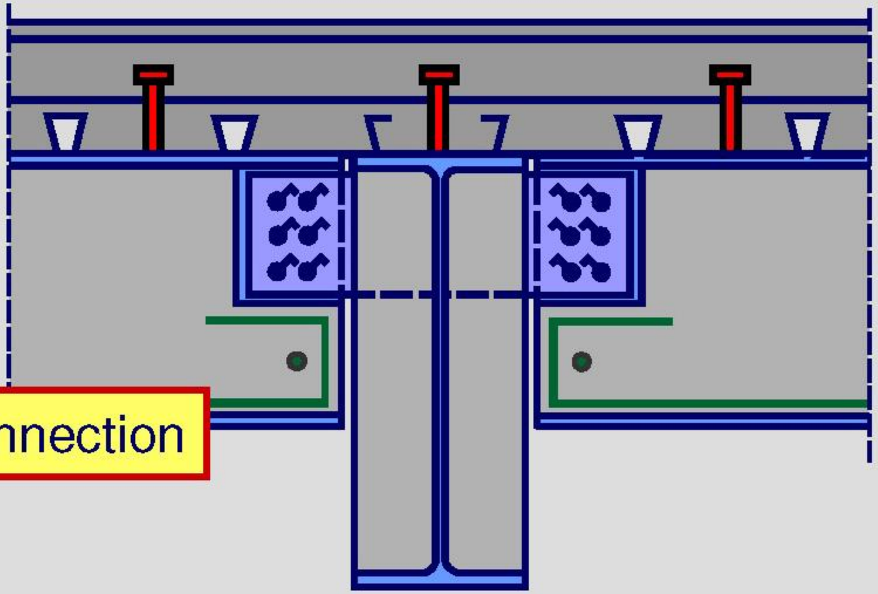


beam to column connection





beam to beam connection

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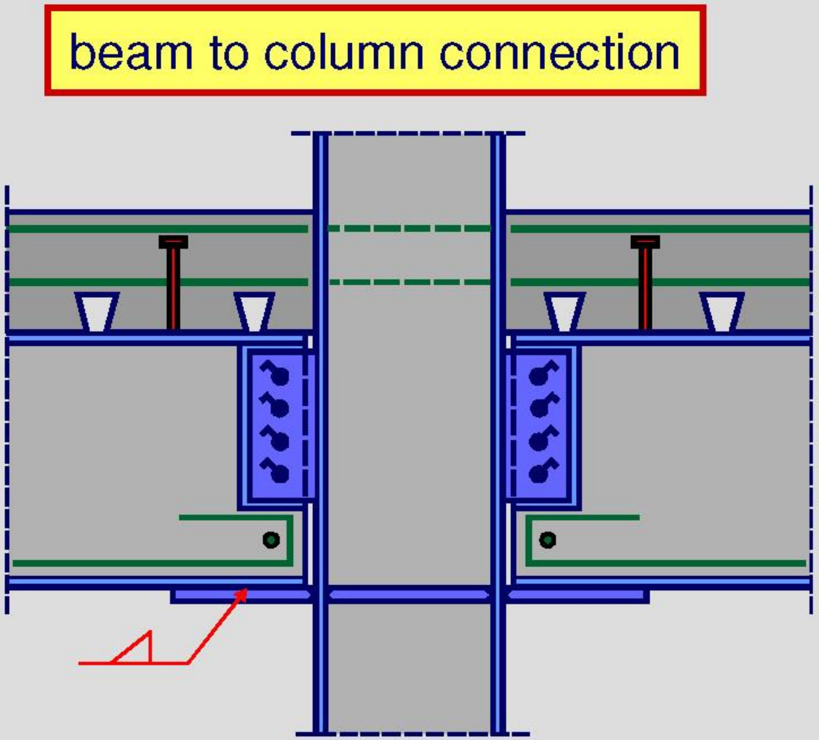
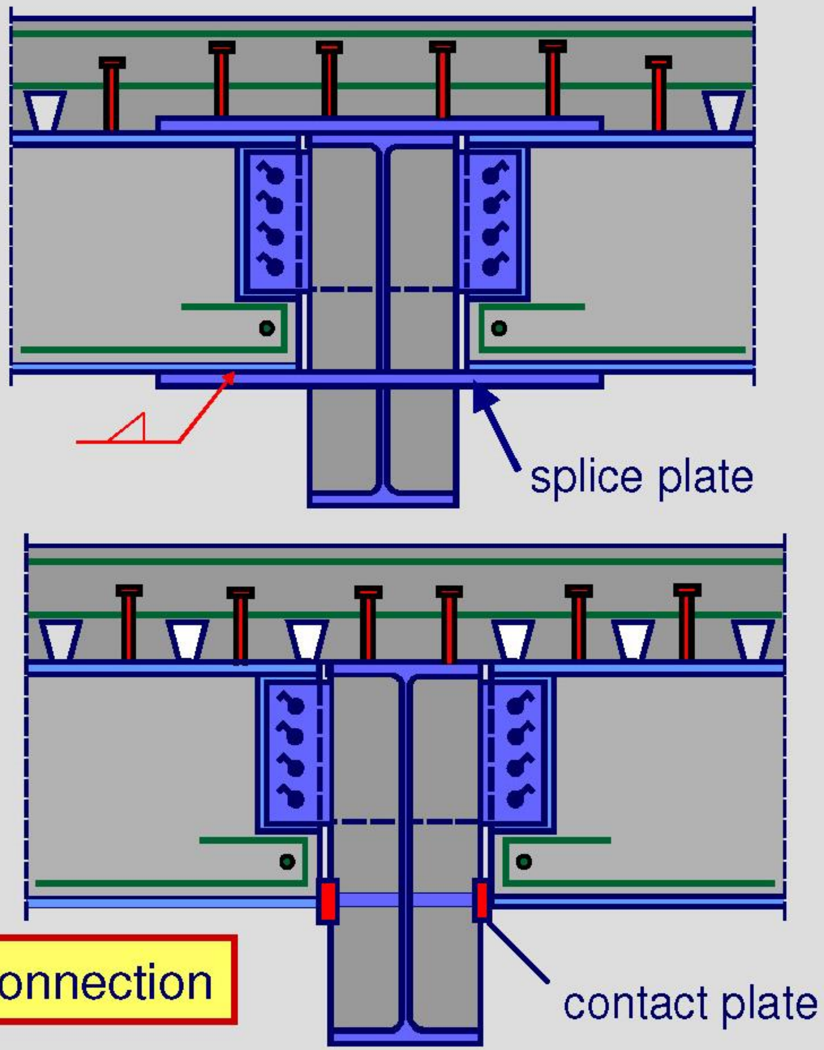
Rigid connections





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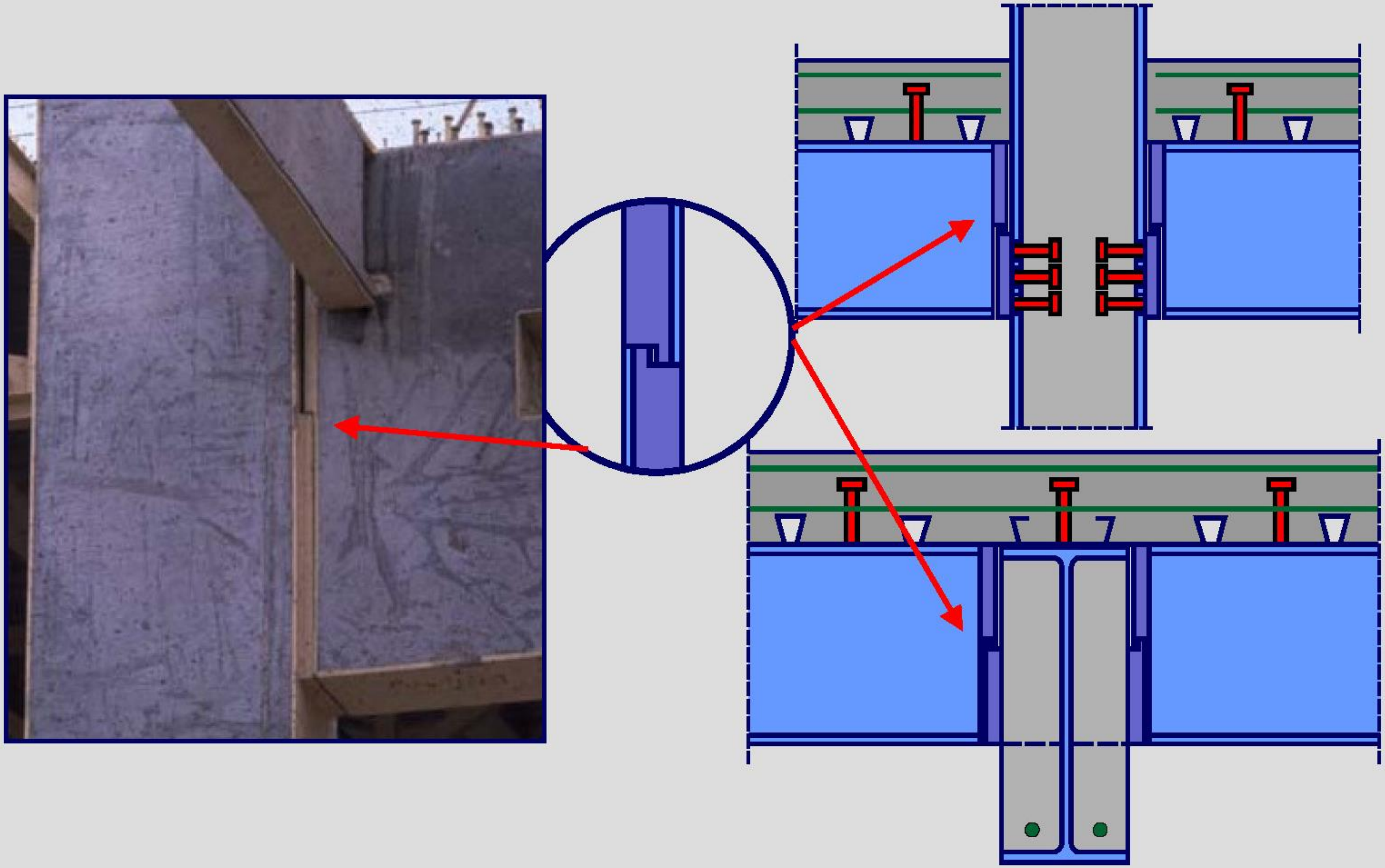
Joints with half end plates



