# Composite Steel-Concrete Structures

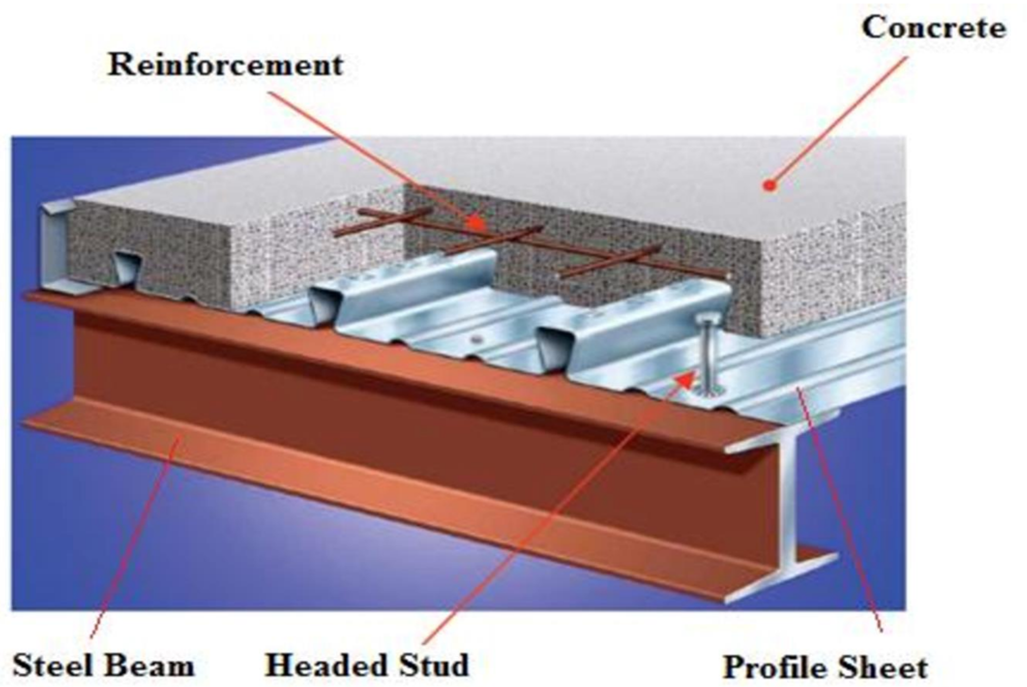
# Sem. 2

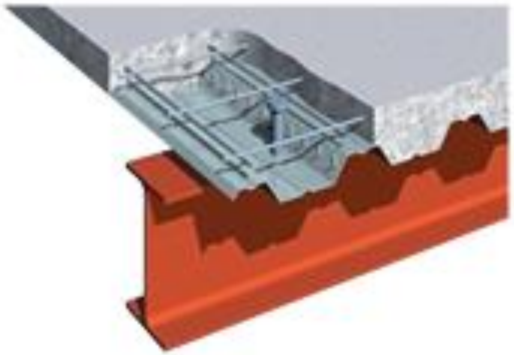
# 2025-2026

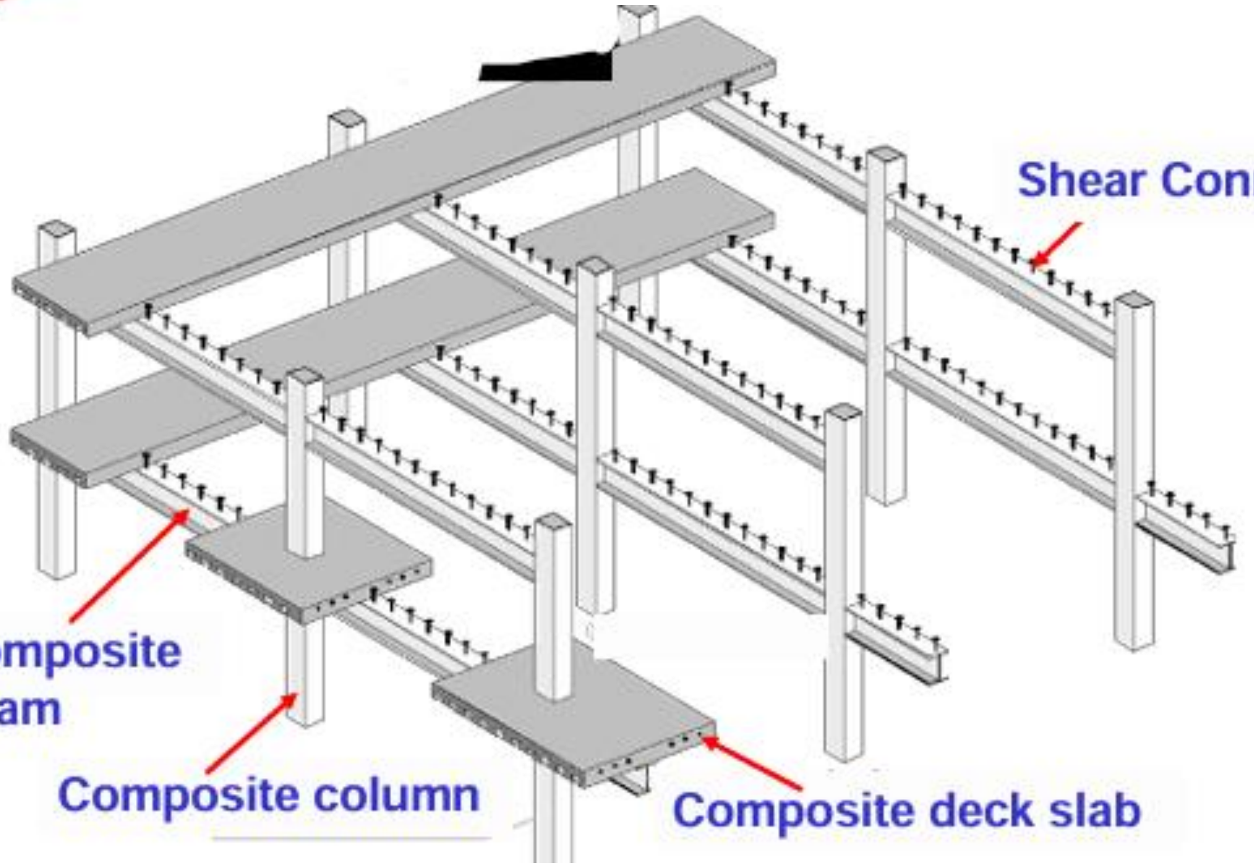
## Prof. Dr. Nael M. Hasan

# Lecture 1-2

- INTODUCTION TO COMPOSITE STRUCTURES
- ADVANTAGES
- DISADVANTAGES
- OBJECTIVES
- Composite beams
- Composite columns
- Composite slabs
- Connectors

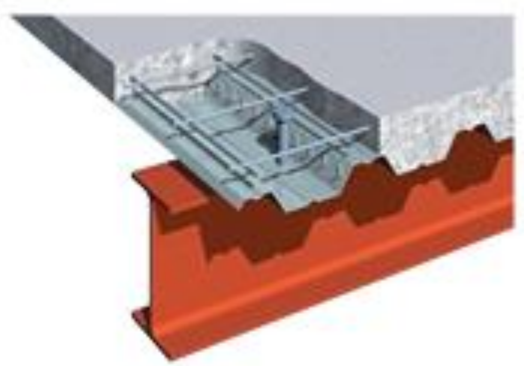


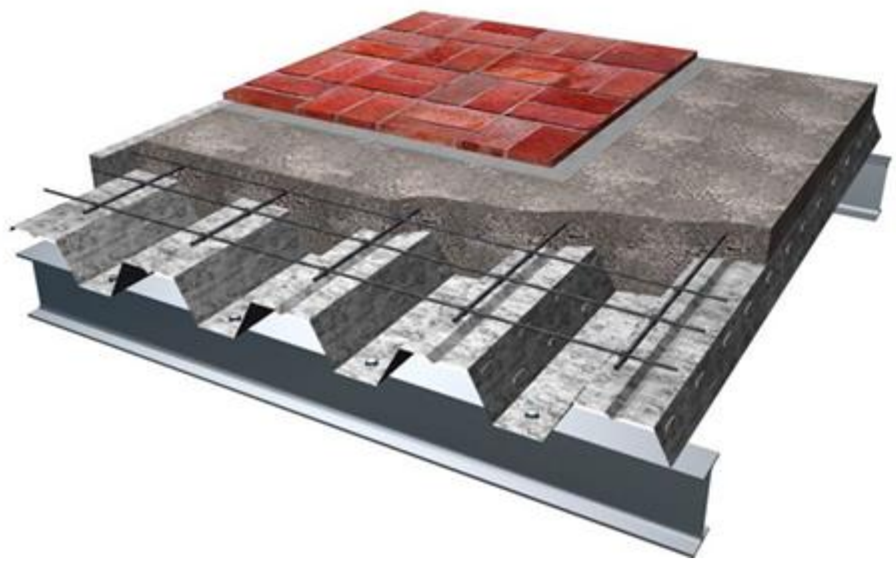



Shear Connectors
Composite beam
Composite column
Composite deck slab

## Introduction:

A composite structure consists of a **flexural stiff steel member** - for example an IPE or HE section -with a **longitudinal shear connection** connected to the **concrete**. From this structural action, a composite structure obtains its load-bearing resistance Although steel and concrete materials behave very differently, they complement each other perfectly.





