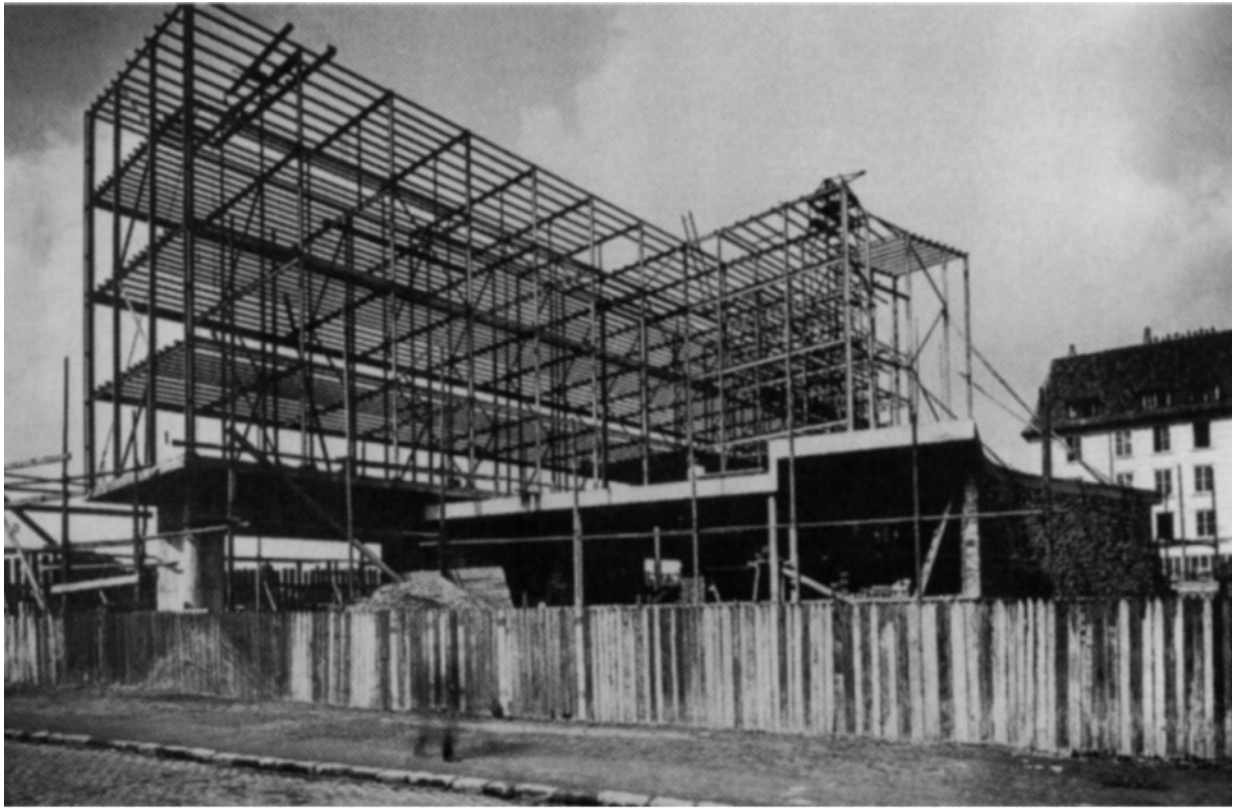
CIVIL-526: Steel structures, selected chapters

Floor joist systems (composite)

Types and design

(ref. TGC 11, chaps. 4 and 10)

Conventional framing system: secondary-primary beams - columns



Swiss Pavilion at the Cité Universitaire, Paris, arch. Le Corbusier, 1932

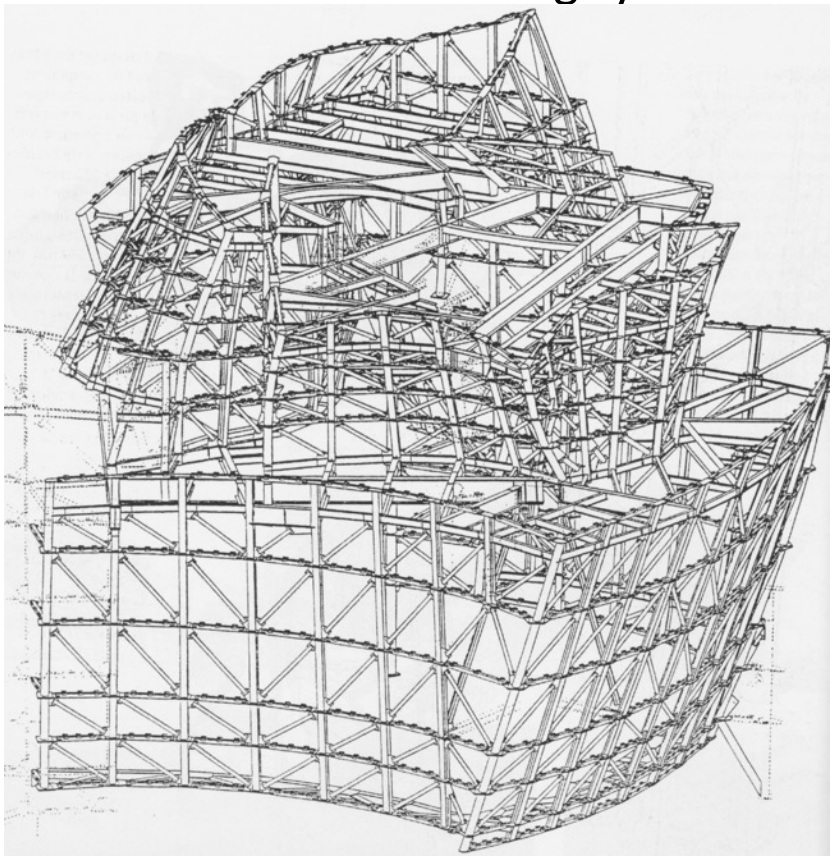
Today: classic framing system

Senn AG steel-frame office building, Ofringen

Developments:

- Fewer elements and beams w/openings
- Fewer or no 2nd beams
- Steel + prefab slabs or composite floors
- Tubular columns (steel or composite)

Today: organic forms, but structurally unfinished, no innovation in the beam-column-bracing system

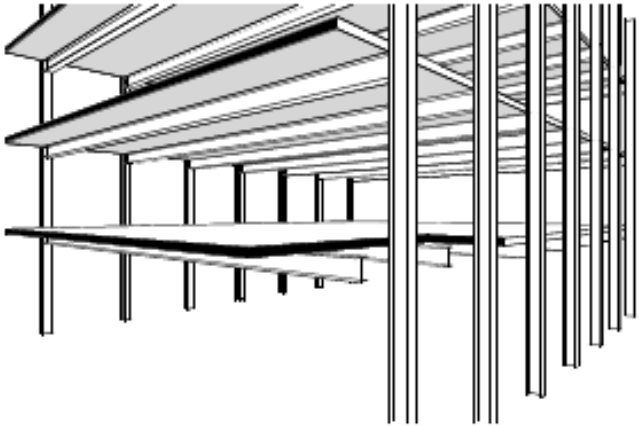


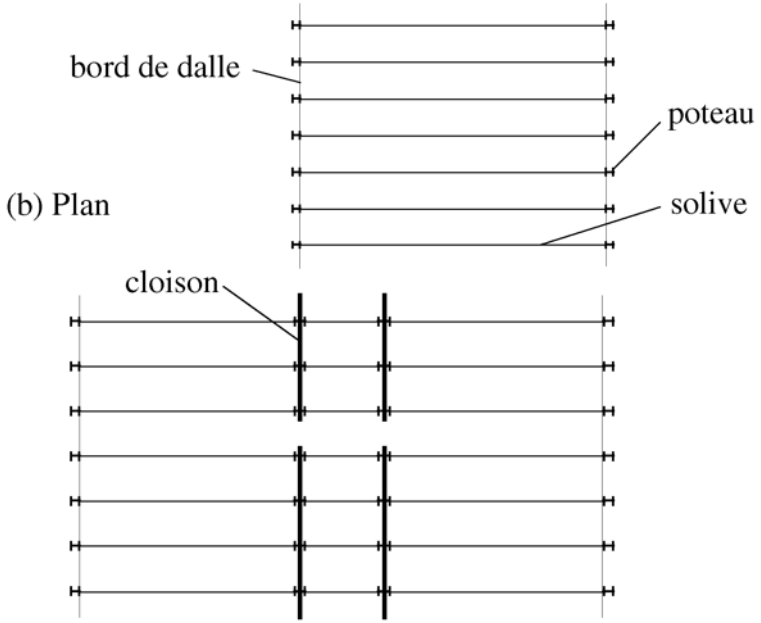
Guggenheim Museum, Bilbao, arch. F. O. Gehry, 1997