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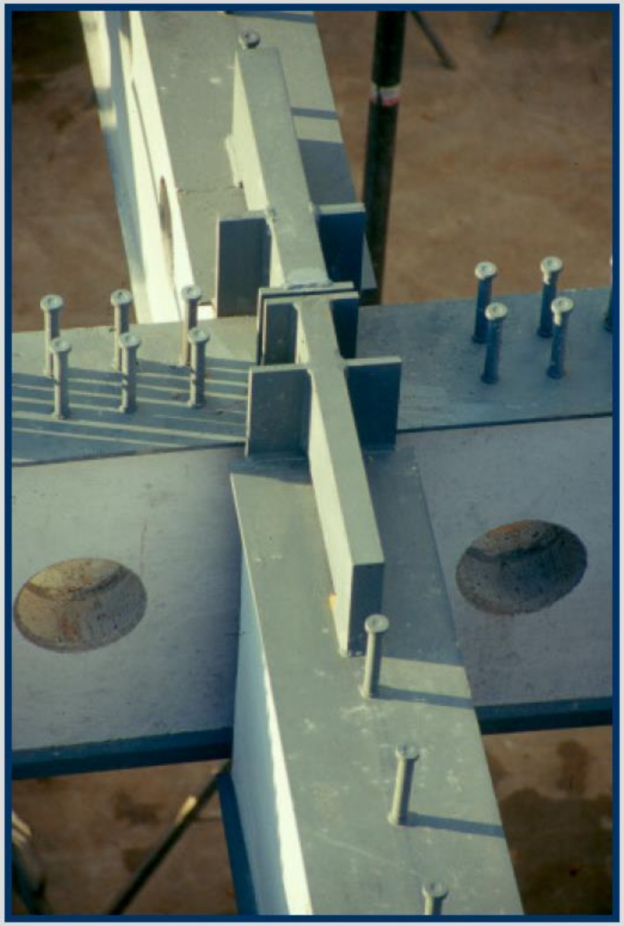
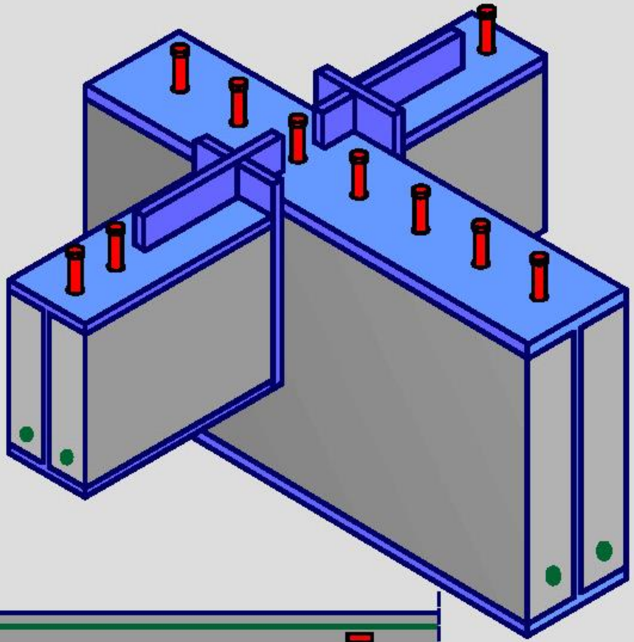
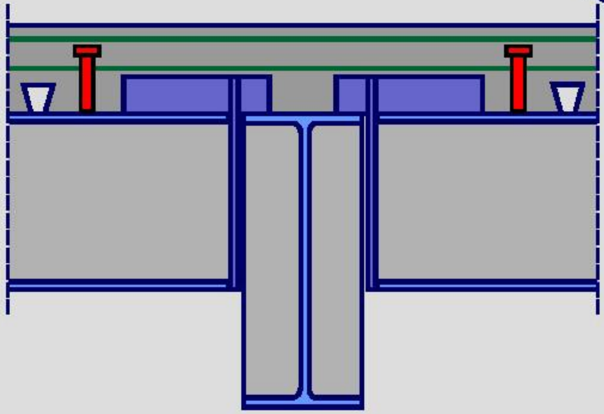
Joint with endplates and cleats







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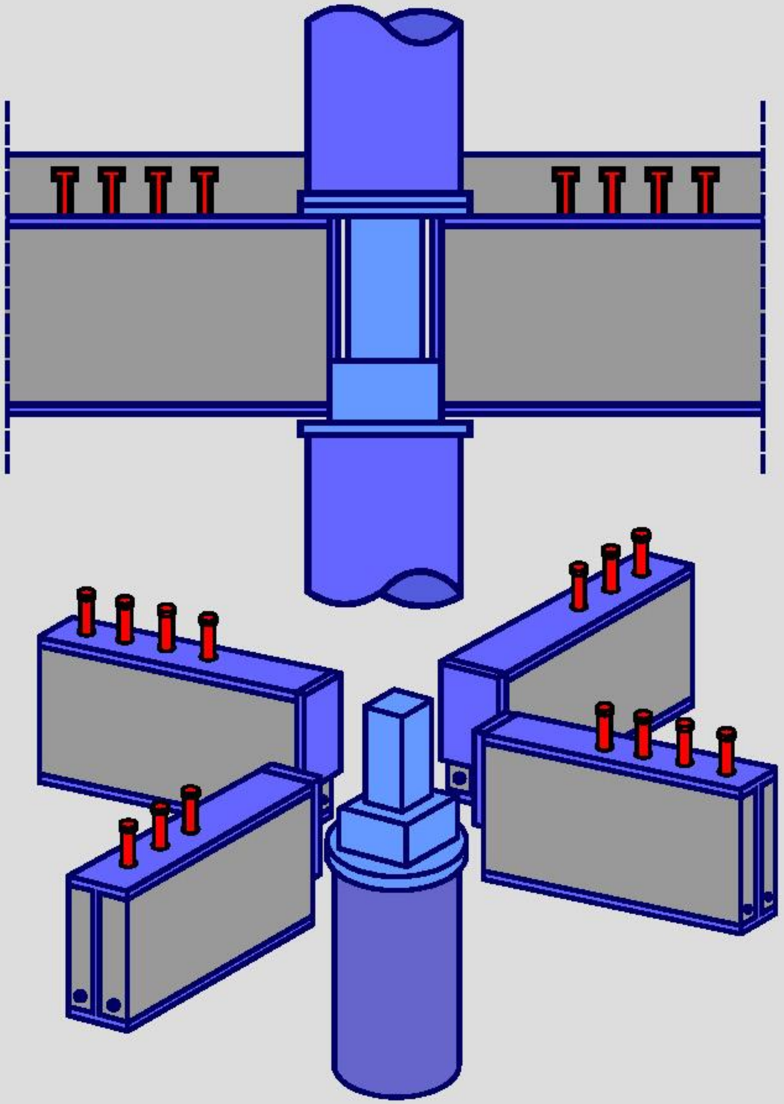
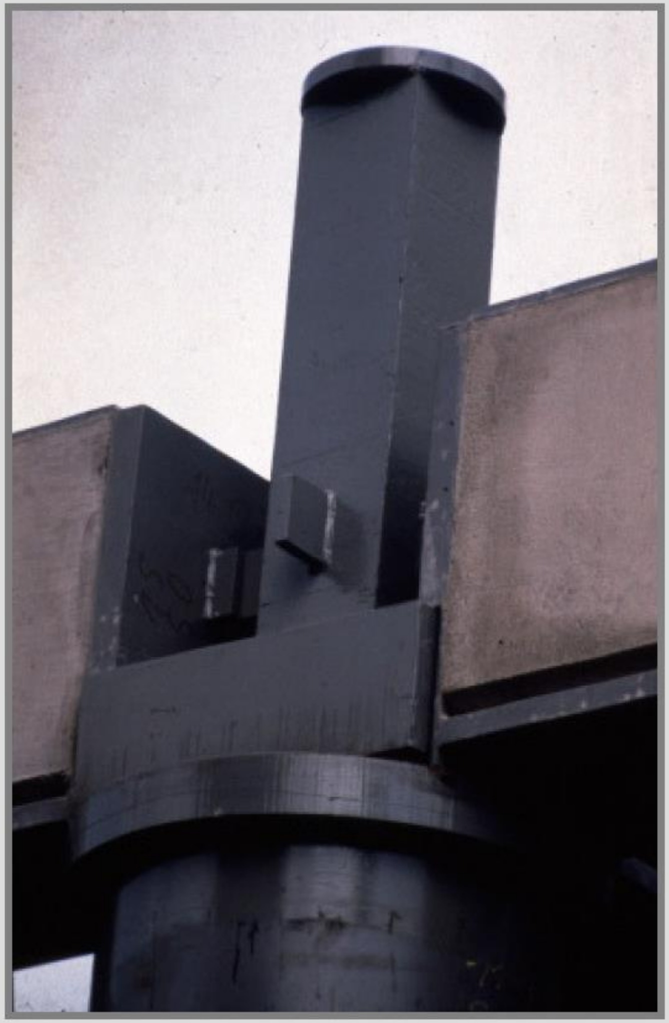
Joint with solid core profiles