Composite member: flexural stiff steel members structurally connected by shear connectors to a concrete component.

## Introduction:

- Concrete excels to **resist compressive forces**; steel is better to resist tensile forces.
- Steel elements are slender and therefore sensitive to flexural and lateral buckling, and local buckling. Due to composite action, these types of **instability** are prevented.
- Concrete **protects steel** against corrosion.
- Concrete protects steel in a **fire situation**, because steel heats up less quickly due to the large mass of concrete. In a fire situation, additionally redistribution of forces from the (warmer) steel to the (cooler) concrete takes place.

## Introduction:

- Steel ensures that the structure has **sufficient plastic** deformation capacity. This prevents the structure from **sudden collapse** without 'warning mechanism' like large deformations. Deformation capacity is also required to allow for a **redistribution** of internal forces.

Three applications of composite members in building structures, from left to right: a beam with welded headed studs, composite floor slab, and composite column(fully encased steel section).

# ADVANTAGES

- The steel deck replaces the **traditional wooden** forms.
- The steel deck is used as a **working platform** during the construction and provides a protective and security function.
- The steel panels **stabilize the pillars** (in general, the main structure) eliminate the need for horizontal stiff diaphragms during the construction. The building, even in the case of high-rise ones, remains provisionally stabilized by means of the steel panels.
- The construction of the metallic structure and the concreting can be done **independently**. The construction speed is not dictated by the concreting.
- **Light concrete** can be used to lighten even more the structure.

# ADVANTAGES

- **Props are normally not necessary** during the construction. Usually, the floor slab is designed so as to avoid the need for auxiliary supports during the concreting of the floor slab (in some cases they may be necessary).
- The steel sheet **replaces the reinforcement** in tension and contributes to resist positive bending moments. In some cases, a supplementary tension reinforcement may be necessary.
- **Fast execution** (the fastest solution)
- **Reduction** of the floor slab depth (the thinnest solution)
- **Reduction of the floor slab self-weight (the lightest floor slab solution).Reduction of the floor slab weight allows saving material in vertical load-bearing elements (pillars, structural walls) and foundation,**

# DISADVANTAGES

- More expensive**. However, the reduction of the load-bearing structure and foundation may provide a global economic advantage. The solution is particularly interesting for high-rise buildings or voluminous buildings.**
- Insufficient **acoustic insulation**. Need for an insulating false ceiling.
- **The need of false ceiling means an increase of architectural floor depth (the advantage of the thinnest solution becomes less evident).**

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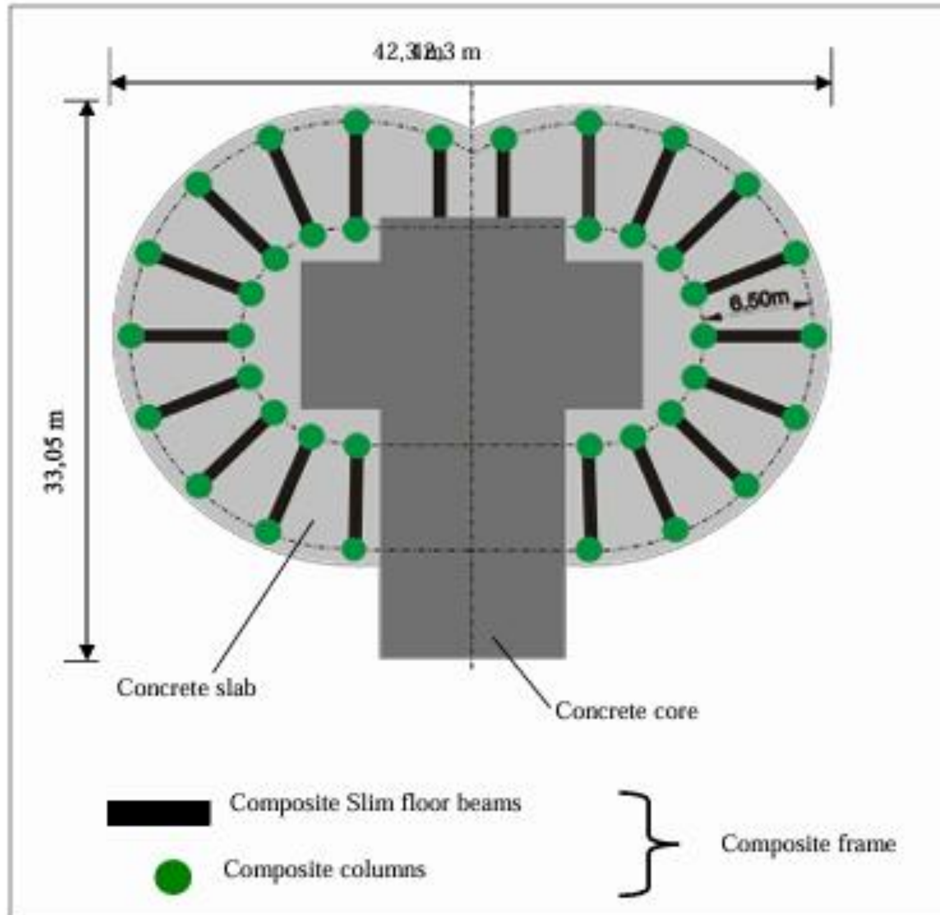
# ADVANTAGES

## Composite Construction

* Speed of Erection and Ductility of Steel
* Cost Efficiency,
* Fire Resistance,
* Corrosion Protection and Compressive Load Carrying Capacity of Concrete