- Deconstructivist approach promoting organic and undulating forms
- The result of a unique combination of stone, glass and titanium
- Bold configuration
- Innovative design
- An attractive backdrop for the art on display here
- A spectacular sculptural **work of art**
- Improvements thanks to BIM?
- What about sustainable development?
- Should remain the exception

Fig. 4.21: Floor and beam systems

Systems with 1 level of beams (without 2nd beams)

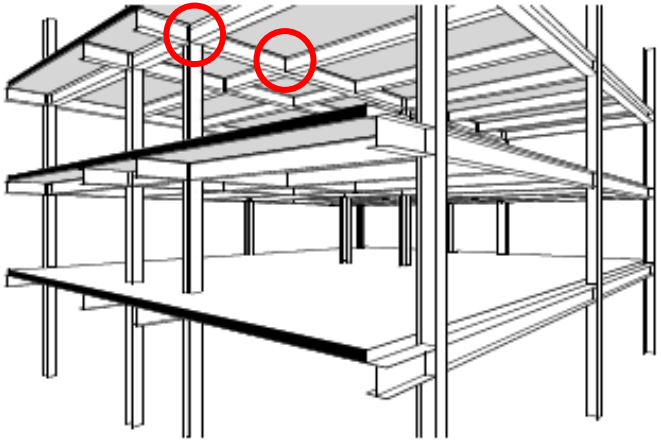


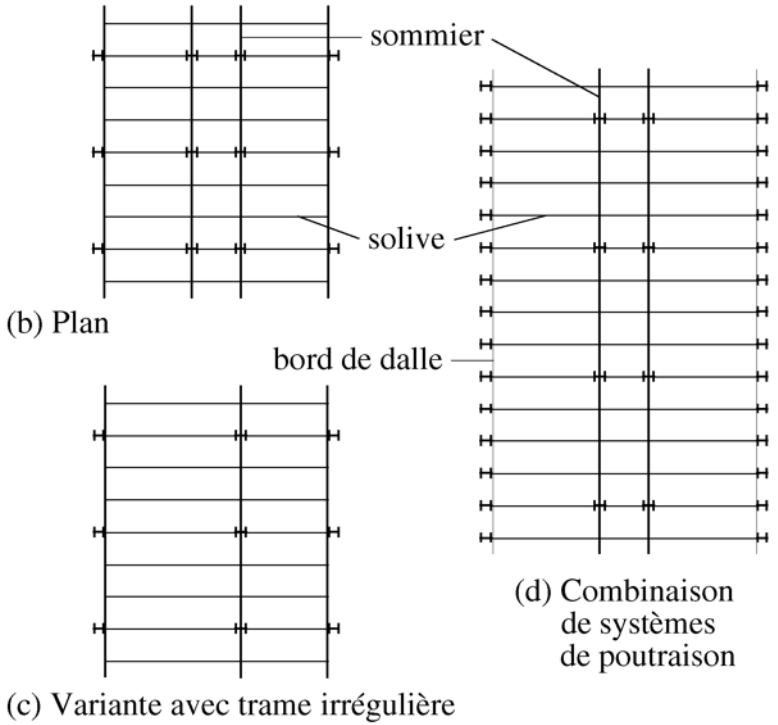


(c) Variante avec deux rangées de poteaux intérieurs

Fig. 4.22: Floor and beam systems

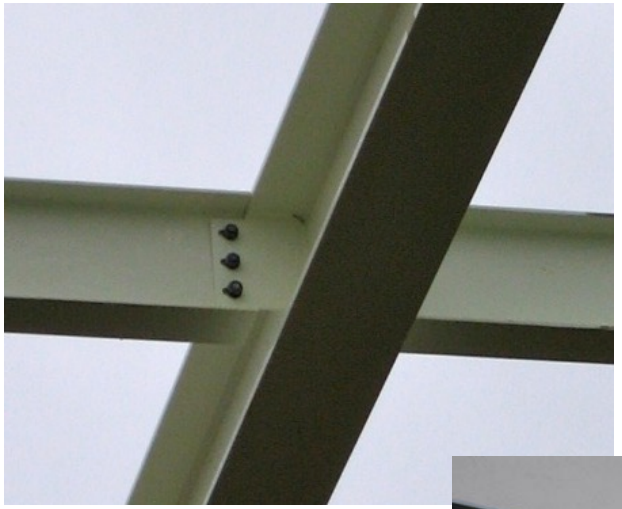
Systems with 2 beam directions: avoids tight rows of columns on the façade