Joint with solid core profile for continuous beams

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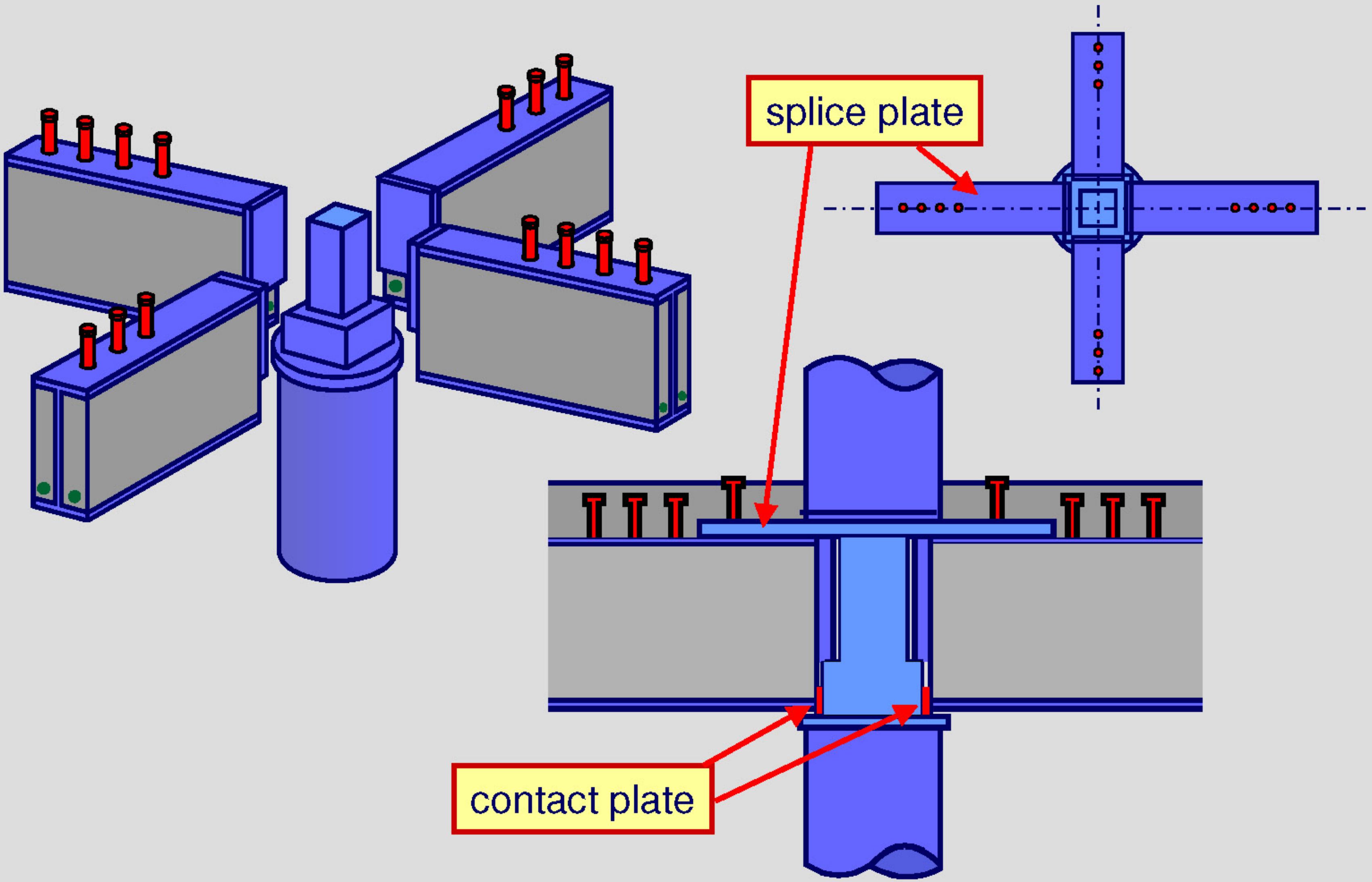

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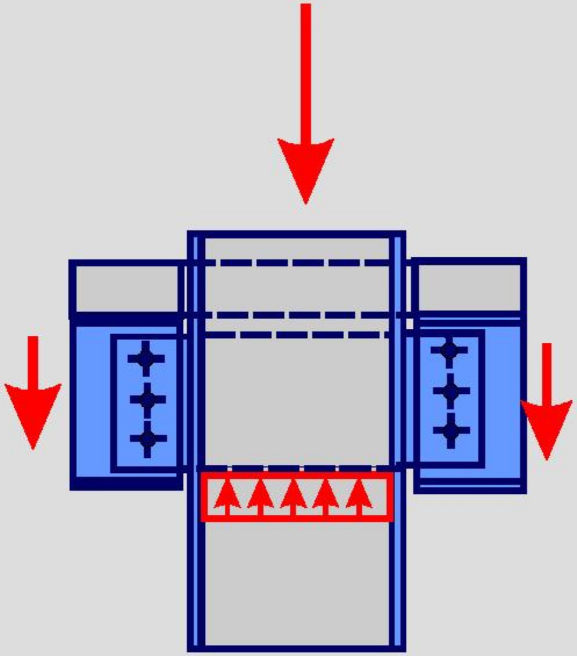
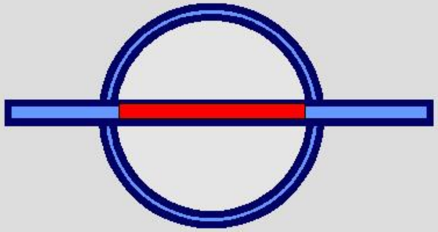
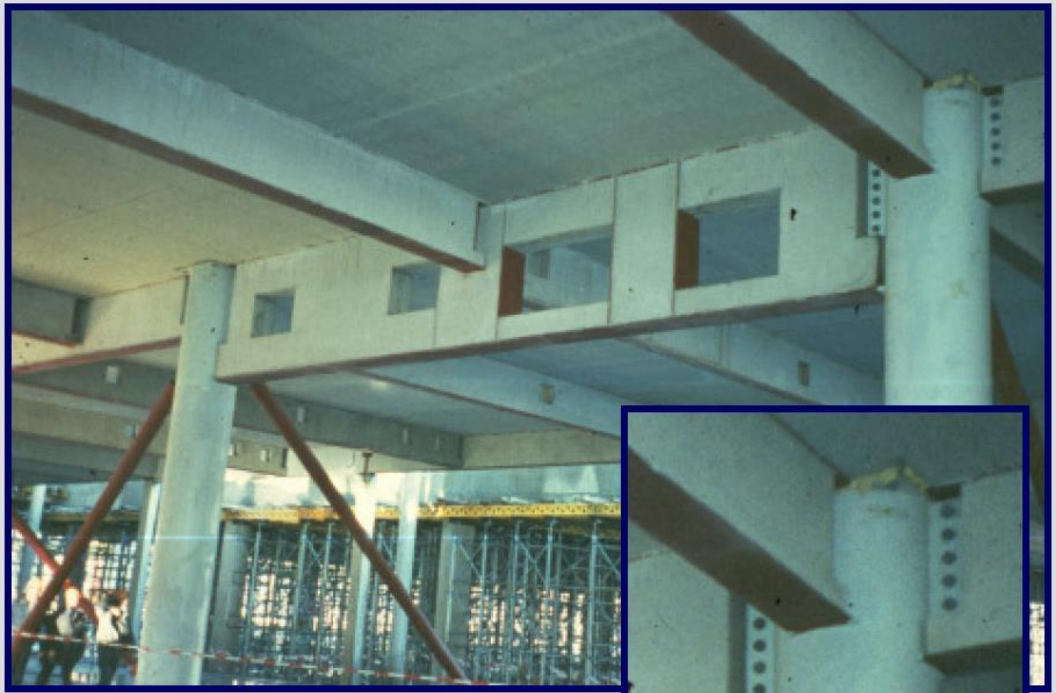
Load introduction with gusset plates







Load introduction with gusset plates

Load introduction with partially loaded end plates

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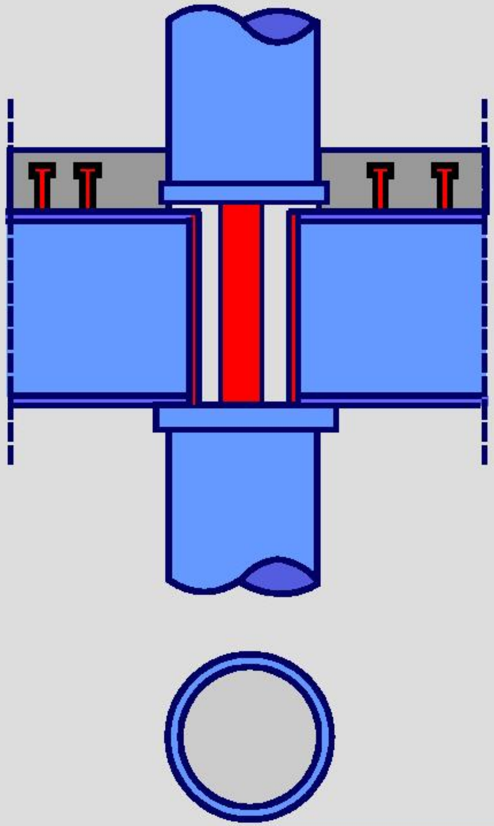

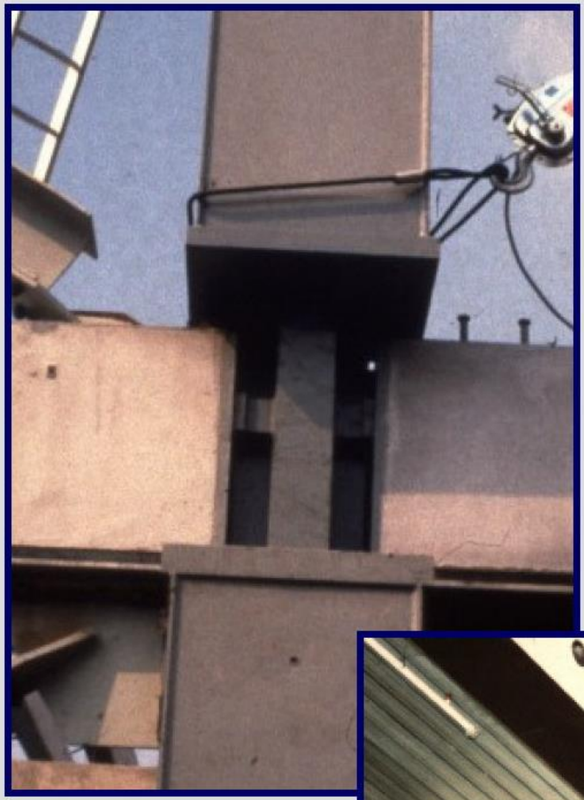

Load introduction with partially loaded end plates

Load introduction with distance plates for columns with inner core profiles

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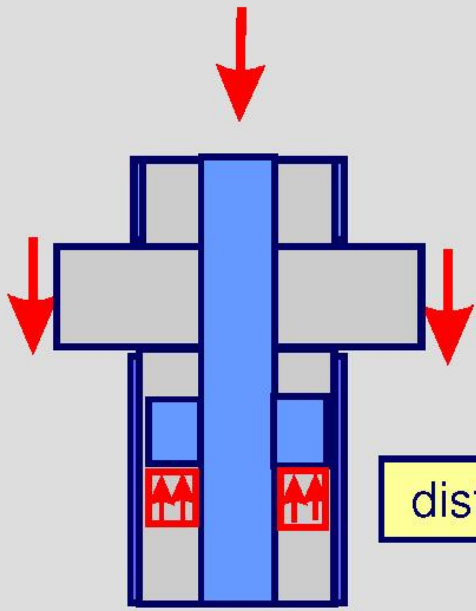
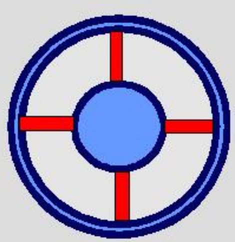