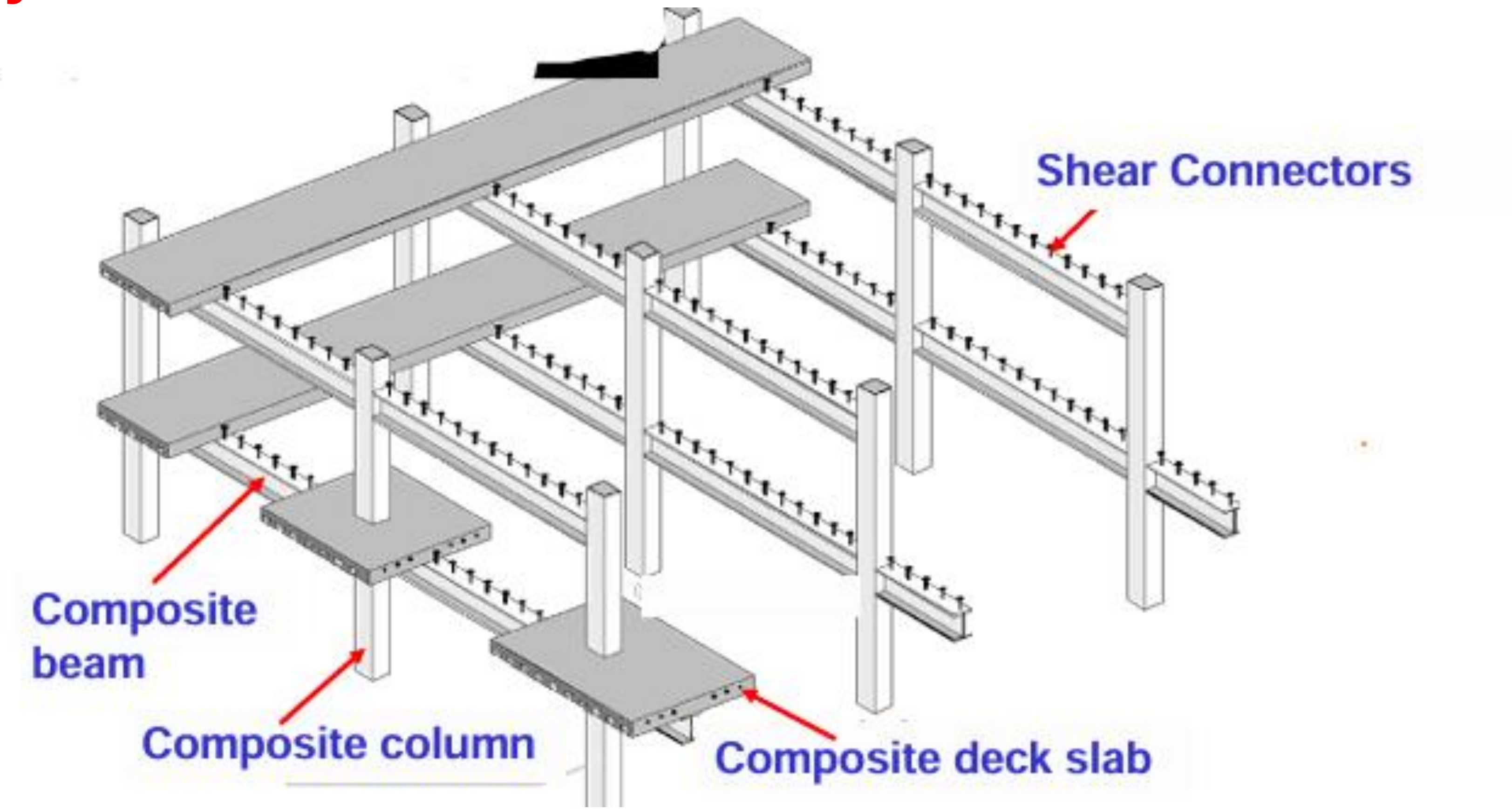
# ADVANTAGES

**Total time of erection: 8 month**
**max. speed 2 to 2.5 storeys per week!**

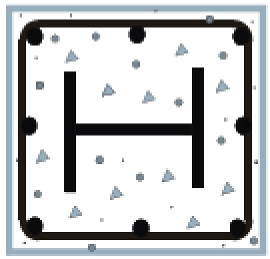


# OBJECTIVES

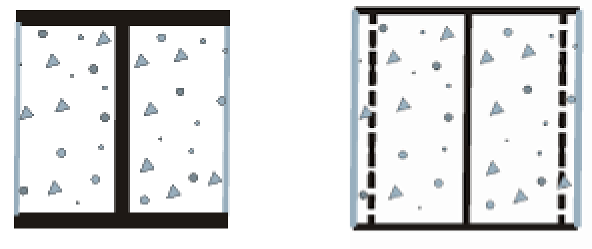
**To learn about the behaviour and design of the steel concrete composite system which can be incorporated in medium to high rise buildings to ensure strength, ductility and economic**



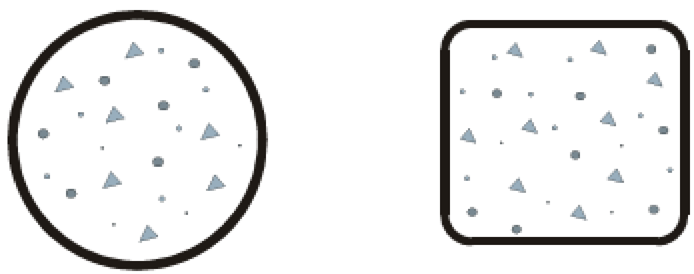
# Composite columns



Fully encased composite
(FEC) Columns



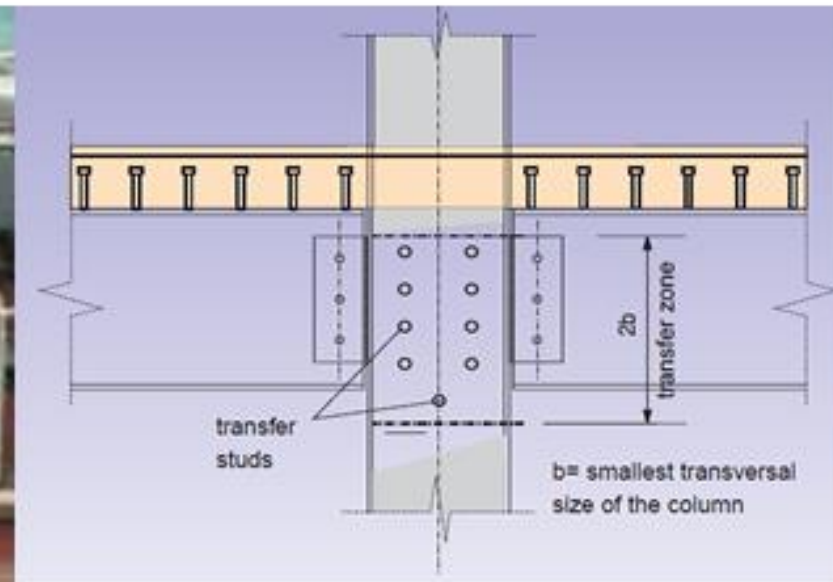
Partially Encased Composite
(PEC) Columns



Concrte Filled Tubes / Hollow Structural Sections
CFT / HSS

# Composite columns

**To exhibit efficient structural response, composite columns should employ shear connectors along the height.**





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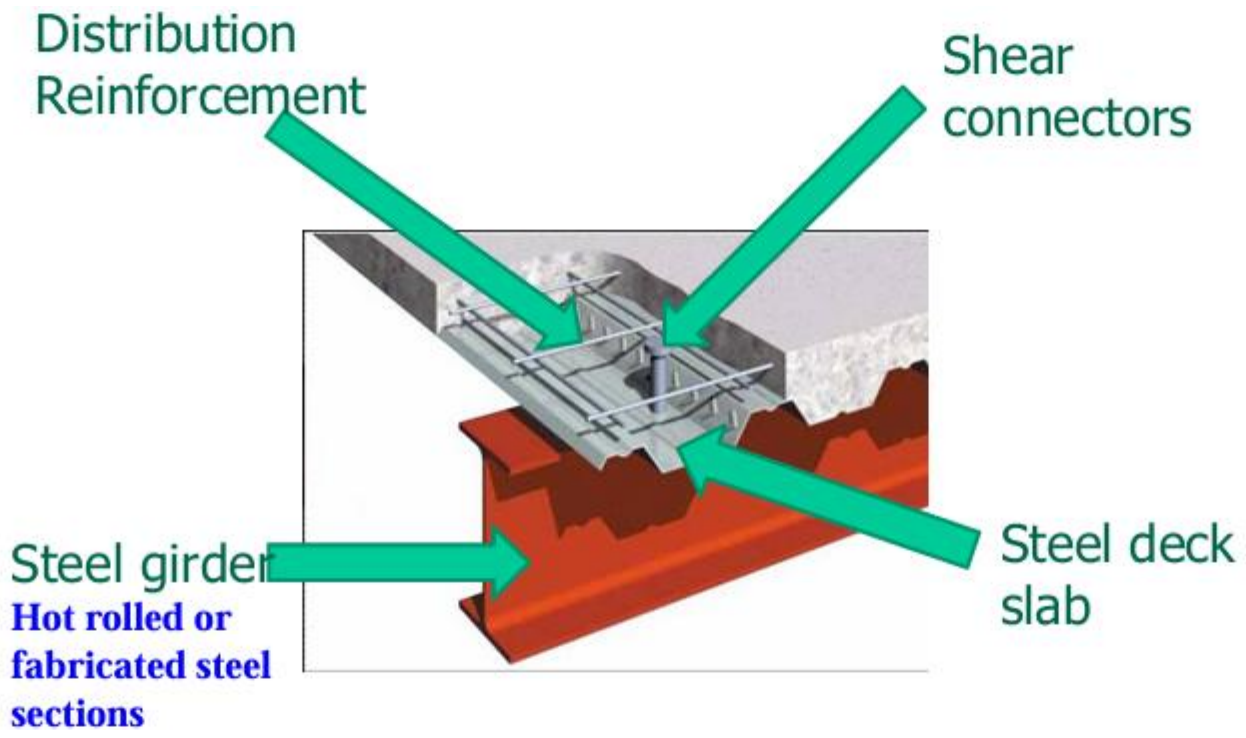
# COMPOSITE BEAM AND SLAB SYSTEM

The slab is generally cast in-situ using profiled, galvanized metal decking as permanent formwork.



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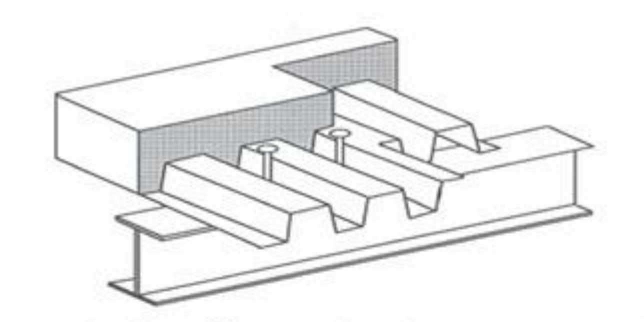
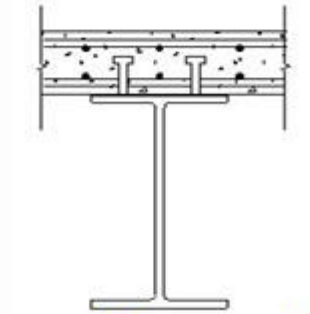