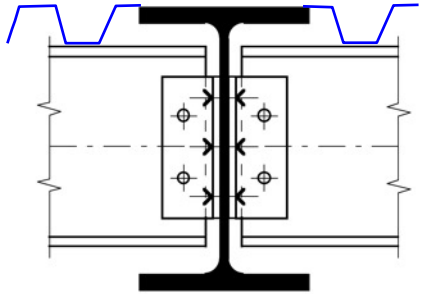


Systems with 2 beam directions

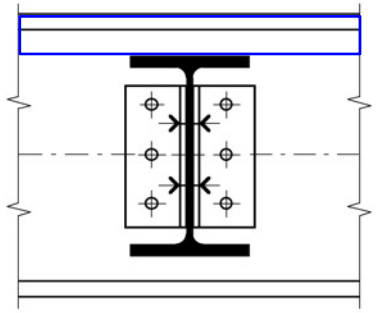
Continuous beds, single-beam joists

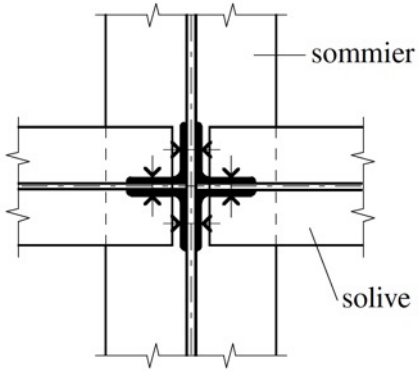


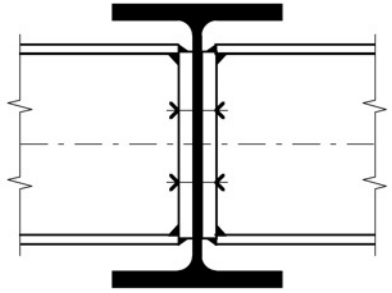
2-directional 2nd and main beam systems



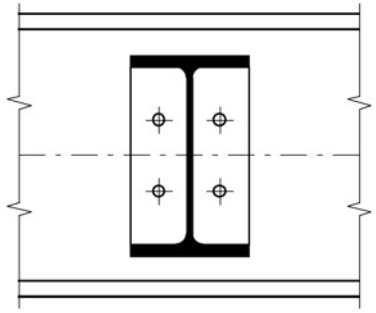
Assemblage par double cornière

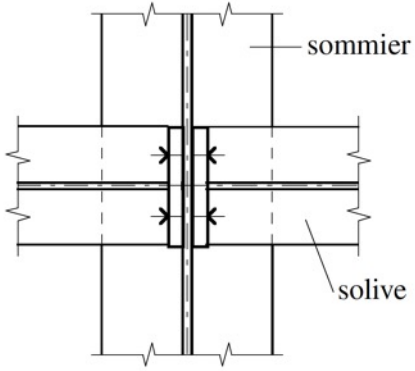






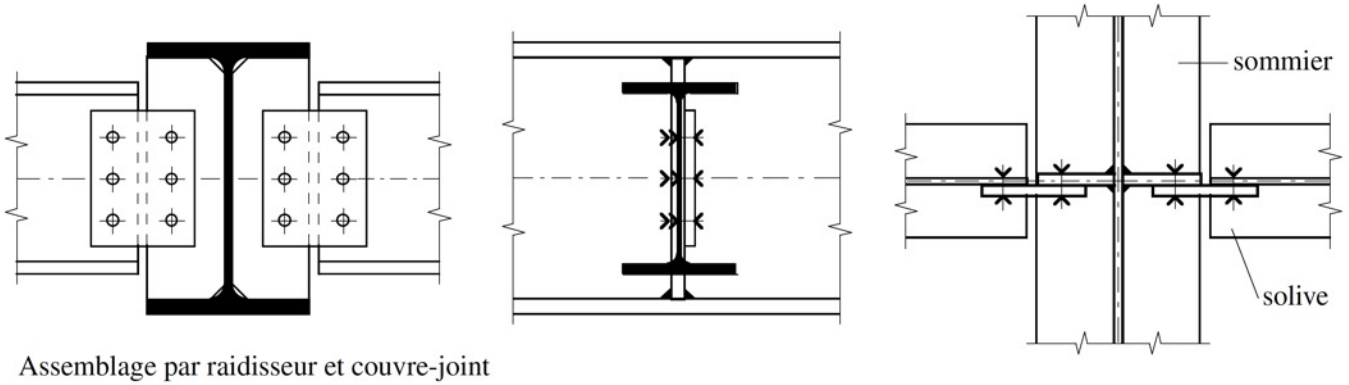
Assemblage par plaque frontale



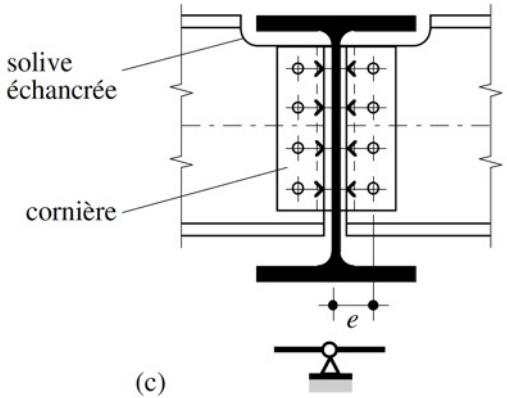


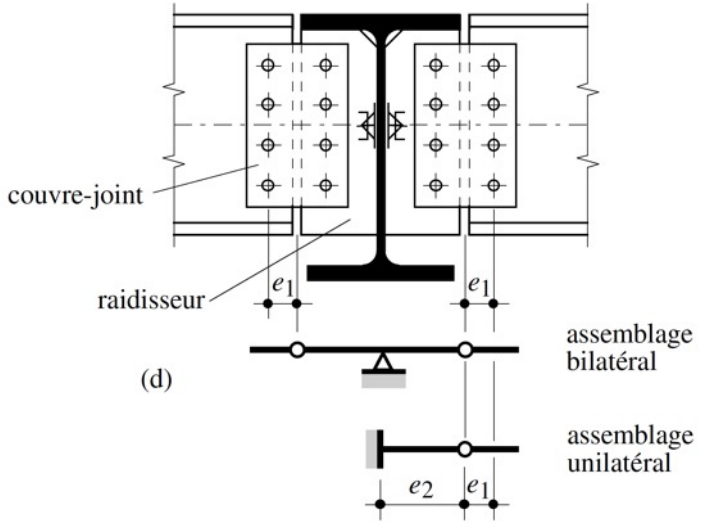
(TGC 11, fig. 10.1)

2-directional 2nd and main beam systems

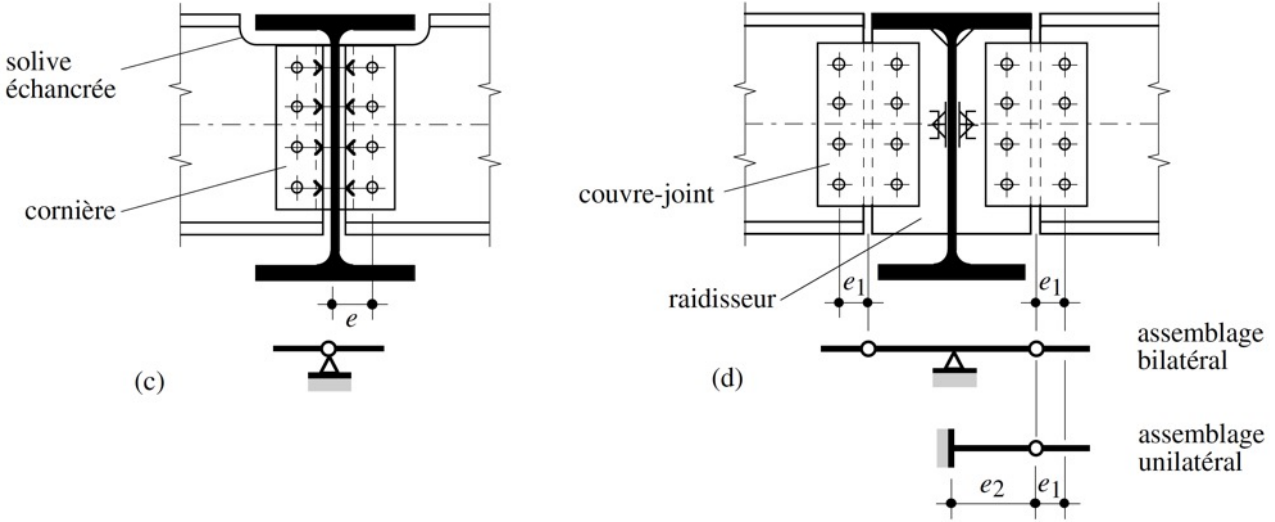


Assemblage par raidisseur et couvre-joint





2-directional 2nd and main beam systems



3) Why indicating the values e, e_1 , e_2 in these hinged joints?

2-directional 2nd and main beam systems

EPFL buildings, Ecublens (VD), centre midi

Dimensioning of beams with large openings in the web ?

- Lawson & Hicks, Design of composite beams with large web openings, report P355, SCI, 2011
- Repeated in TGC11 § 10.4
- Now integrated in the new EN 1993-1-13 (soon to be published)

Two-directional system without beams. Fig. 4.35: Reinforced concrete slab-floor, steel columns (limited spans)