distance plates



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Part I-6

Examples of composite buildings

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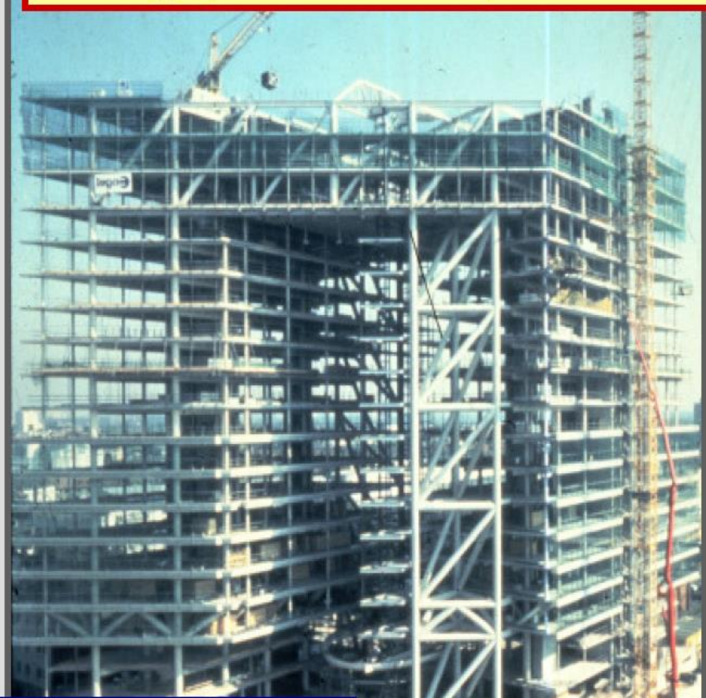
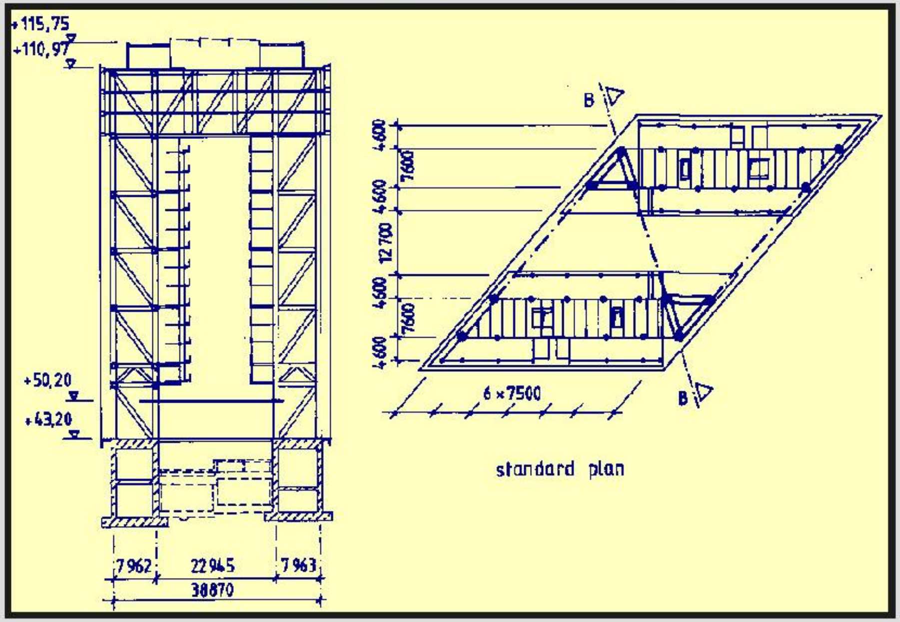
High-rise building in Düsseldorf “Stadttor Düsseldorf”

Bracing systems with composite columns



Composite columns, composite beams and composite floors



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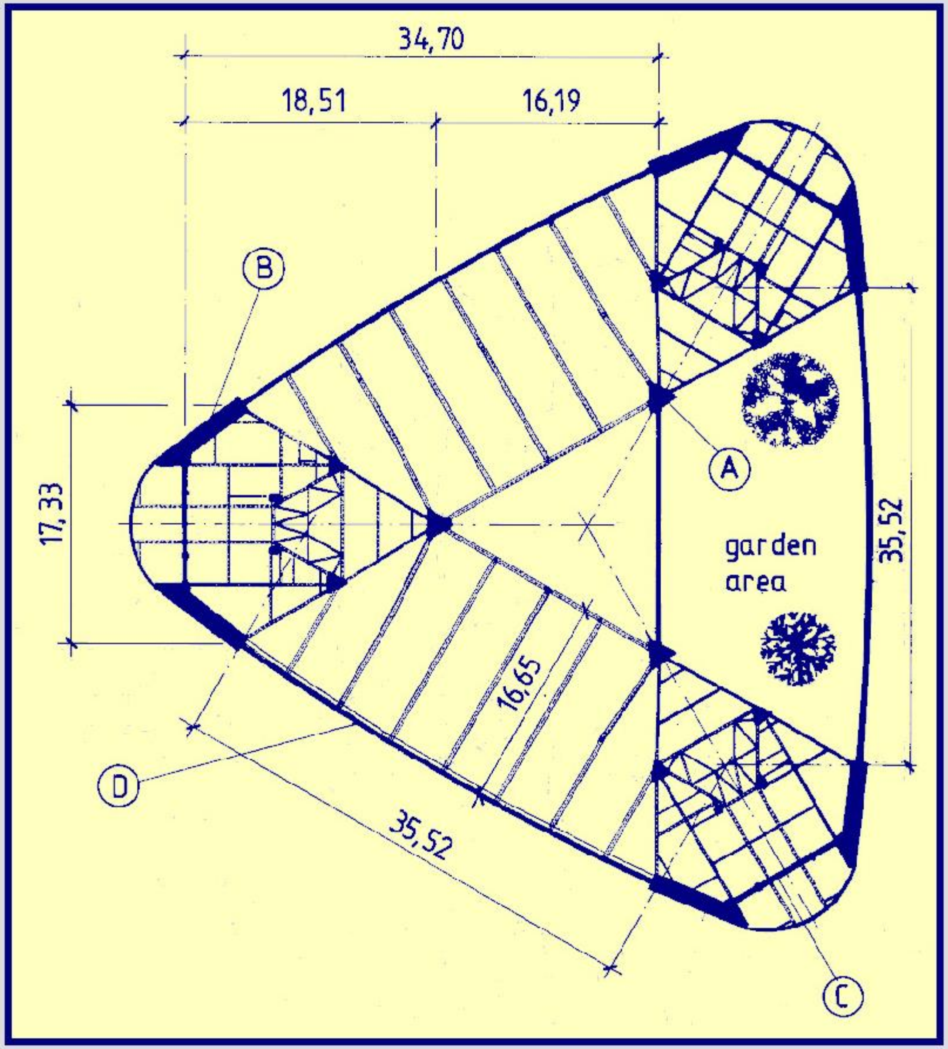
Commerzbank Tower in Frankfurt



Commerzbank Tower in Frankfurt

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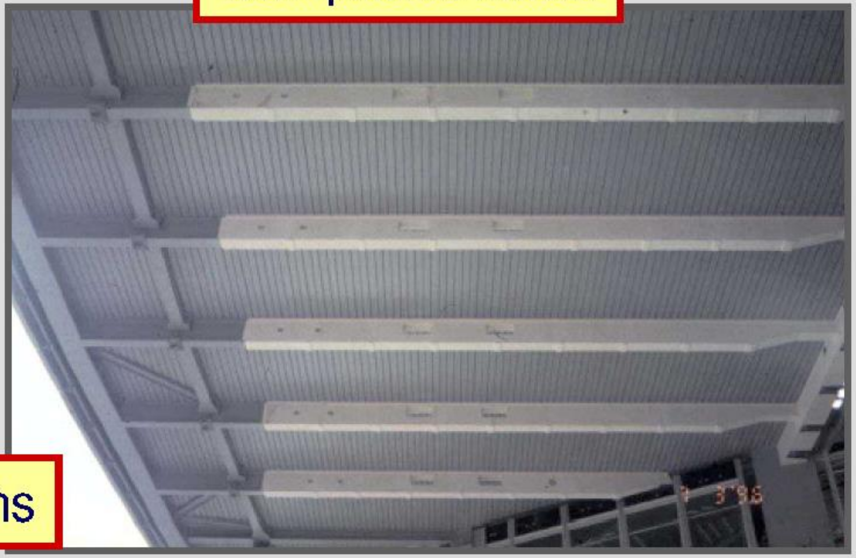