Deck rib ⊥ to the beam

Deck rib || to the beam



**Beam without steel deck**

**Fully encased beam**

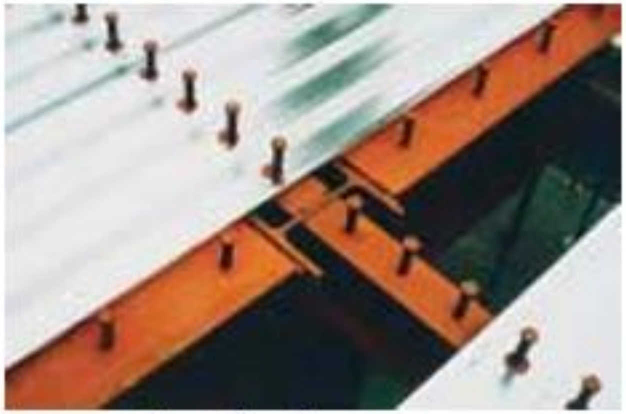
# COMPOSITE BEAM AND SLAB SYSTEM

**Connectors between steel and concrete components influence significantly the stiffness, strength and ductility of the composite systems. Such connectors can be designed with different degree of interaction.**

# COMPOSITE BEAM AND SLAB SYSTEM

*Non continuous metall decking over the beams*

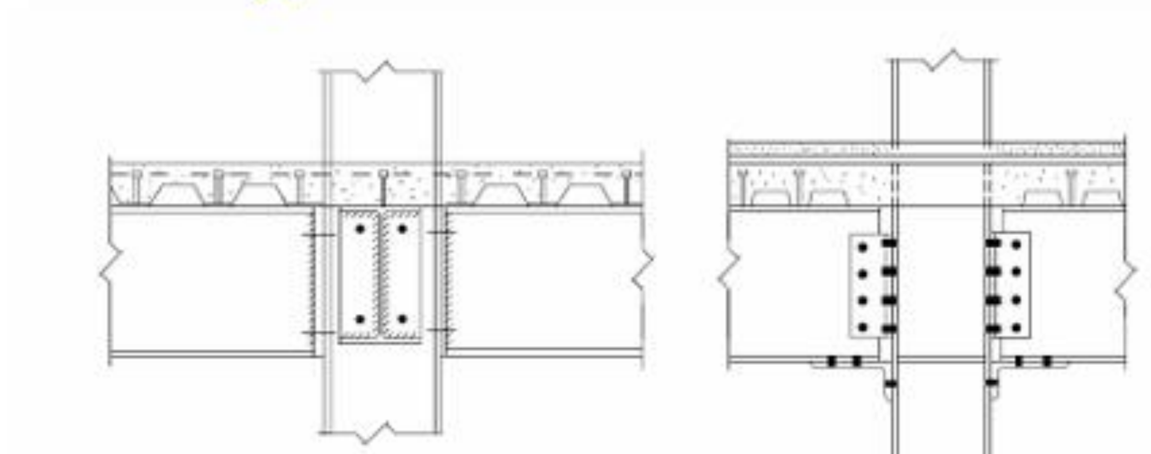
*"Through deck welding" on site*



*Steel decking with circular holes.*

# COMPOSITE CONNECTIONS


**Typical Base Column Connections**



**Typical Beam Column Connections**

## Composite beams

In a composite beam, steel and concrete attain composite action by longitudinal shear connection.

A designer has a lot of freedom in choosing various design elements, the method of execution (whether propping is used for example), and the choice of the type of connections between beams and columns or between two beams in case of continuous beams.

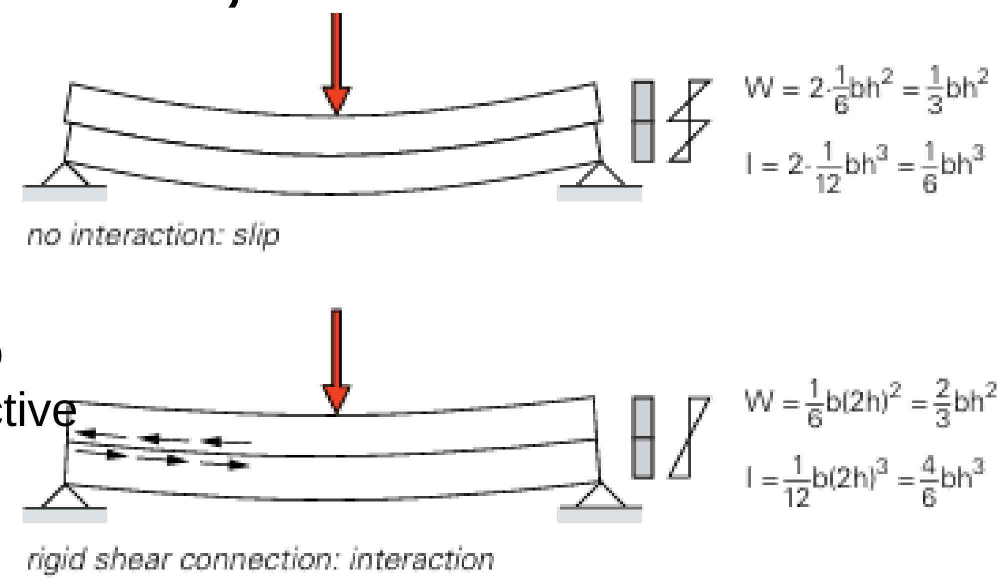
## Structural system

A composite beam generally consists of three parts:

- concrete slab (acting as a top flange); -
- steel beam; -
- connection devices (for example headed studs). -

**The concrete slab of a composite beam is almost always part of the concrete floor in a building (fig.**
**In practice, the floor is mainly a:**

- **composite slab;**
- **concrete planks;**
- **prefabricated concrete slab;**
- **in situ concrete slab**

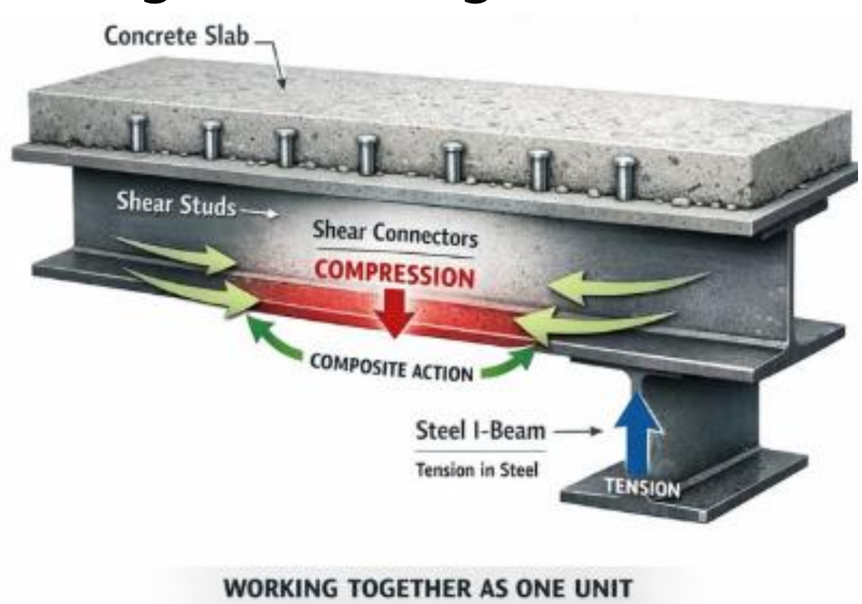



The structural shear connection of two timber beams increases both the effective section modulus W and the second moment of area I.

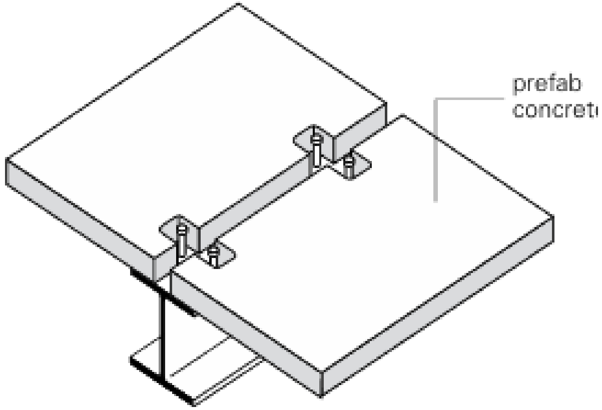
# Concrete + Steel (Composite)

Perfect Harmony in Composite Structures!