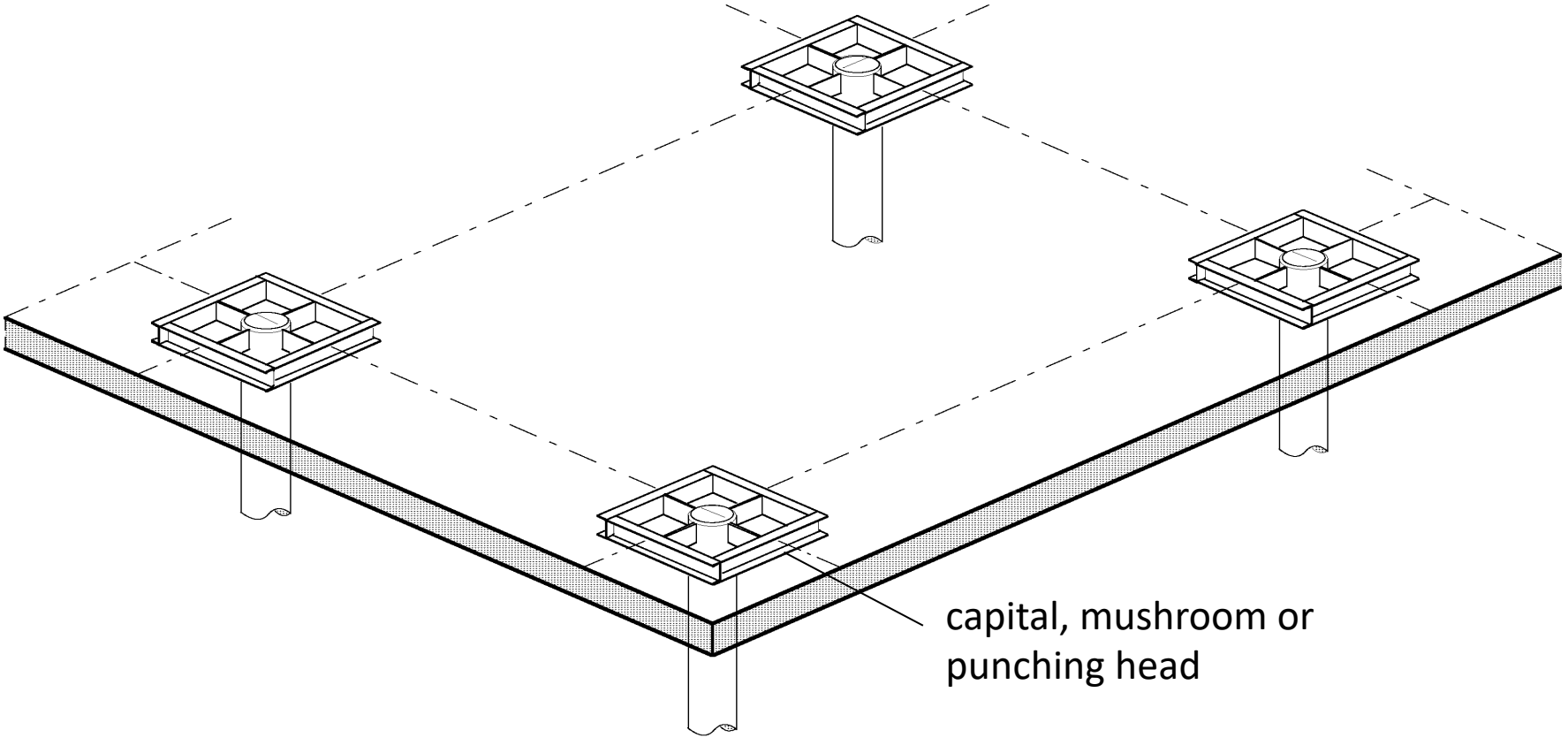
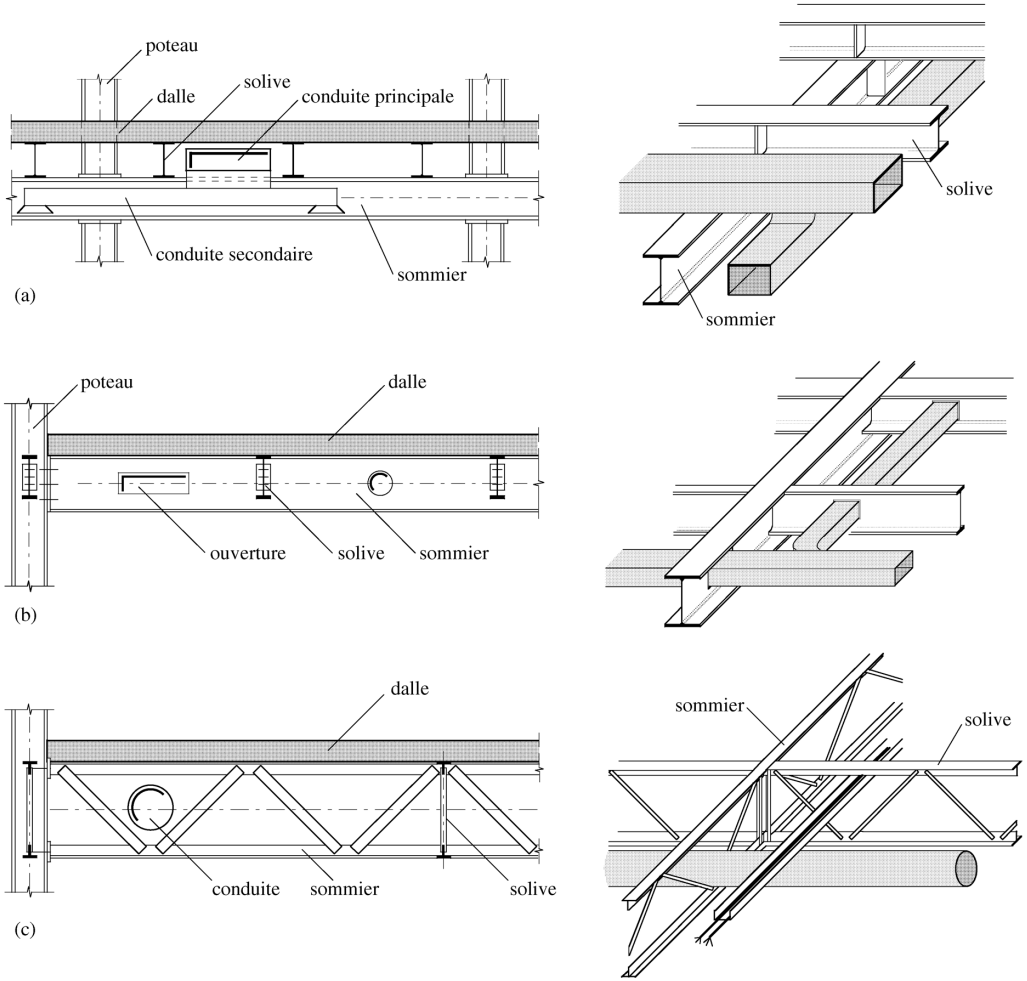
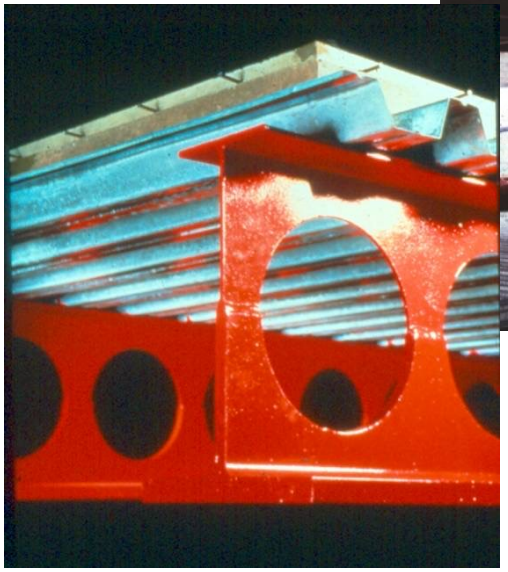


Fig. 4.23: e.g. floors with two-directional beam system



Castellated beams, or with large openings in the web



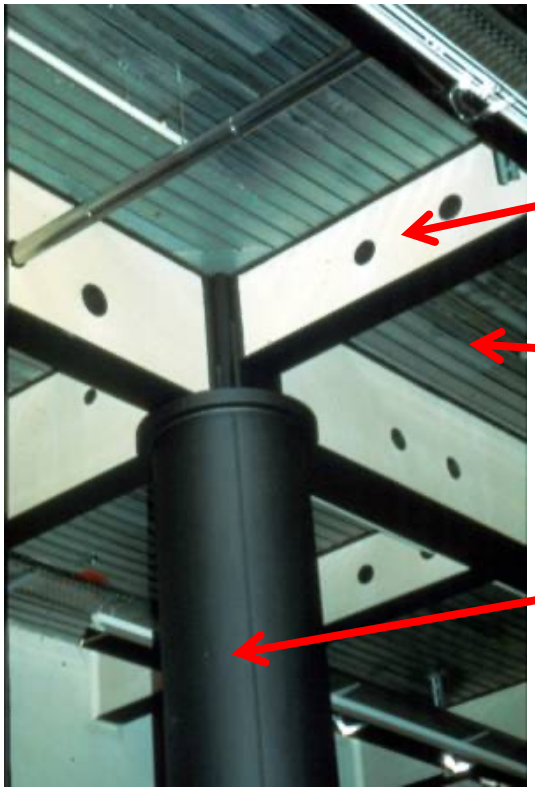
Beam with reinforced opening (near support)