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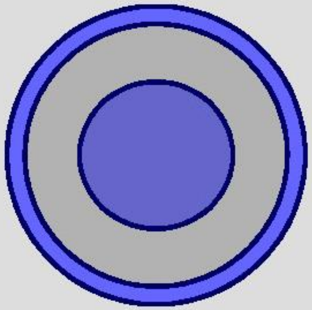
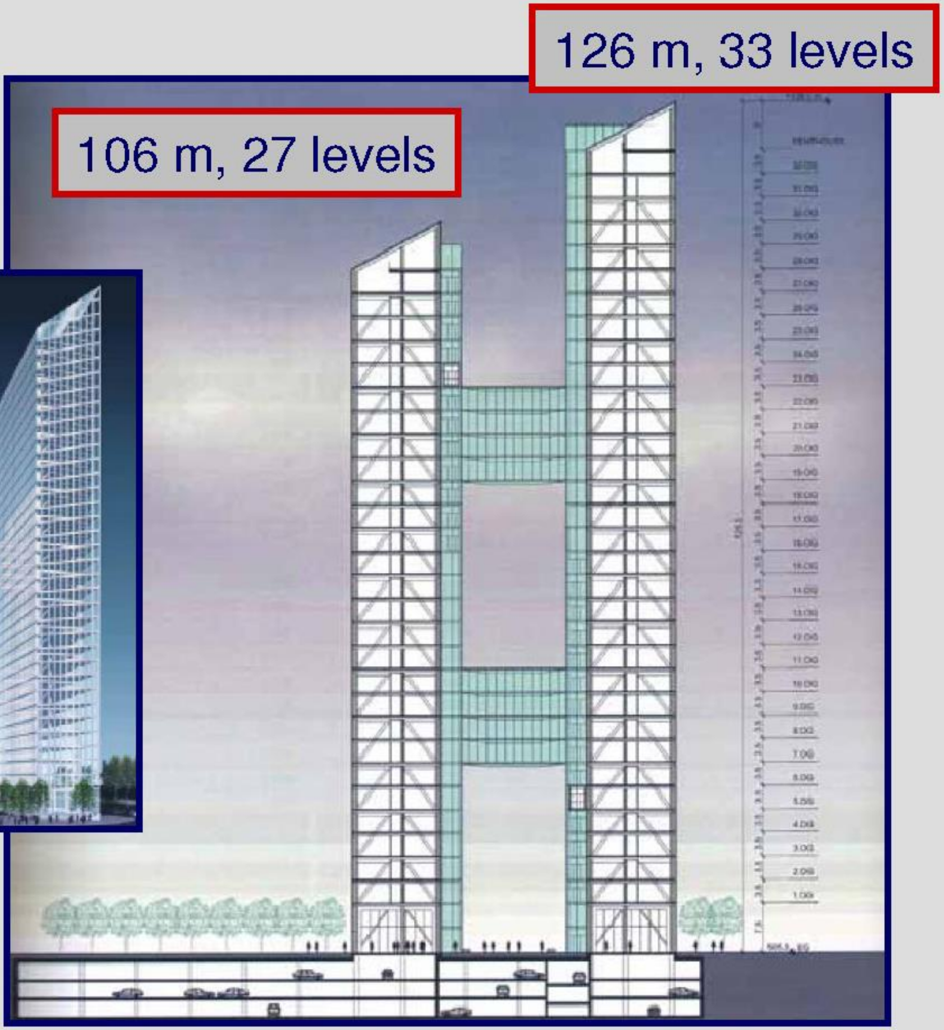


Composite columns with inner core profiles

Highlight Munich Business Towers



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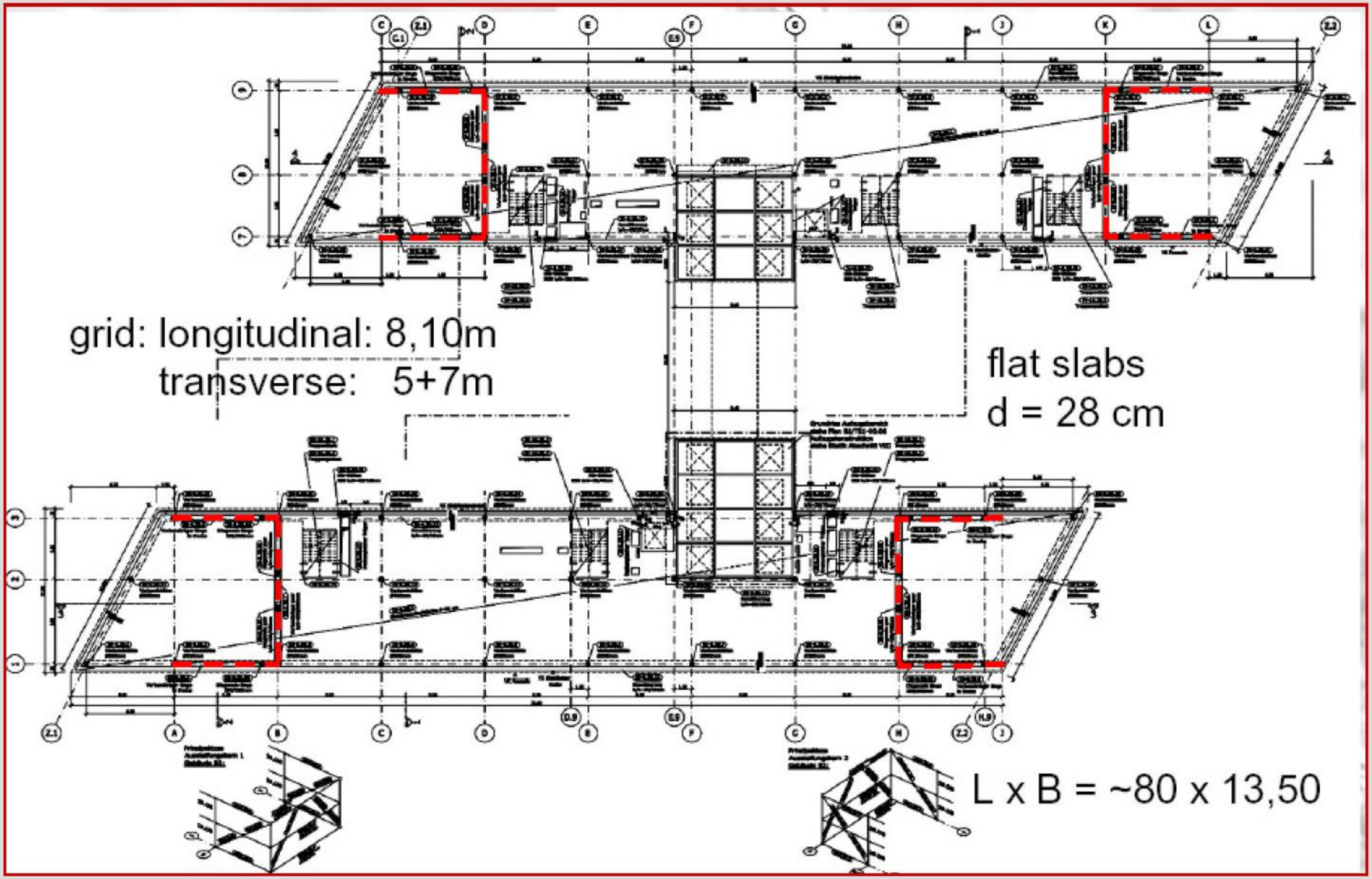
Highlight Munich Business Towers



Highlight Munich Business Towers

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Highlight Munich Business Towers

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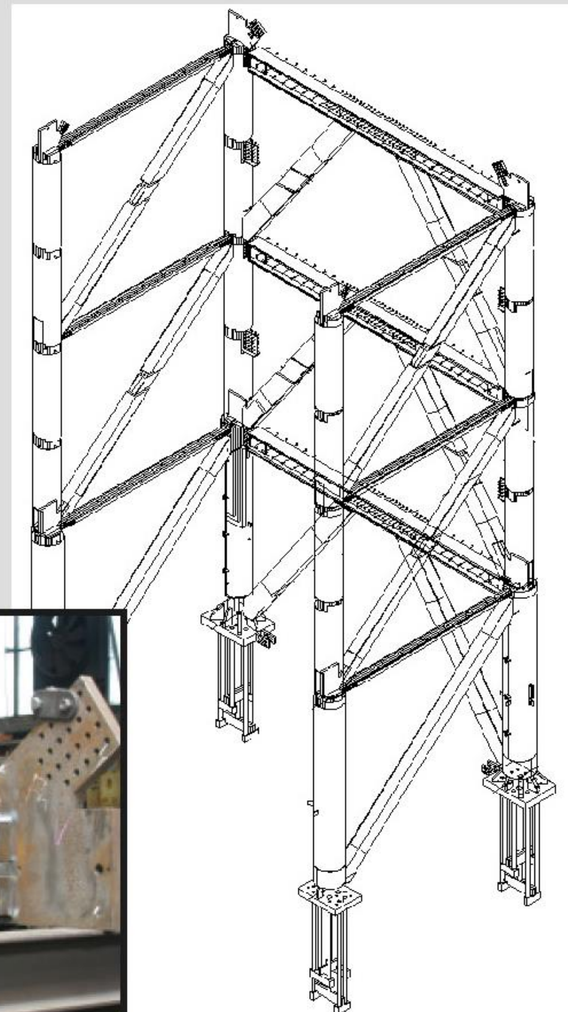

Highlight Munich Business Towers

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Office buildings

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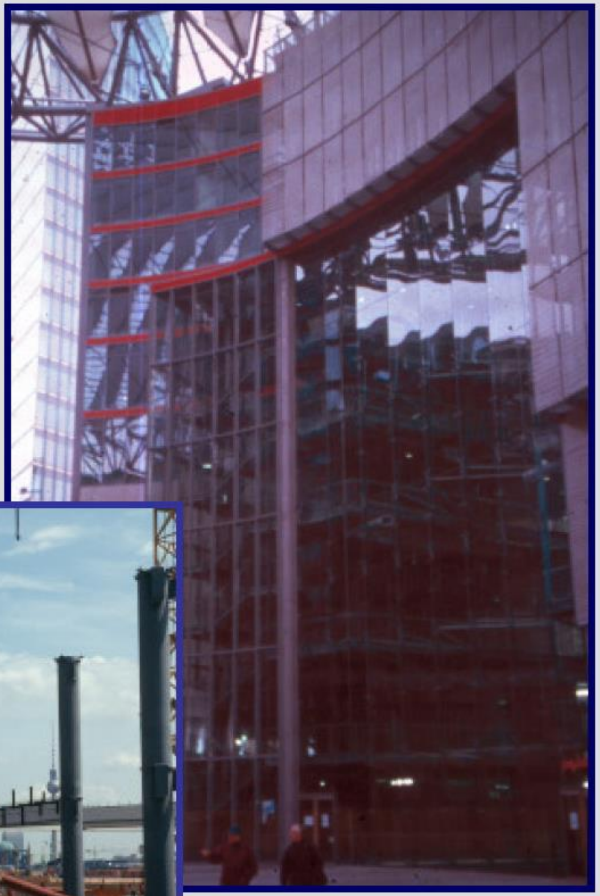