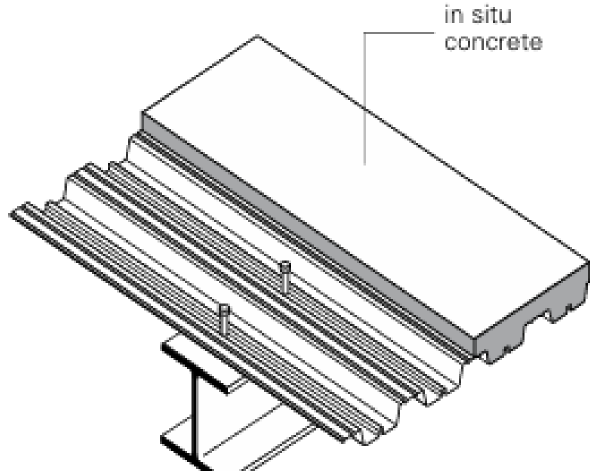
In modern construction, combining steel and concrete allows structures to resist both tension and compression efficiently. Steel provides tensile strength while concrete handles compression, and shear connectors ensure they act together as a single, strong unit. Ideal for beams, columns, and slabs, this composite approach results in stronger, more durable, and cost-effective buildings and bridges



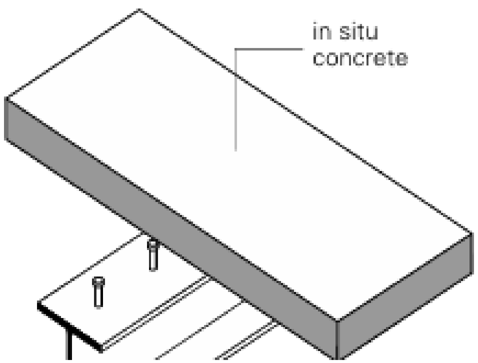
# Composite Beams

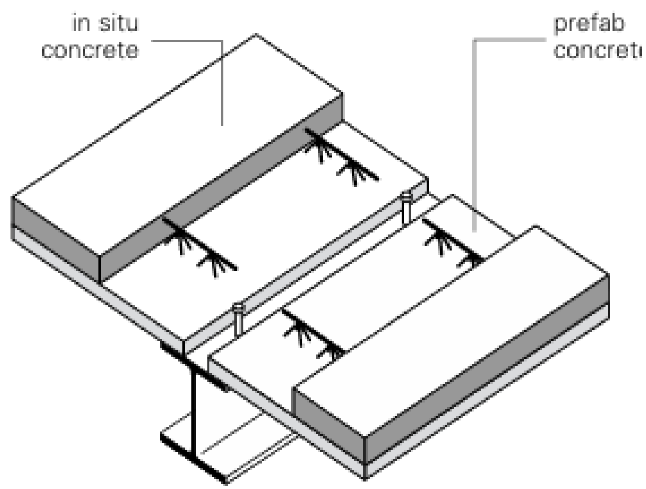



*prefabricated concrete slab*




*composite floor slab*




*formwork slab (concrete plan*

Different variants of a steel beam acting compositely in combination with a concrete floor slab.

# Composite Beams

Two examples of steel beams to be used in composite members: (left) rolled sections and (right) cellular beams.

## Usable steel beams are:

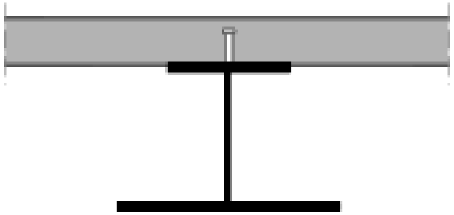
**hot-rolled H or I section;**

**- welded plate girder;**

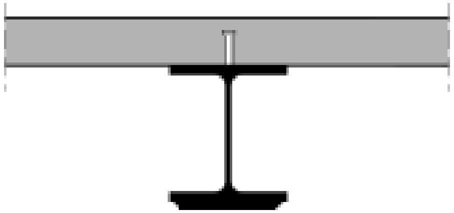
**- integrated floor beam (type IFB and SFB);**

**- castellated (cellular) beam;**

**- lattice girder.**



asymmetric plate girder



symmetric hot-rolled section with a welded bottom plate

After the concrete has cured, the concrete slab acts as top flange of the composite beam. Therefore, it may be beneficial to apply an asymmetrical steel section

The connectors (such as headed studs, or just studs) are essential to transfer longitudinal shear forces between the concrete slab and the steel beam

Depending on the deformation properties (stiffness and deformation capacity), there are rigid or flexible headed studs

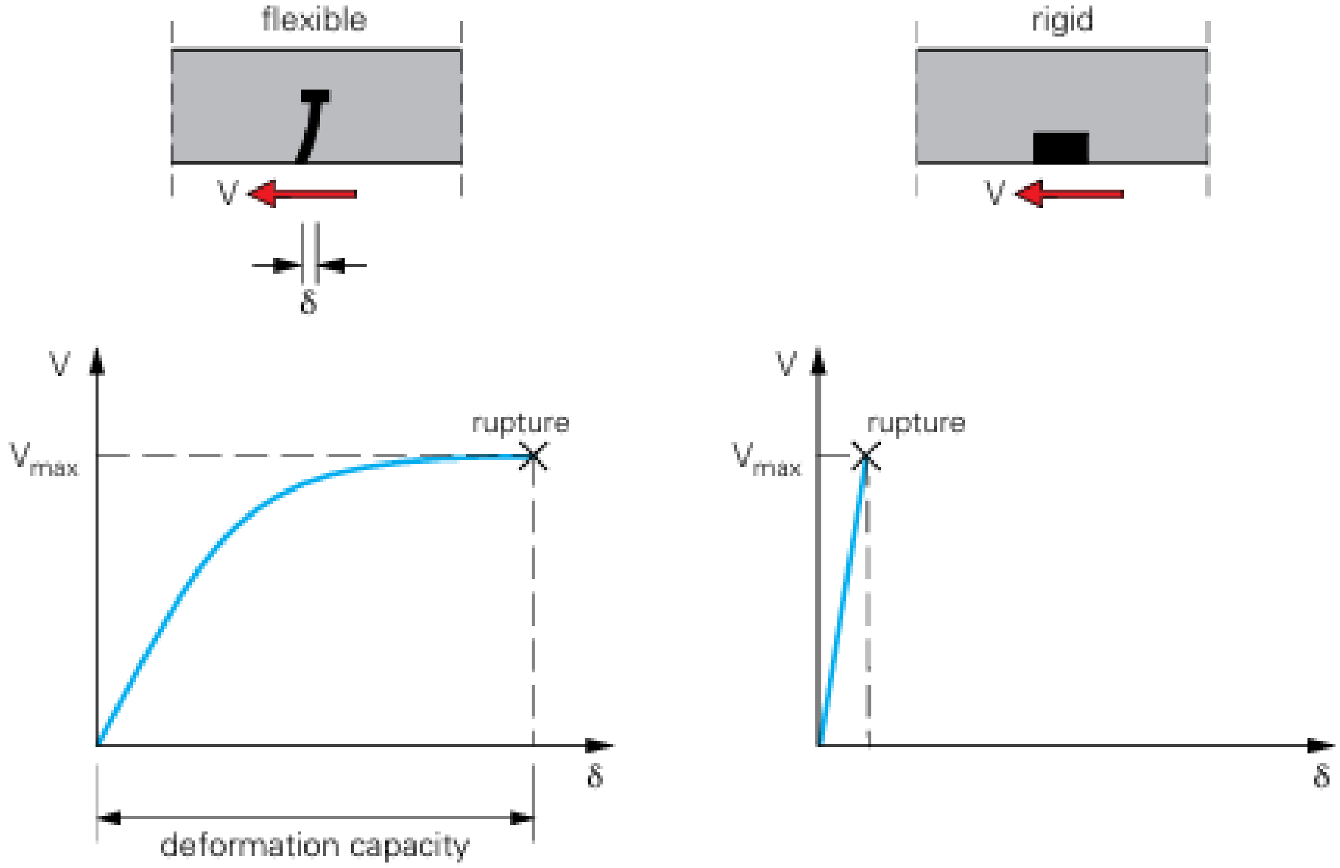
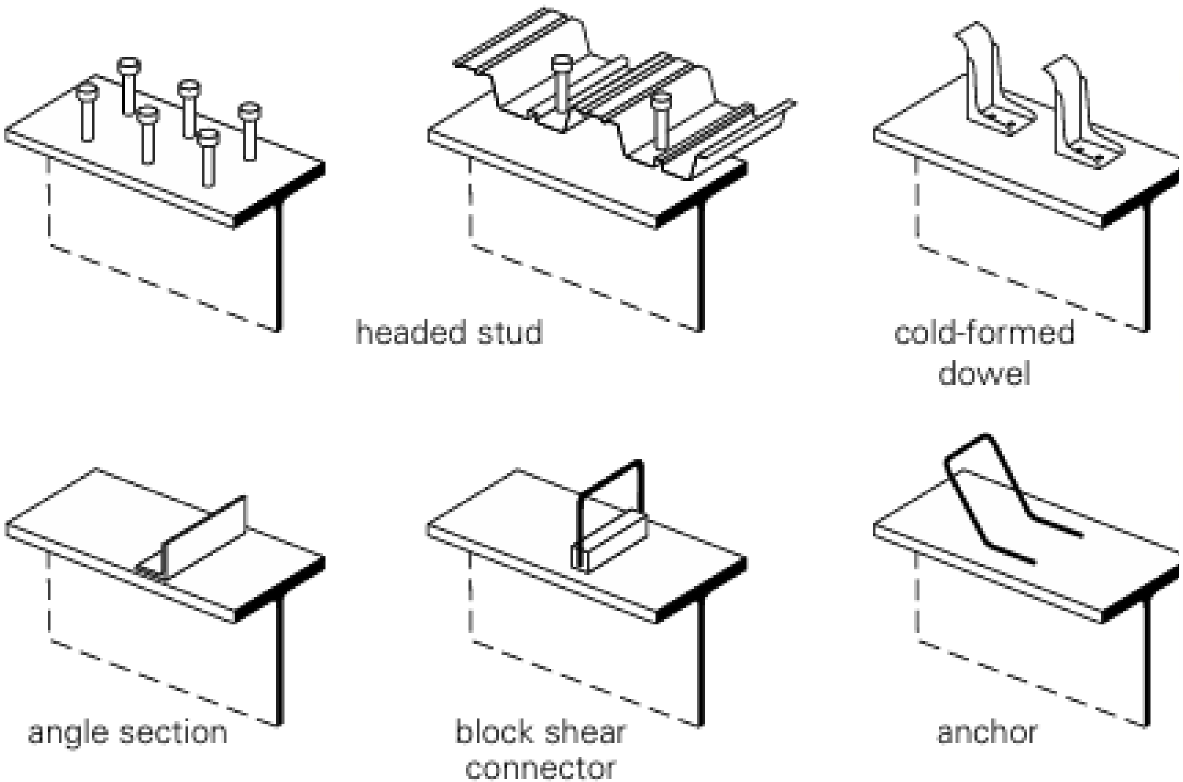
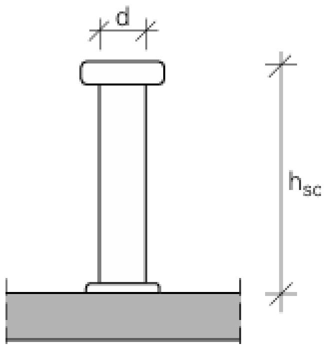