Design rules: Hicks, S.J., Lawson, R.M., and Design of composite beams with large web openings, report P355, SCI, 2011

Castellated beam with reinforced opening

New shapes ("angelina" beam)

Steel-concrete construction



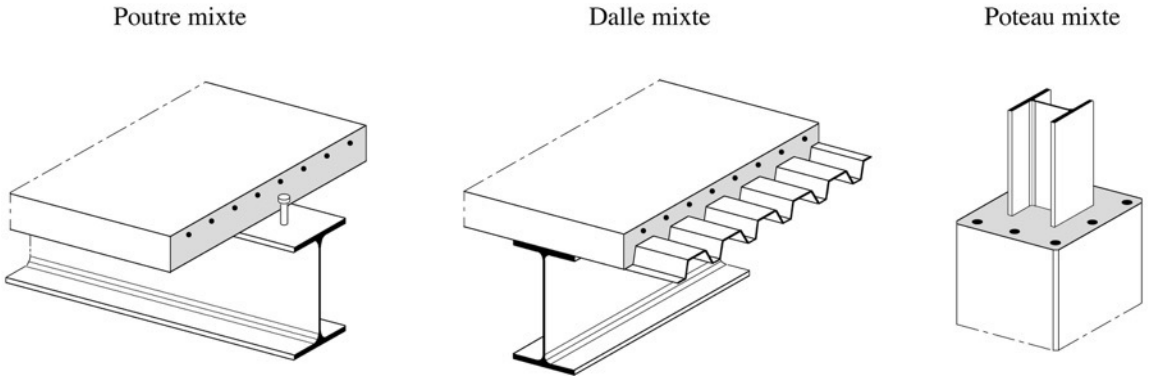
Composite construction, references

TGC 10

- § 4.7: General, equiv. steel sections, sizing/checks under N, M, V, interaction
- § 5.8: Composite beams, composite slabs (w/corrugated steel decking) under bending M
- § 6.5 : Composite columns under compression N

TGC 11

- § 4.4: Floors
- § 7.2: Corrugated steel decking
- § 9 : Composite slabs (incl. corrugated steel decking)
- § 10.5: Composite beams
- § 13.6: Composite columns
- § 14.4 Bracings w/corrugated steel decking (diaphragm)



Standards SIA 264 & EN 1994-1-1 & EN1994-2

Composite steel-concrete construction

Beams, usually composite

Floors, usually composite

Fire requirements, concrete between flanges of beams and columns

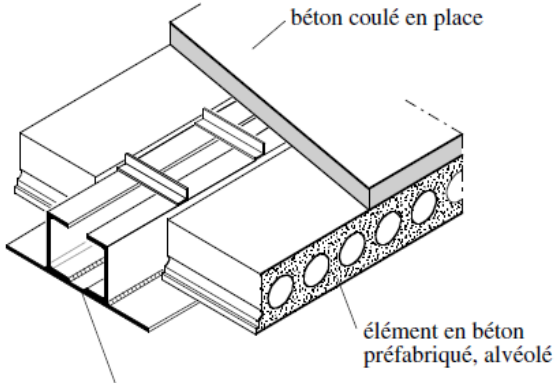
Modern, integrated composite systems

1. Shallow or slim floor (plancher mince)
2. Integral beam floor: hollow slab or collaborating composite floor (plancher collaborant)
3. Other: e.g. integrated beam floor and under-pinned (poutre intégrée et sous-tendue)

Purpose: min. height, while keeping integration of services pipes separate (flexibility and sustainable construction)

Fig 4.34: shallow or slim floor

Concrete cast in-situ

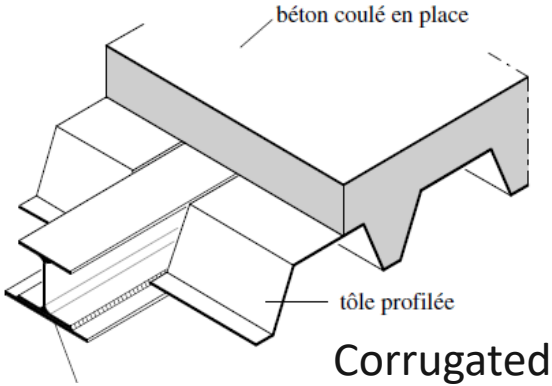


poutre composée soudée

Fabricated girder

Prefab hollow core concrete slab

Concrete cast in-situ

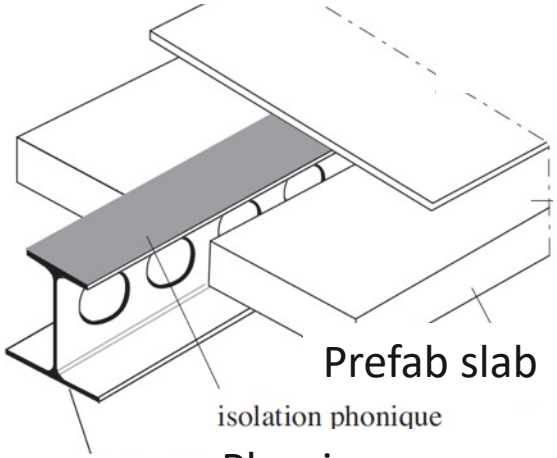


Fabricated girder

Corrugated steel decking

Floor and covering

chape et finitions



Prefab slab

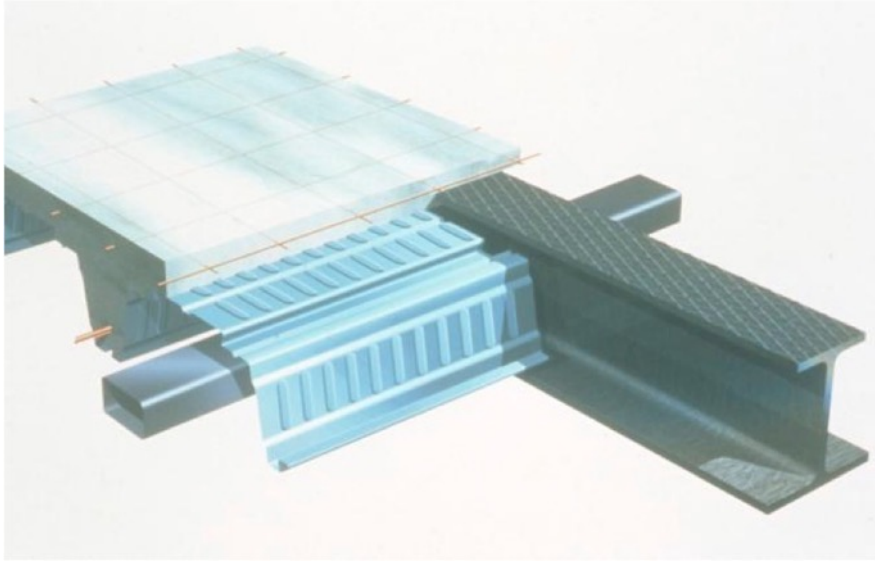
Fabricated castellated girder

Phonic insulation

4) What other advantages do you see in integrated floor systems?

Shallow or slim floor

Yesterday: the CVSEs were laid, then the remaining area was filled with concrete to increase plate stability/stiffness
Tomorrow: systems where there is no need to fill !