Sony-Center Berlin

Office building and production unit of Siemens in Berlin

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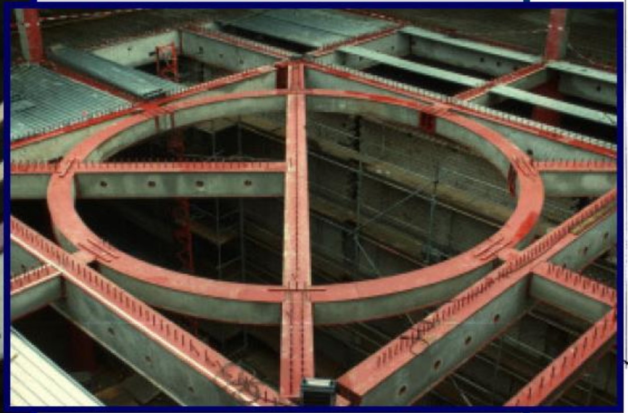

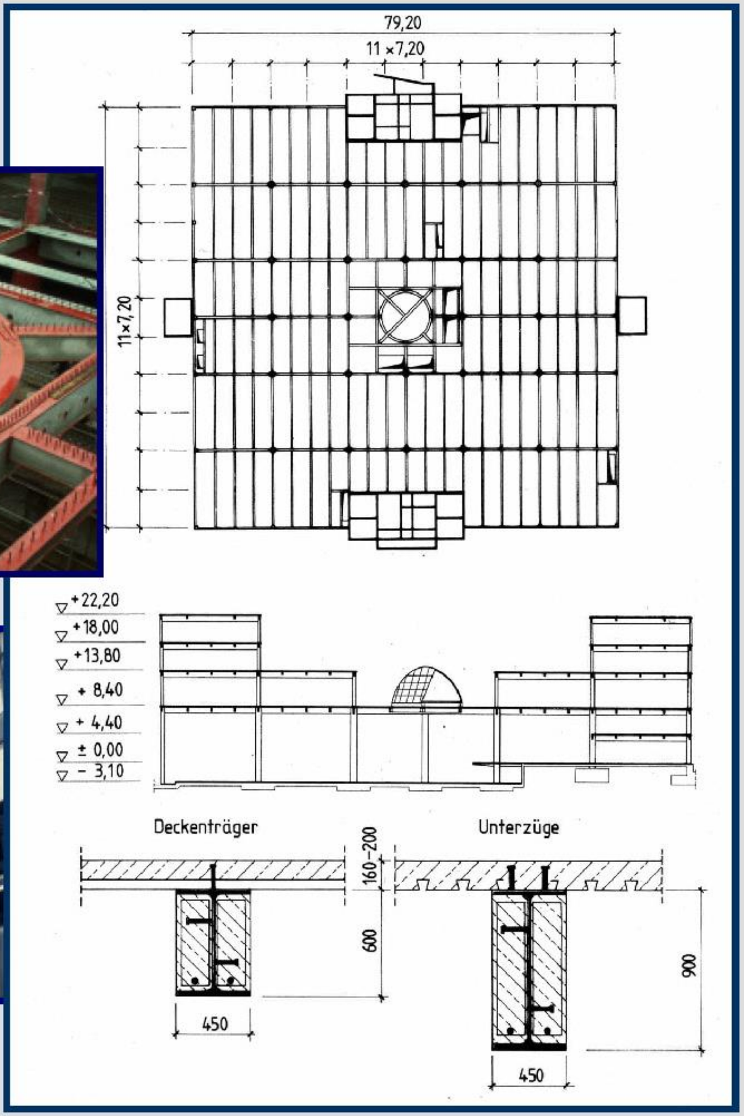

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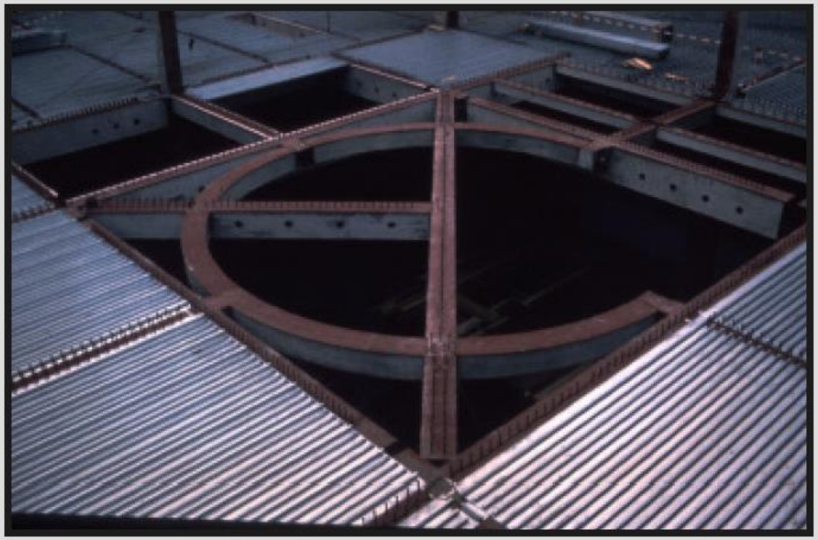

Body unit of Porsche in Stuttgart

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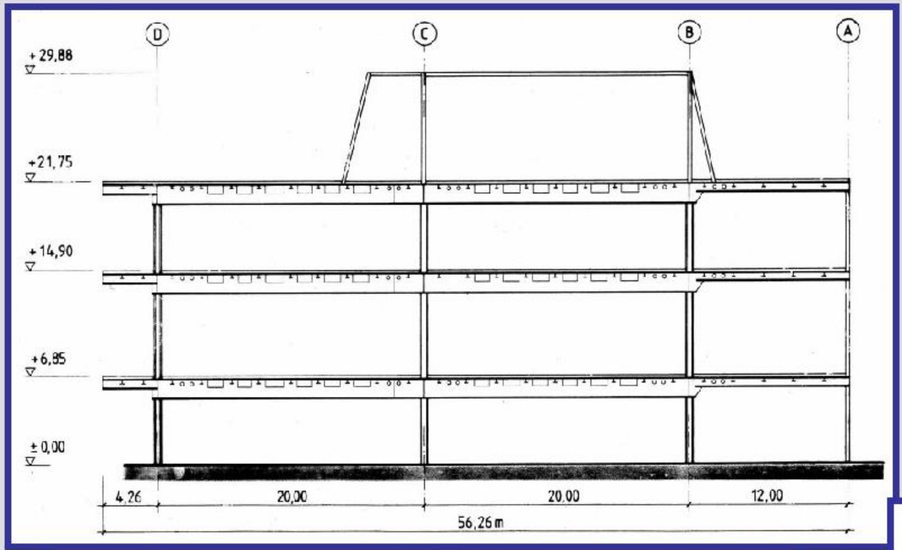

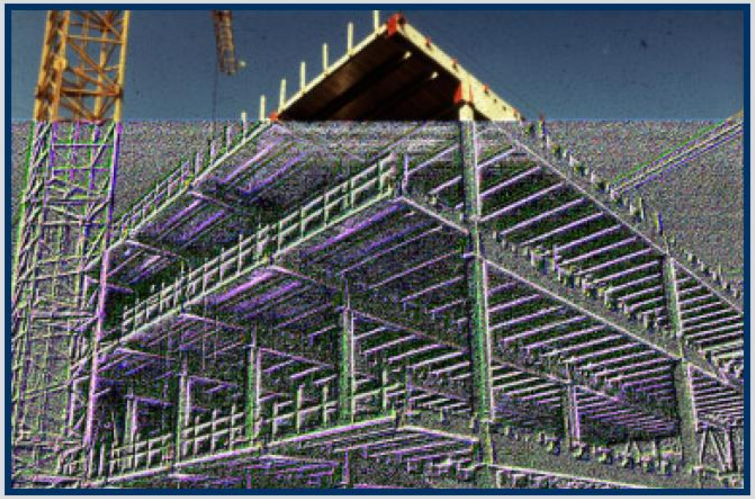

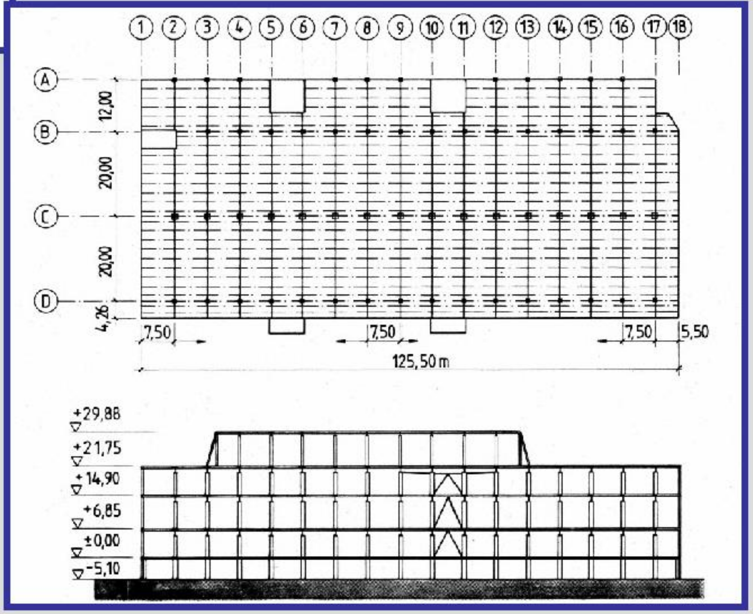

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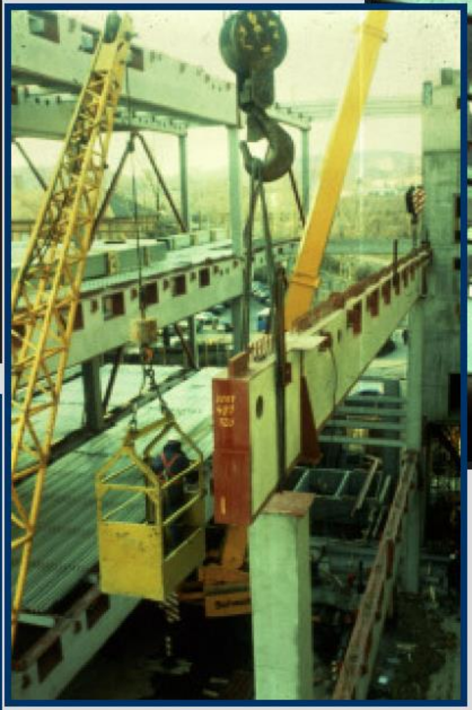
Body unit of Porsche in Stuttgart