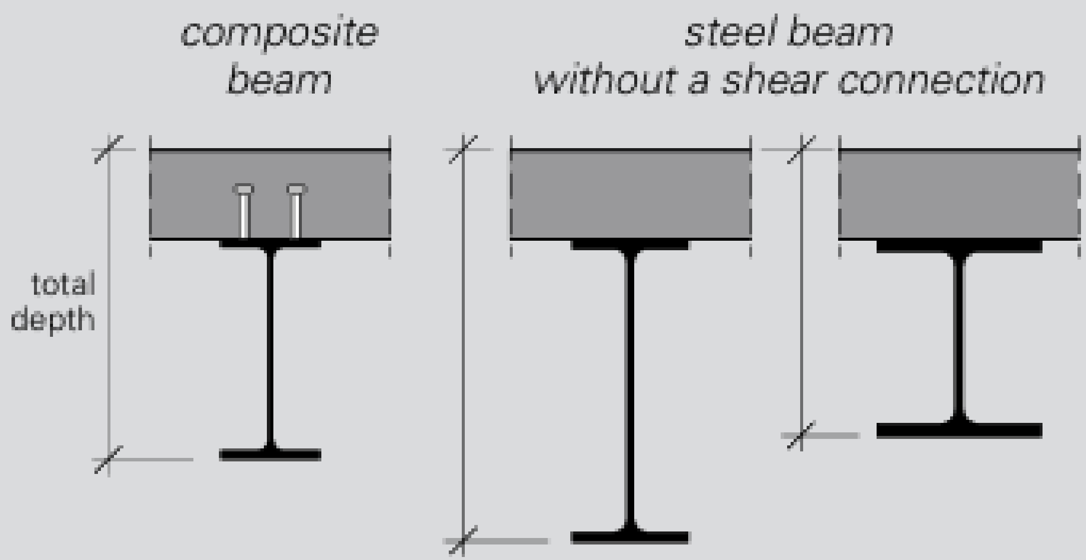

Illustration of different behaviour of (left) flexible and (right) rigid shear connectors.




Examples of shear connectors




Headed stud.




| | | | |
|---|---|---|---|
| steel section | IPE 400 | IPE 550 | HEB 360 |
| total depth | 560 mm | 710 mm | 520 mm |
| bearing capacity | 100% | 100% | 100% |
| steel weight | 100% | 159% | 214% |
| structural depth | 100% | 127% | 93% |
| bending stiffness | 100% | 72% | 46% |

Comparison between a composite beam and steel beams without a shear connection.

**Design**

With regards to the execution of a composite beam, two variants can be distinguished, namely:

- propped;
- unpropped.

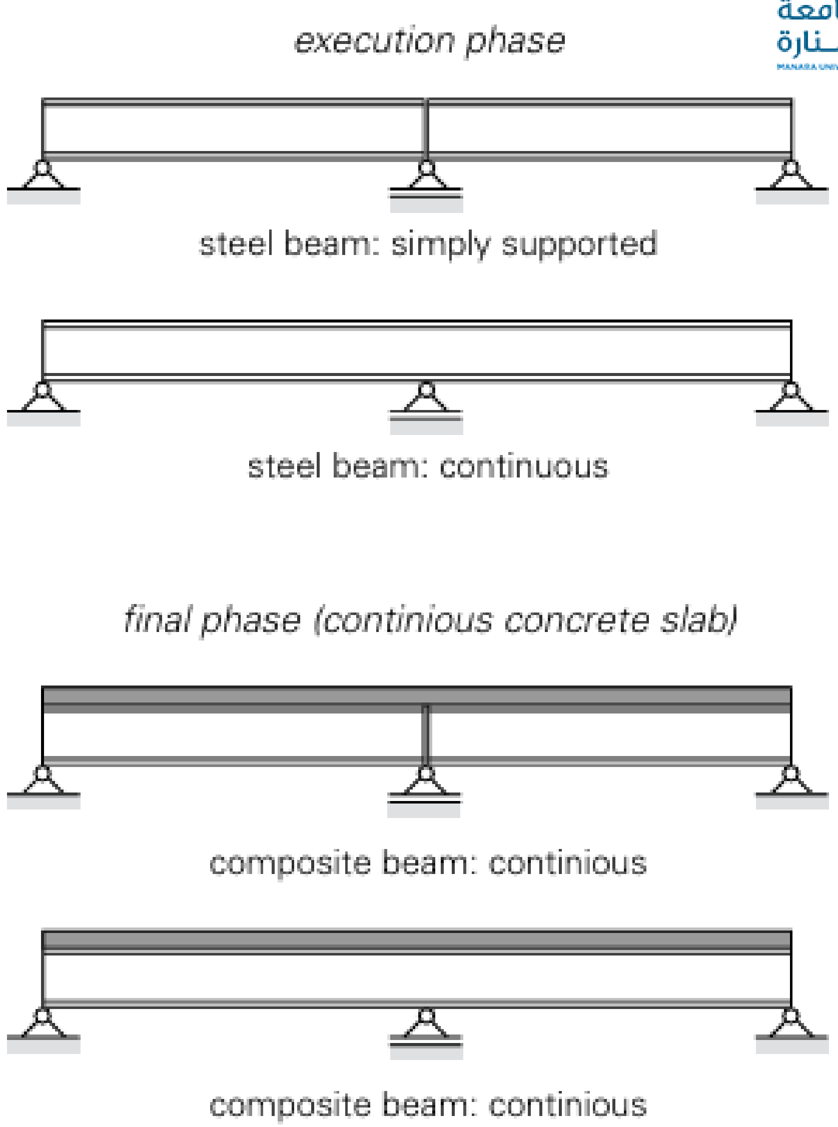
**Propped**. The steel floor beams and/or the formwork for the concrete floor - for example profiled steel sheets or concrete planks - are propped from the ground floor or from the underlying floor.

- The props are only removed after the concrete has been cast and has sufficiently cured..

- **Unpropped**. The formwork for the concrete floor is not propped and rests on the steel beams during execution. steel beams bear the total self-weight, including the uncured ('wet') concrete mix. This execution phase may govern for the dimensions of the steel beam.

## Connections

Especially when considering continuous beams, connections between beams and columns or those in between consecutive beams play an important role in the design.