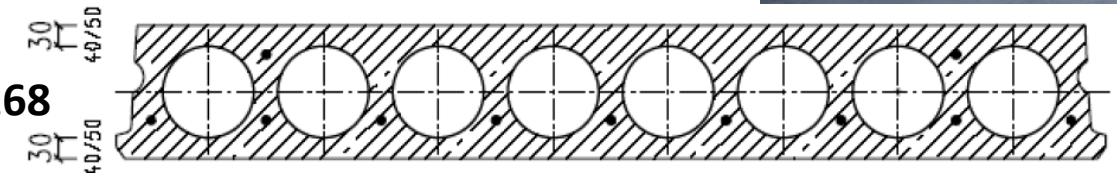
Shallow or slim floor with integrated beam

Integral beam floor

Advantages of using prefabricated hollow slab elements:

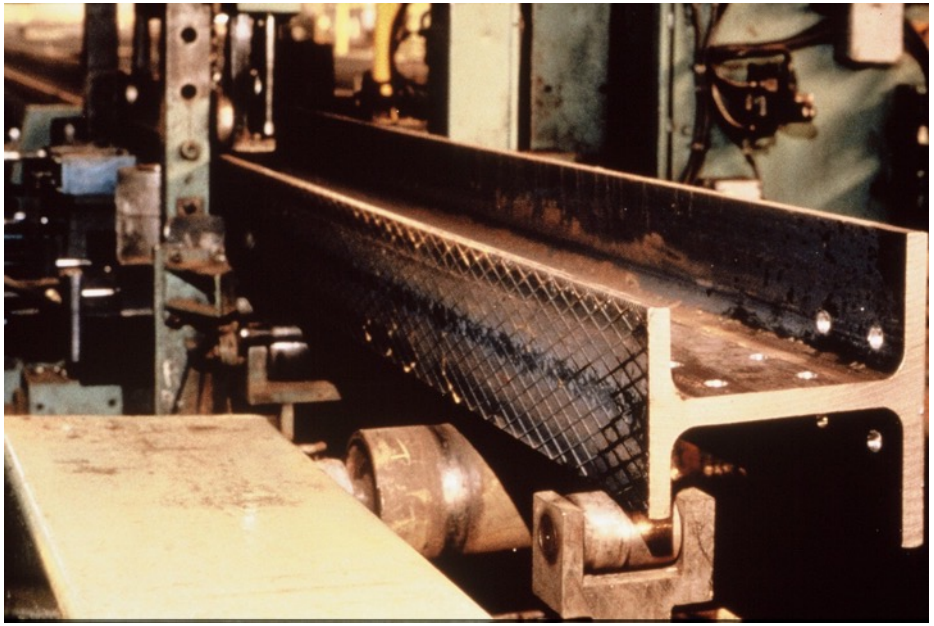
- Large spans with limited slab height
- Lightweight
- Quick assembly
- Good fire resistance
- Possibility of using removable piping (if suitably designed)

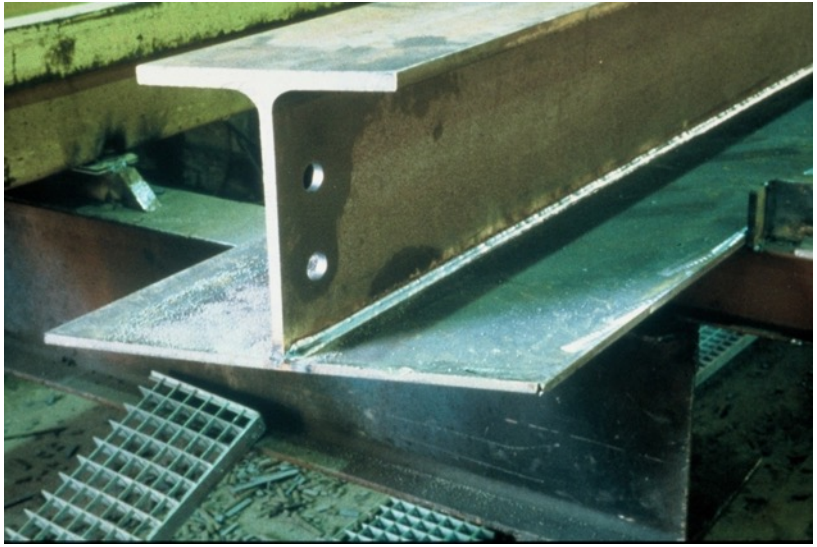
EN 1168



Integral beam floor

Integral beam floor





Integrated double-floor beam system

Slimline Floor System:

- Slab supported by lower flange
- Integral beams higher than slab
- Integrated services on the slab
- 2ème floor, wood, chipboard, etc. on top
- Good thermal and acoustic inertia
- Separated elements, easily to dismantle, upgrade

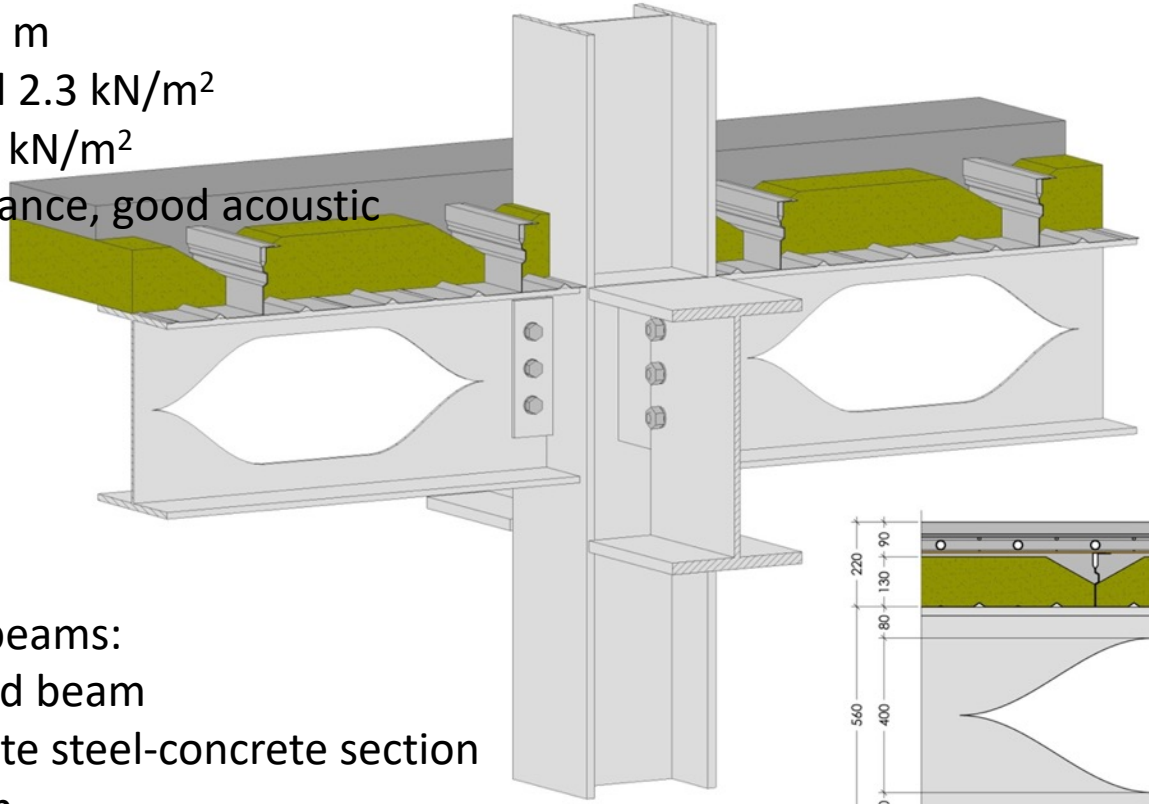
https://www.steelconstruction.info/Floor_systems

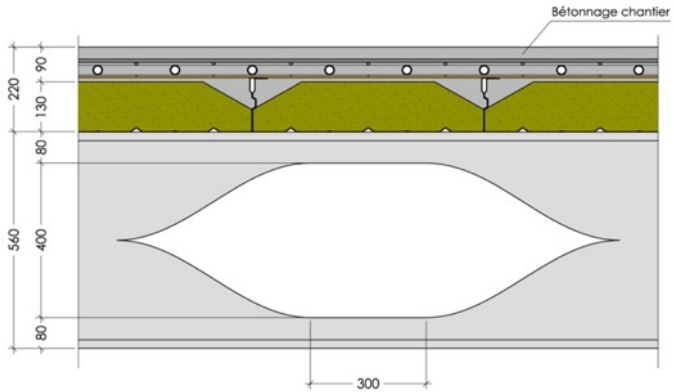
LEWIS IFD and light steel frame floor systems

Combination castellated beam with collaborating floor

Collaborating composite floor, Cofradal 200:

- Span 4.80 m
- Dead load 2.3 kN/m^2
- Payload 3 kN/m^2
- Fire resistance, good acoustic





"Angelina" beams:

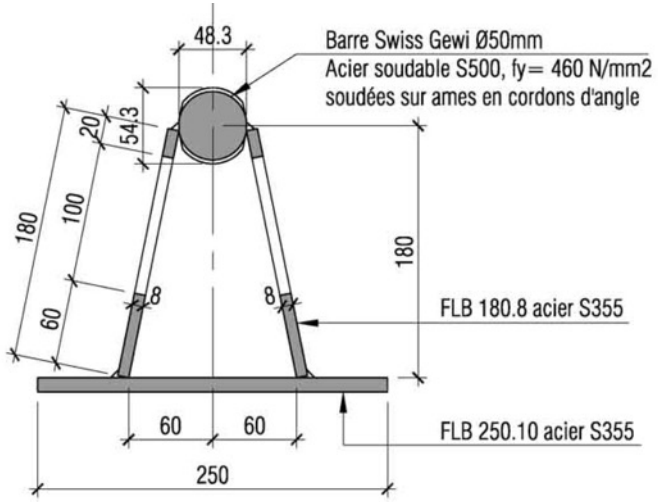
- Castellated beam
- Composigte steel-concrete section
- Span 15 m

Innovation: floor with integrated, under-pinned beam (with support struts and tension rod)

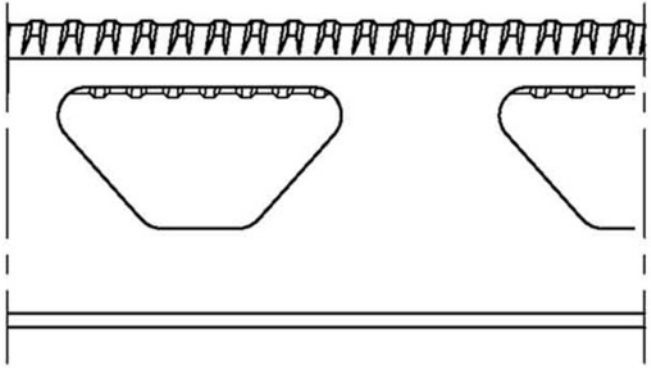
- Floor structure of the Rolex workshops, Geneva
- Development by engineering firm INGENI
- Floor 250 mm high (all included), with struts, 12.5 m single beam spans

Beam integrated into concrete slab = Top chord of the under-pinned beam

Innovation: floor with integrated, under-pinned beam



Integrated beam



Open source software (from research, supplied by industry)

For example, at ArcelorMittal:

- Design of steel structures: portal frames, beams and columns, trusses and beam-column connections
- Design of composite structures: composite columns and beams, connections and integrated floor beams
- Honeycomb beam calculations
- Fire resistance calculations: resistance of composite beams and columns, gas and steel temperatures
- Seismic calculations: reinforcing concrete structures with steel
- Estimating costs: estimating the price and weight of steel and multi-storey buildings
- Sustainability: life cycle assessment and environmental impact of composite structures for buildings and bridges

https://constructalia.arcelormittal.com/en/toolbox

https://constructalia.arcelormittal.com/fr/page_principale_des_outils

Open source software (from research, supplied by industry)

https://szs.ch/fr/downlaod-sujets-specialises/

Outils de dimensionnement

Stahlbau Zentrum Schweiz
Centre suisse de la construction en acier
Centro svizzero per la costruzione in acciaio
Swiss Center for Steel Construction

▶ **Connexions**

ACoP (1.0.2) | ArcelorMittal | ENV 1993 | Raccords, raccord de plaque de tête poutre sur support

COP2 (1.05) | ArcelorMittal | EN EN 1993-1-8 and EN 1994-1-1 | Raccords, dimensionnement des raccords mixtes selon l'Eurocode

▶ **Construction en acier**

ABC (Setup ABC 3.62) | ArcelorMittal | EN 1990-1994 | Domaine d'application: poutres et poutrelles de plancher plat

A3C (Setup A3C 3.01) | ArcelorMittal | EN 1993-1-1 und EN 1993-1-2 | Poteaux, poteaux en acier et poteaux mixtes acier-béton

ACoP (1.0.2) | ArcelorMittal | ENV 1993 | Raccords, raccord de plaque de tête poutre sur support

PORTAL+ (1.38) | ArcelorMittal | Vérification des portiques en acier selon les normes EN 1991-1-3, EN 1993-1-4, EN 1993-1-1 et EN 1998-1