Paint unit of Opel in Eisenach

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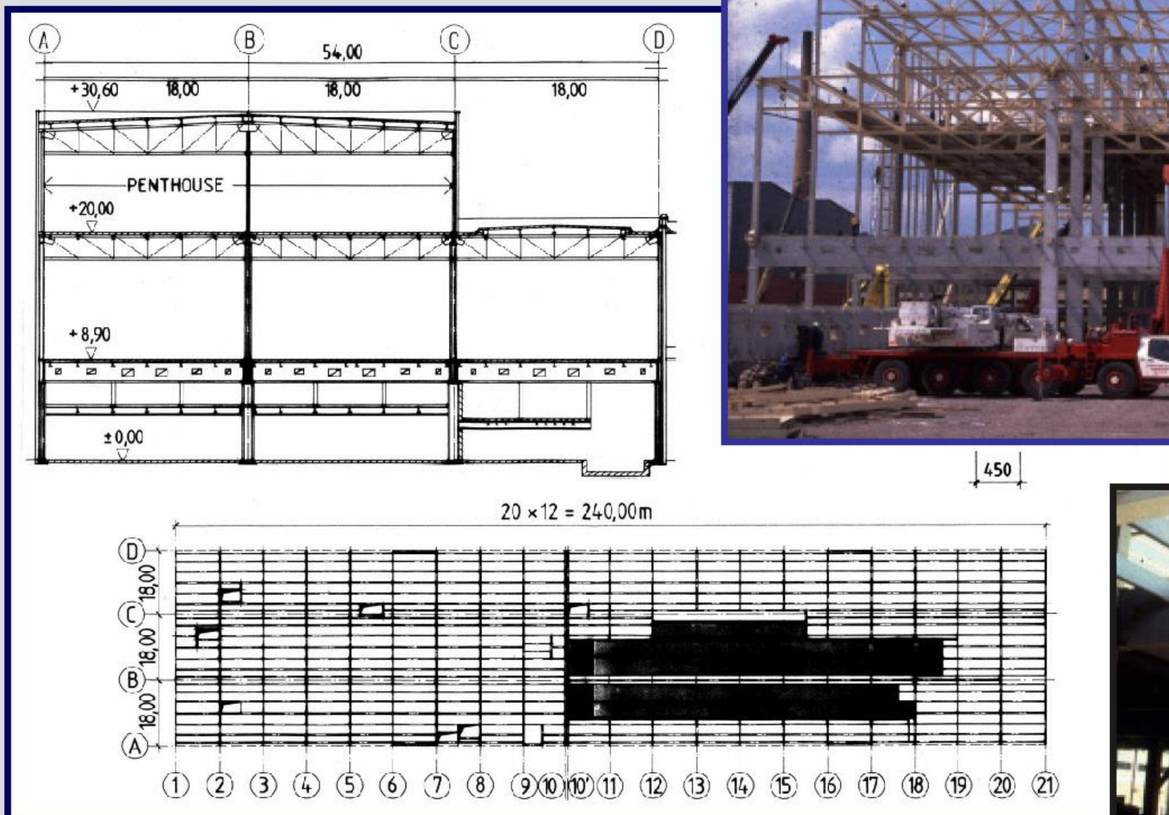

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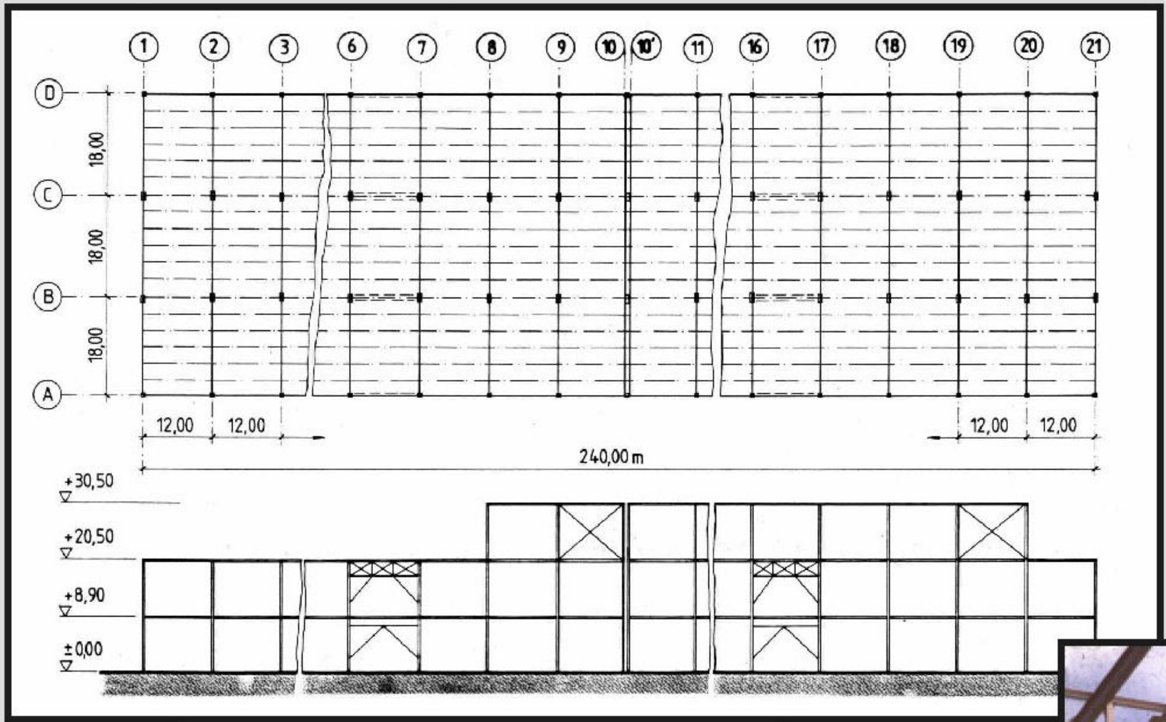
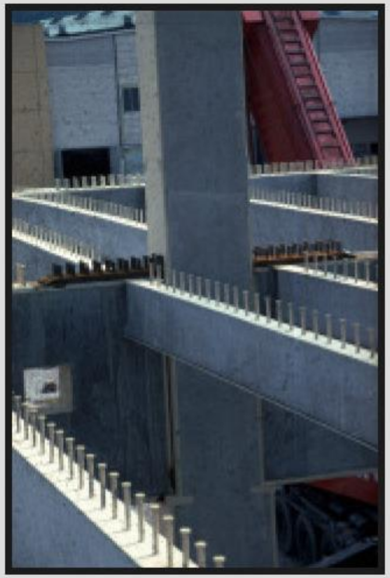
Paint unit of Opel in Eisenach





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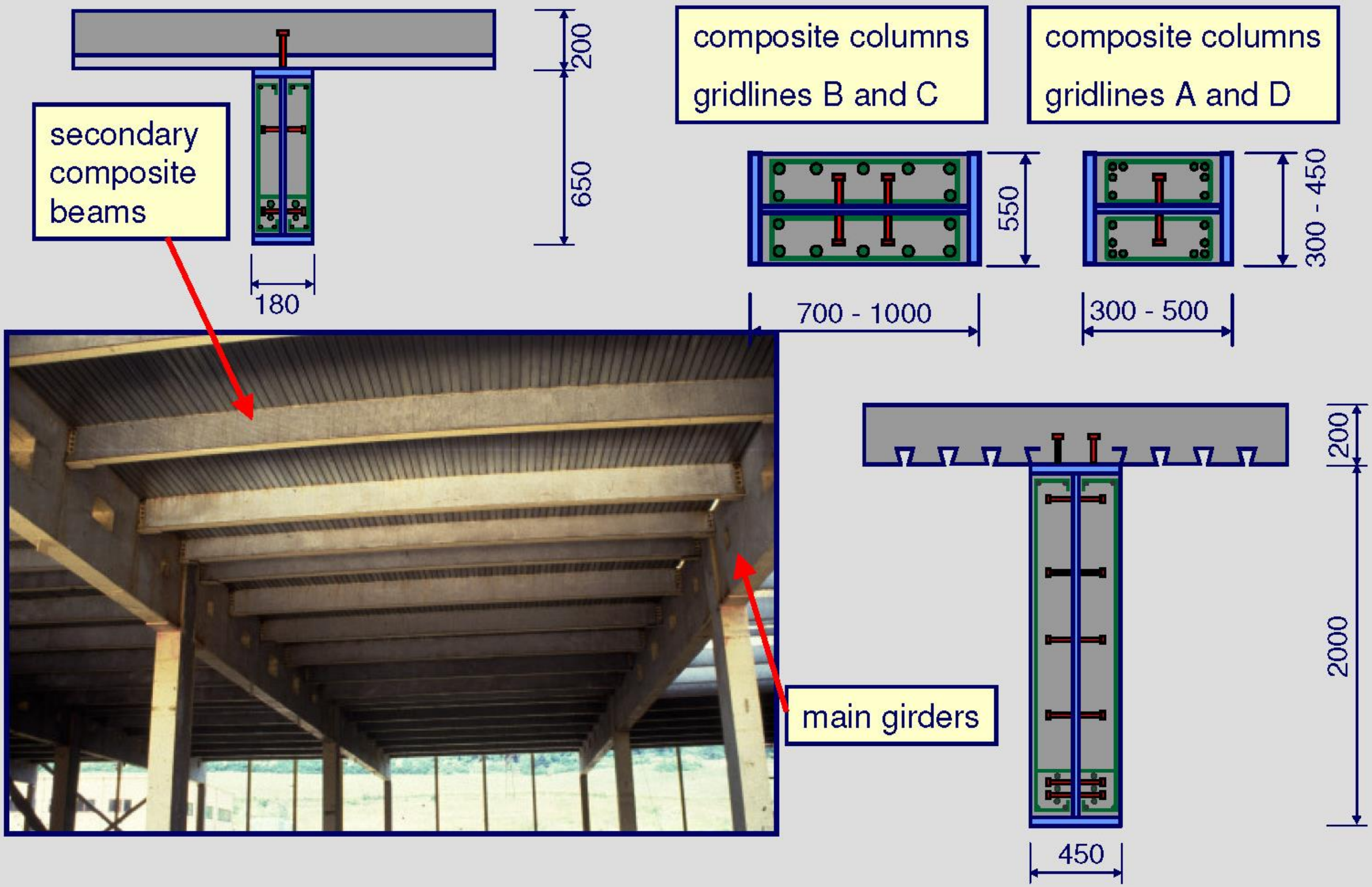