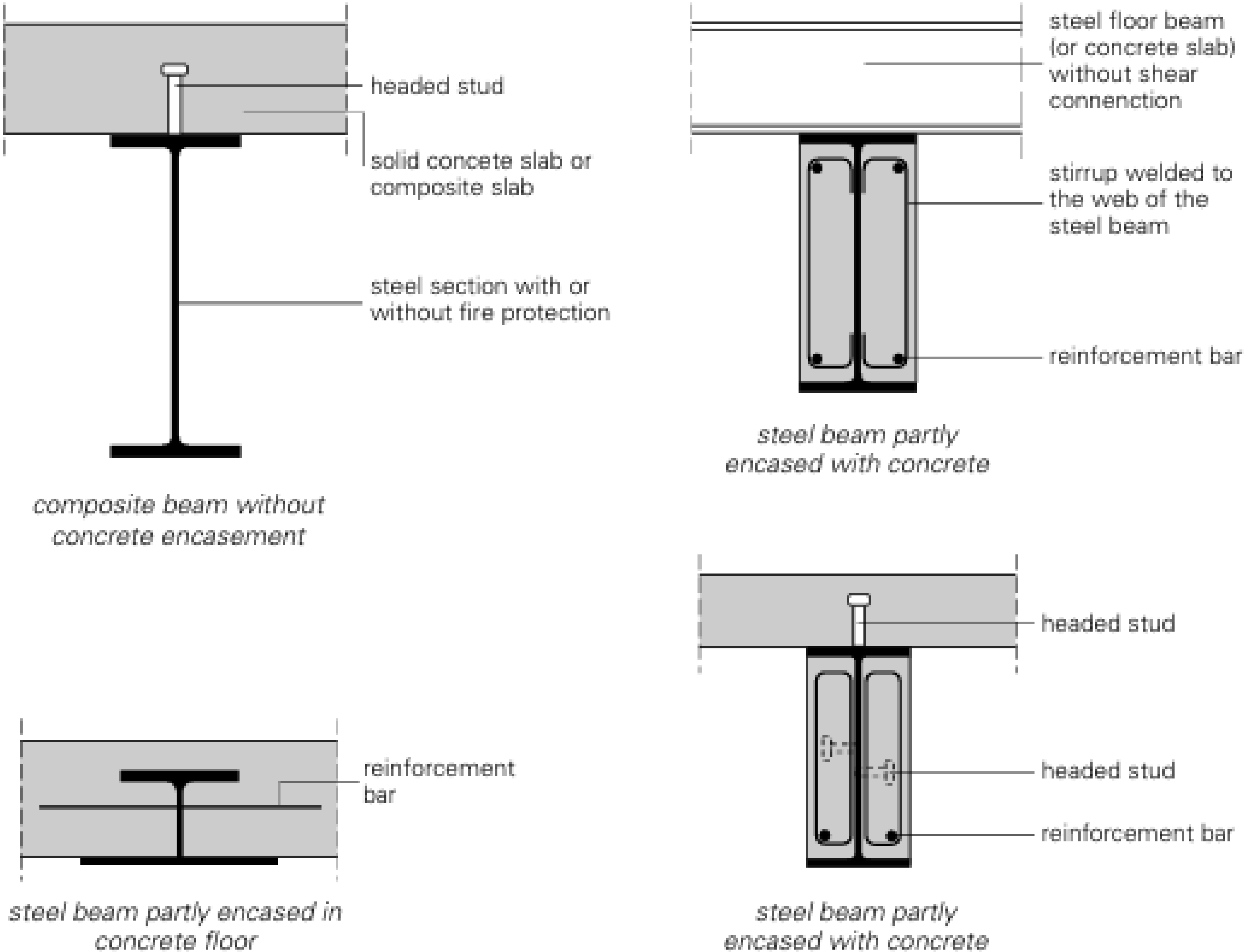


**Fire resistance**

In case of a fire, composite beams act more favorably in the case of a fire compared to 'regular' steel beams.

EN 1994-1-2 provides assessment rules for the following four types of beams:

- composite beam consisting of a steel beam without concrete filling;
- composite beam with a partially encased steel beam;
- partially encased steel beam (with only concrete between the flanges);
- steel beam partially embedded in the concrete slab.




The four different types of composite beams, for which EN 1994-1-2 provides the design rules for fire resistance.

# Composite slabs

- Composite slabs are especially suitable when incorporated with a steel frame and can also structurally interact with the steel floor beams.
- Composite slabs can also be used in combination with beams of other materials, such as reinforced concrete and timber.
- The execution of the composite slab - propped or unpropped - has a significant impact on the design process. Composite slabs

# Structural system

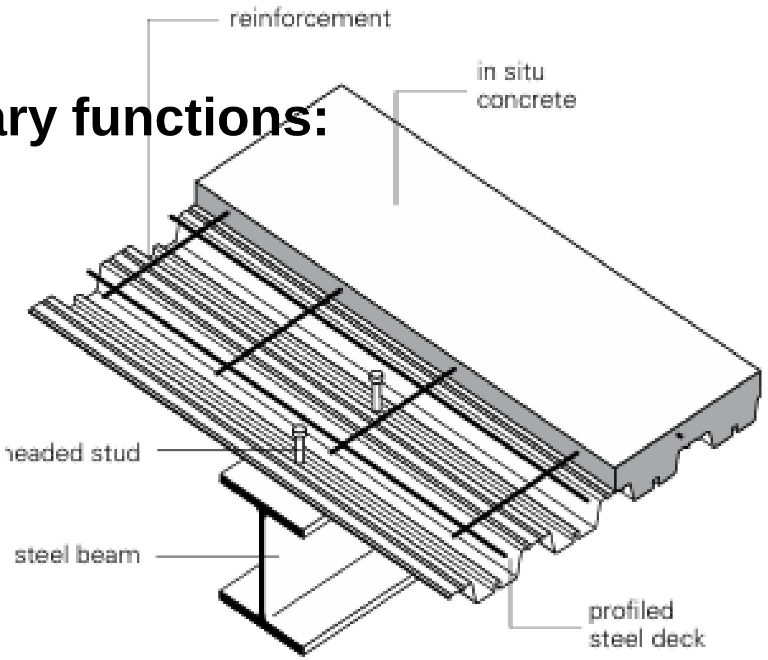
A composite slab consists of a thin profiled steel sheet that structurally interacts with the concrete cast on top of it (fig.). The **composite action** of slabs is similar to that of composite beams: the two materials work together because the concrete and the steel sheeting are structurally connected through longitudinal shear connection.

**The profiled steel sheeting has three primary functions:**

– act as a workplace during the execution;

– act as formwork for the in situ concrete slab;

– act as the reinforcement for the concrete slab.