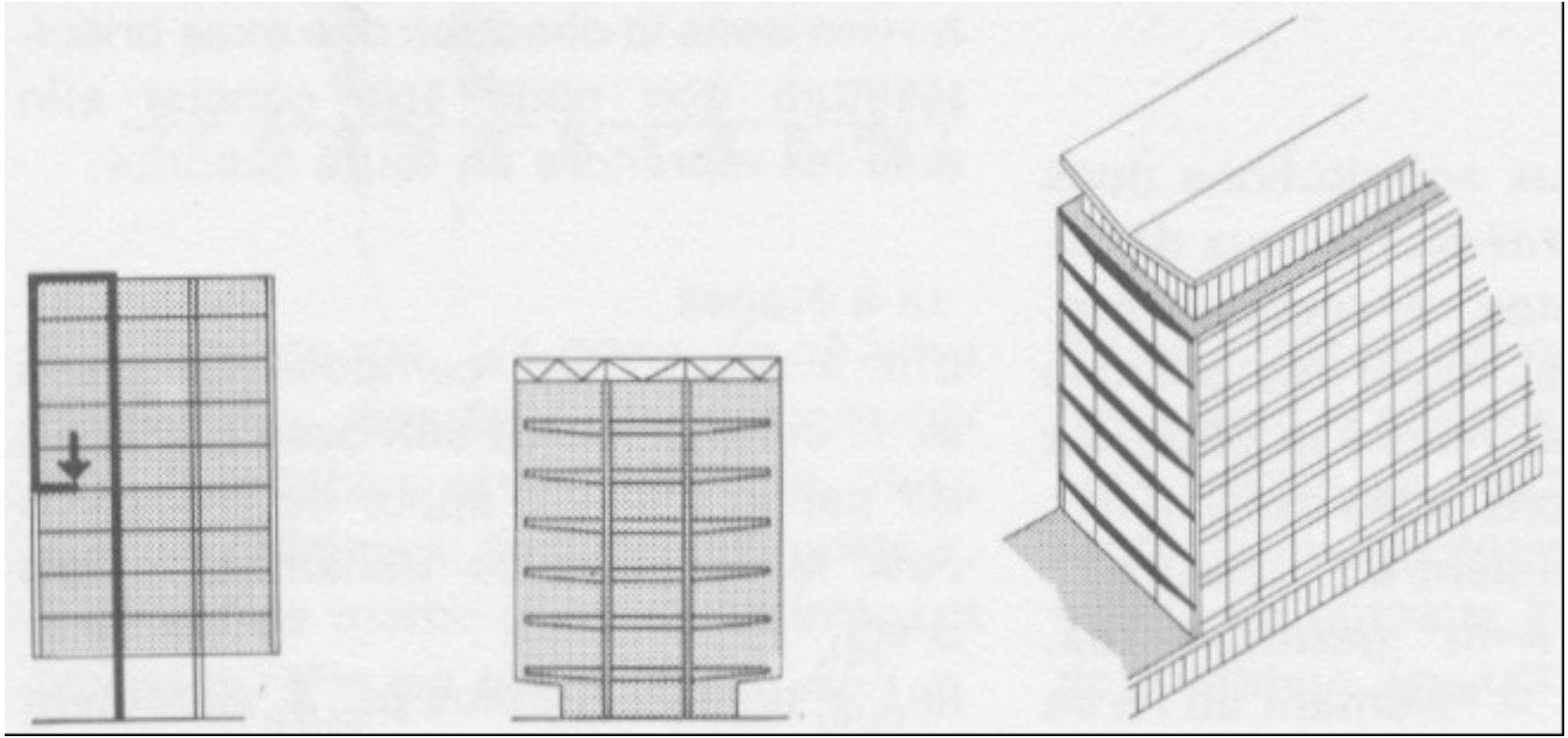
▶ **Construction mixte**

▶ **autres liens sur ce sujet**

APPENDICES

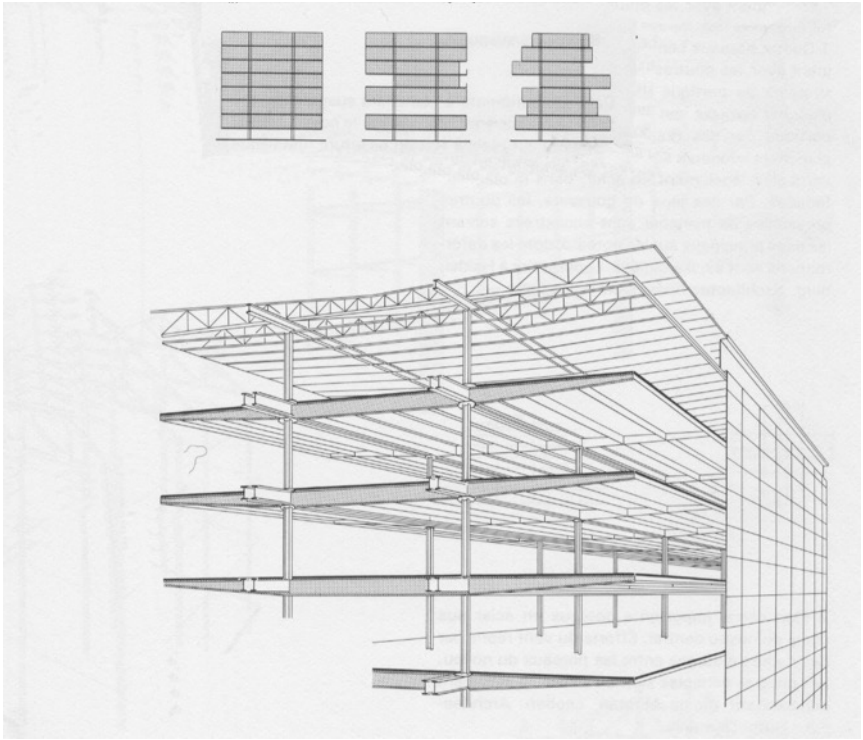
Buildings, structural systems & examples

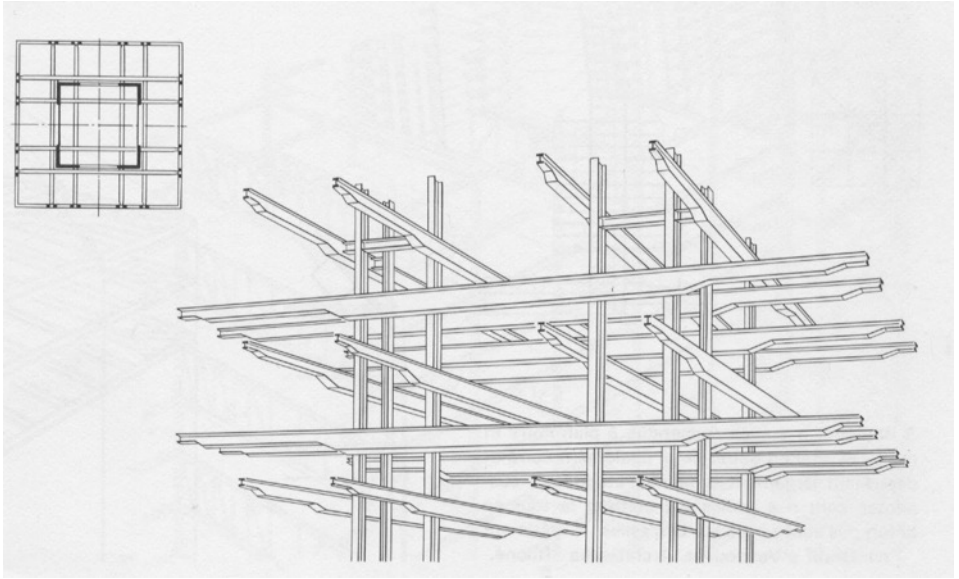
No more columns in the façade: e.g. cantilevered floors



Source: STRUCTURES IV, A. de Bussierres

No more columns in the façade: e.g. cantilevered floors

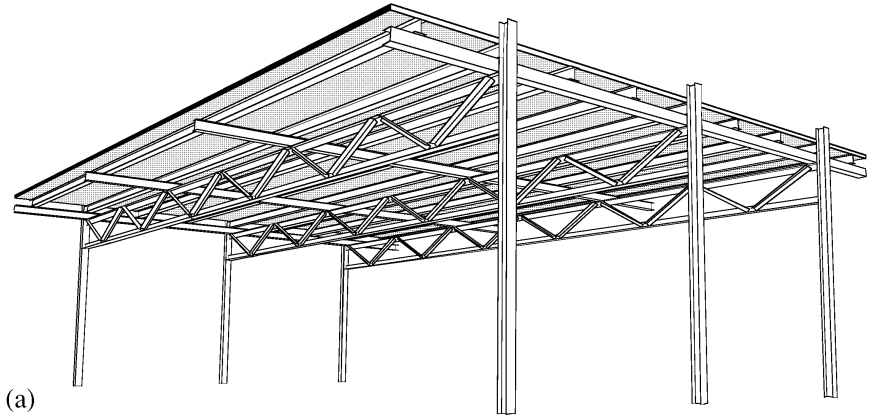




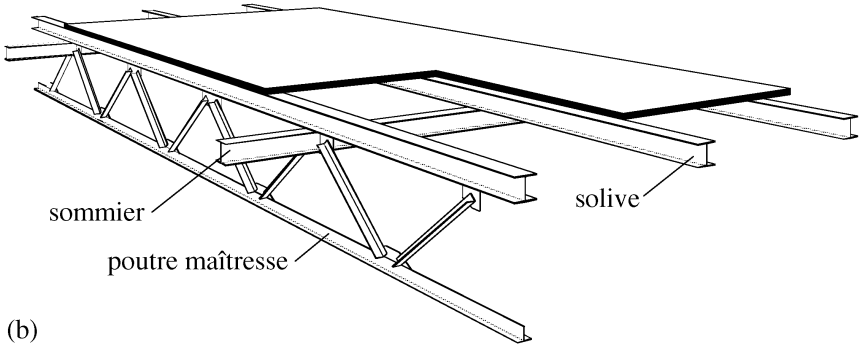
Source: STRUCTURES IV, A. de Bussierres

Fig. 4.24: Floors, 3-level beam systems

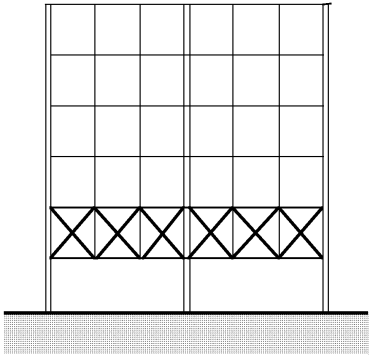
Steel often more interesting if large spans without columns



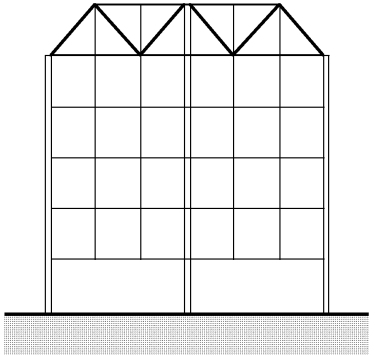
(a)



(b)



(c)



(d)

2-directional beam systems, long spans

Continuous columns, main girders with bolted endplates, lattice girders

Main composite welded I-girders, secondary composite lattice girders

Photos A.Nussbaumer, Messehalle, Basel

Suppression of column(s), single-storey truss beam

Photos A. Nussbaumer, Bât. B. Braun, Crissier, 2009