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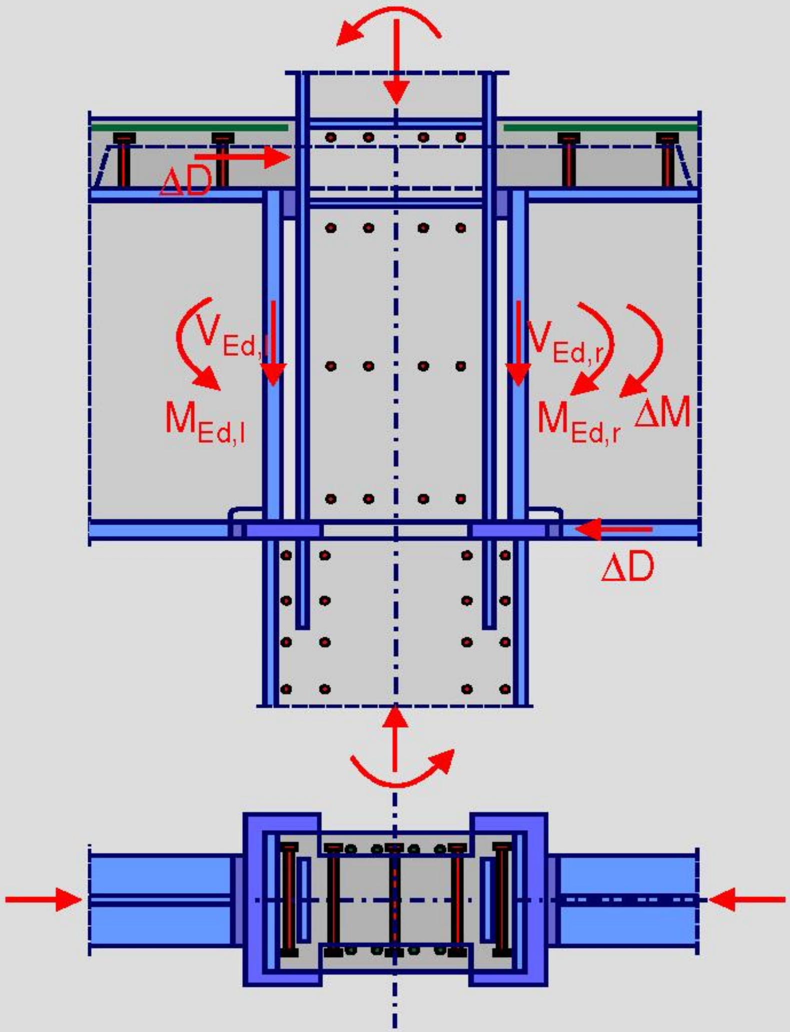

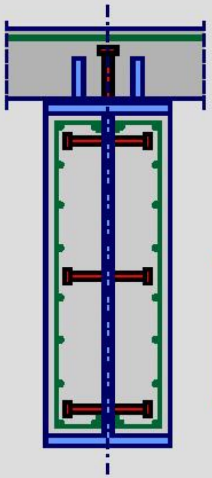

Full strength and rigid frame joint

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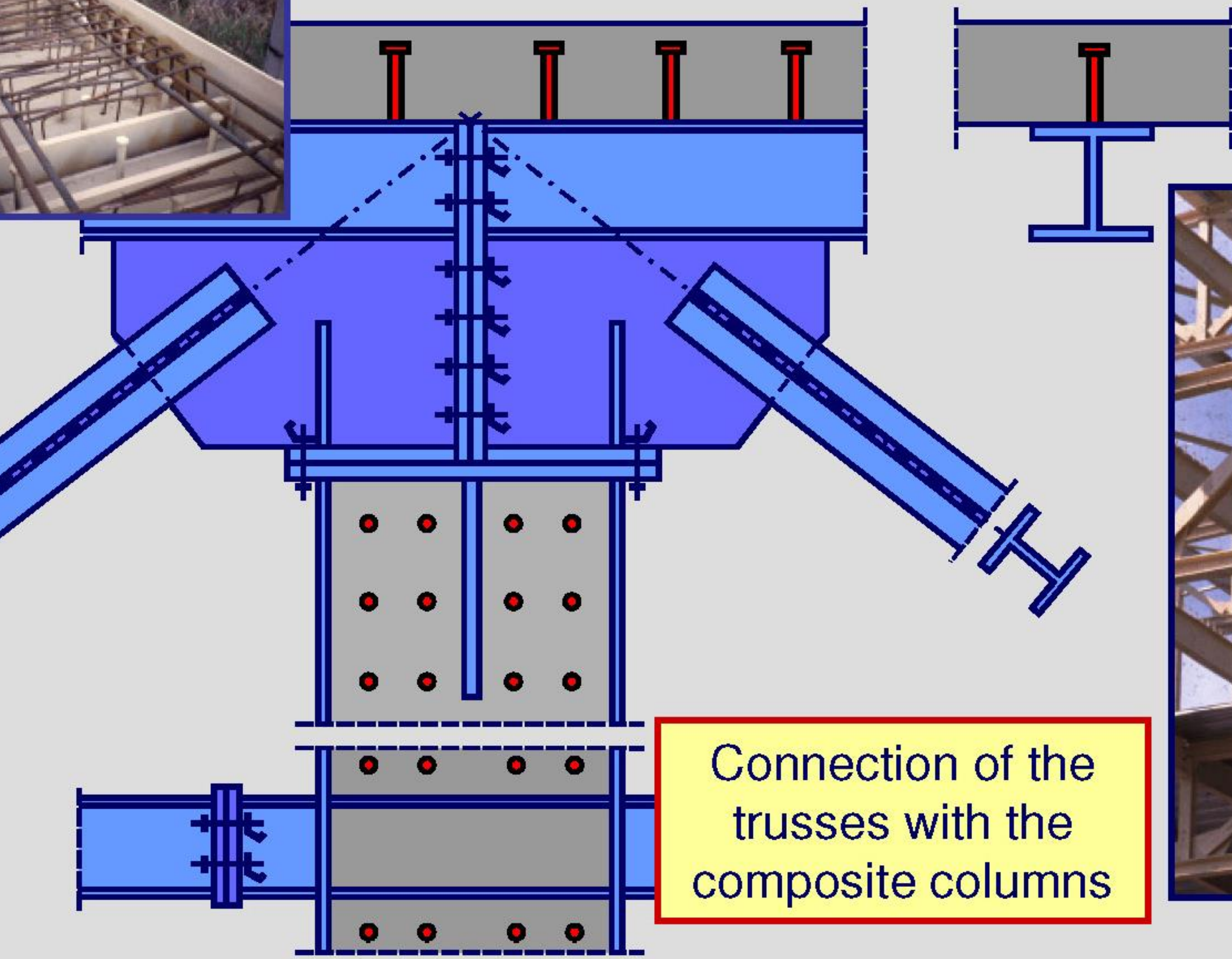
Paint unit of Opel in Eisenach



Connection of the trusses with the composite columns

Airport Hannover

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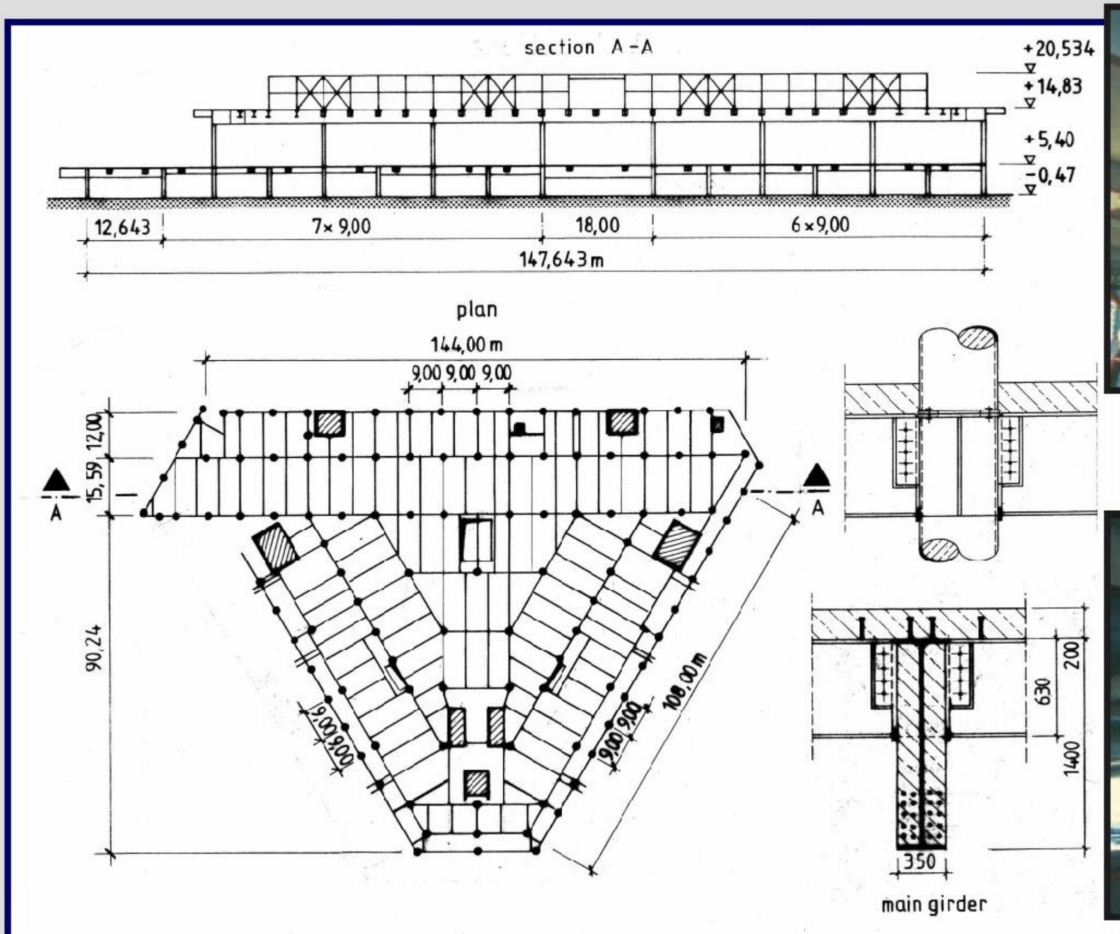

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Composite Steel and Concrete Structures

Innovative Solutions for Outstanding Buildings

Thank you very much for your kind attention!