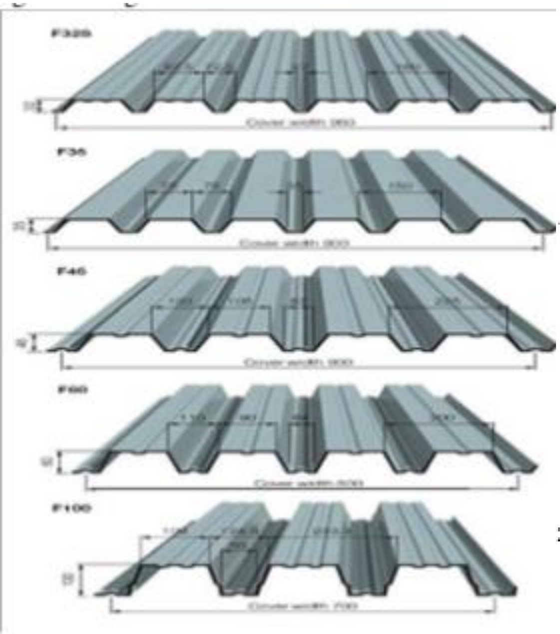

Example of a composite slab

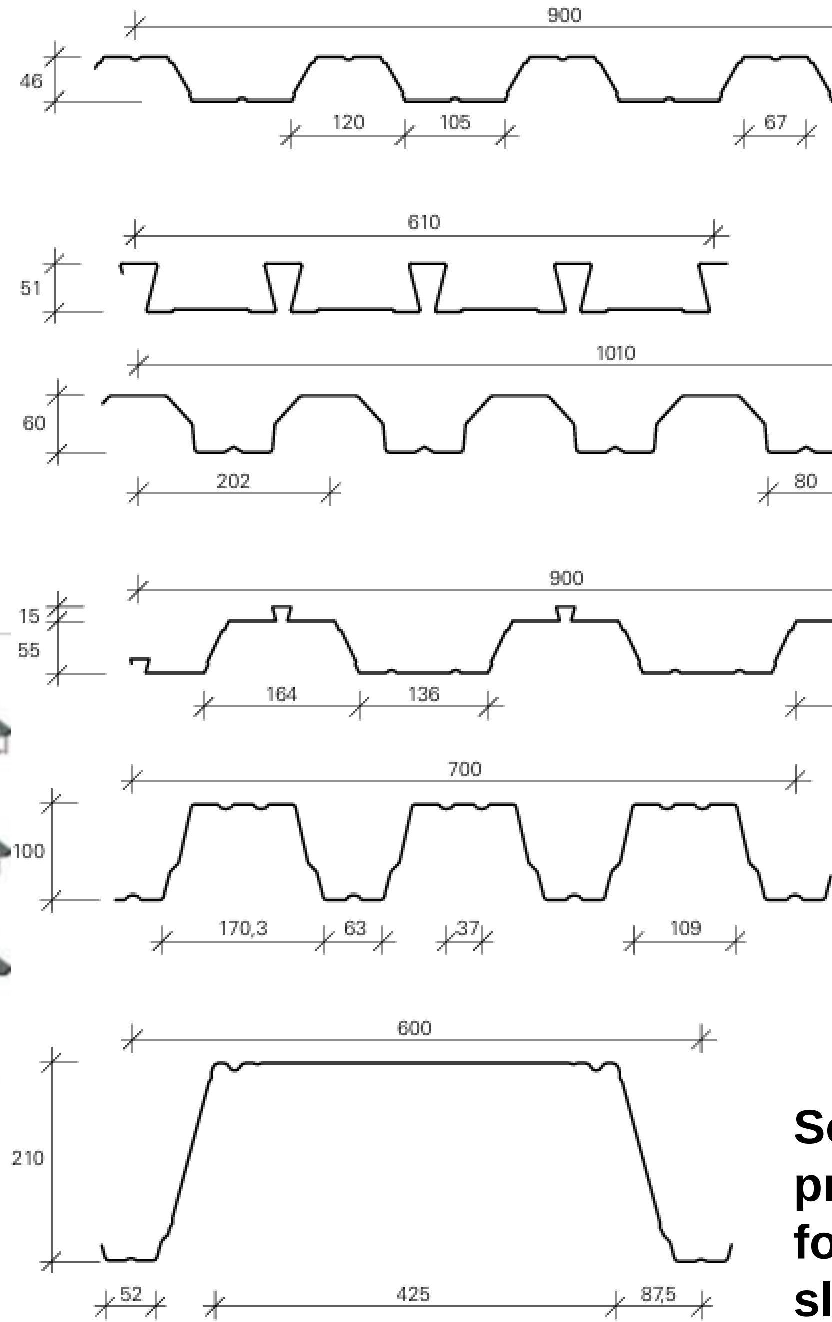
# Structural system

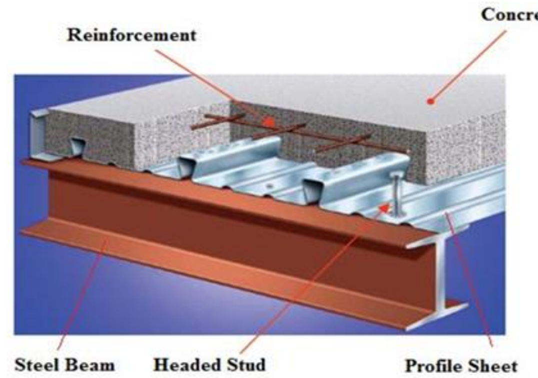
A wide product range of profiled steel sheetings are commercially available , distinguished by their:

* * shape, depth, rib spacing,
* * type of longitudinal stiffening,
* * implementation of the overlap between two steel sheets,
* * and the way in which composite action is achieved

# Structural system

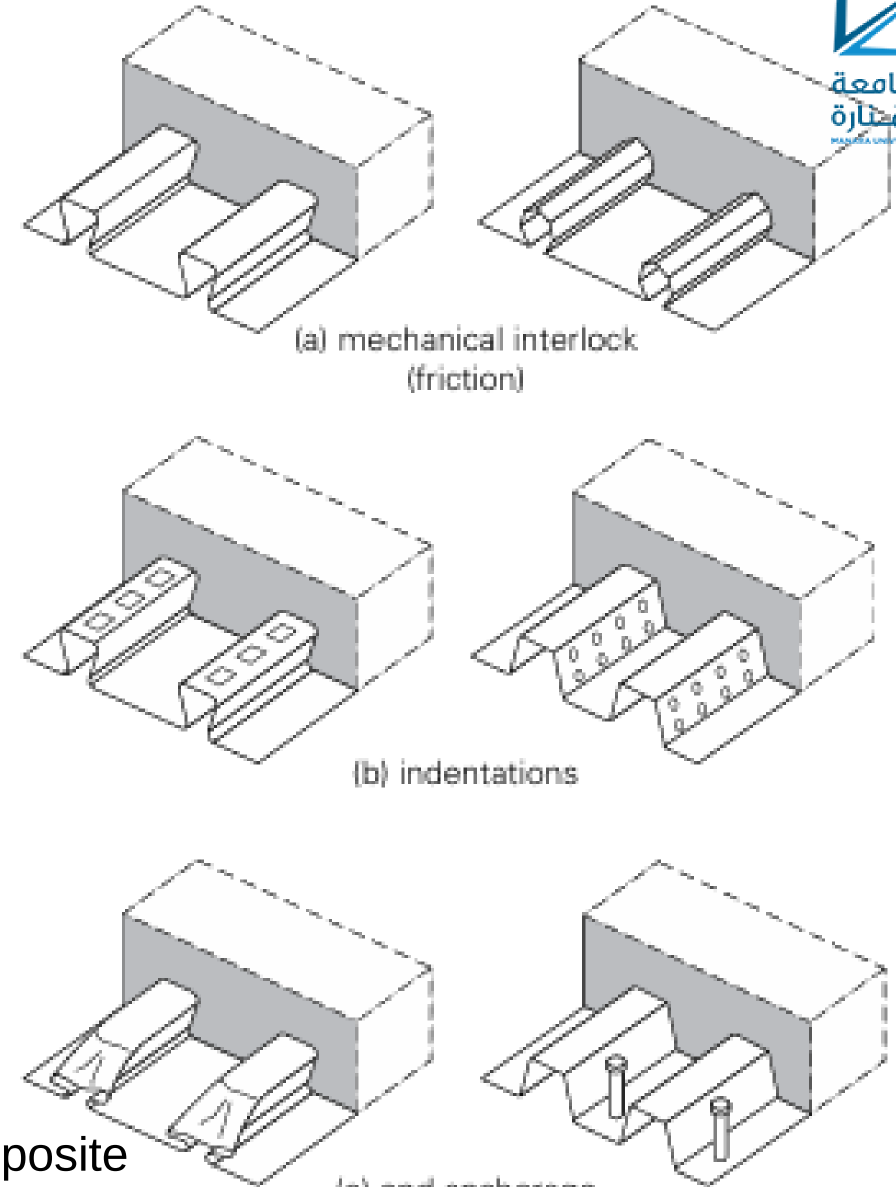





**Some examples of profiled steel sheetings for composite floor slabs.**

The composite action between the steel sheeting and the concrete is based on one or more of the following **mechanisms**:




– **mechanical interlock** due to re-entrant shaped parts of the profiled sheeting;

– **indentations** (or embossments) rolled into the sheeting;

– **end anchoring** by studs or a deformation (flattening) of the ends of the sheeting

The mechanisms through which the composite action between the steel deck and the concrete is achieved in composite slabs.


Studs can often be welded through the *sheeting to the steel floor beams.

End anchorage provided by deforma tion (flattening) of the sheeting ends.

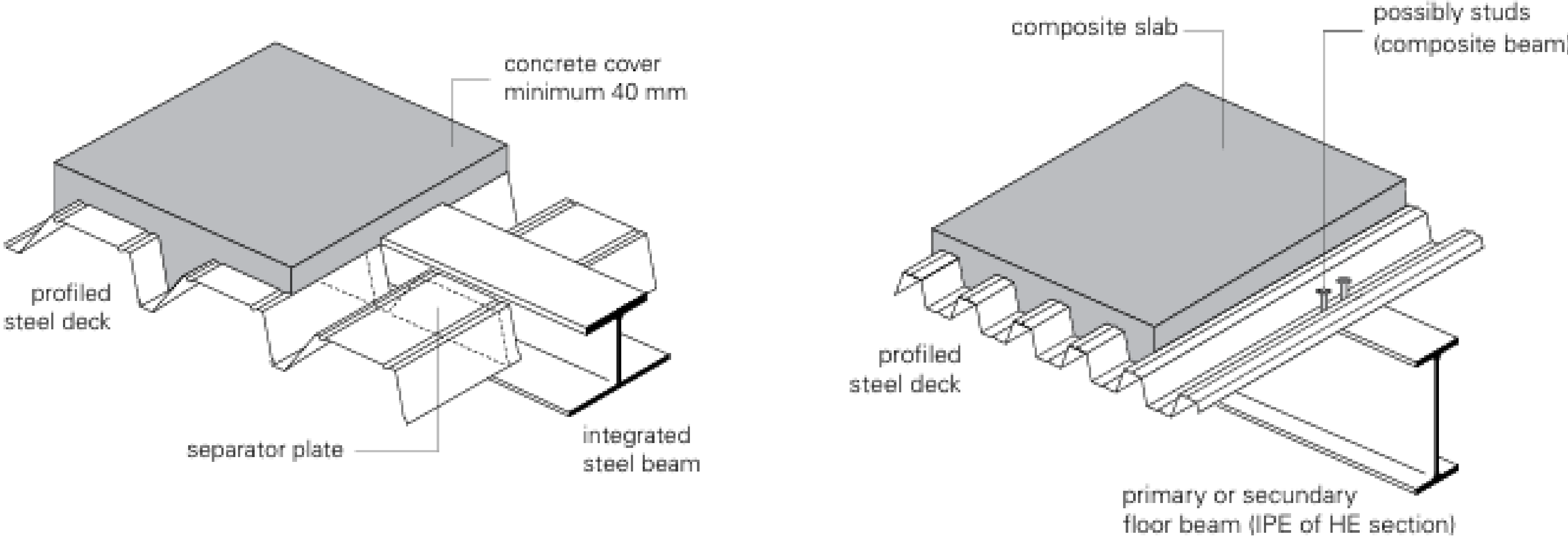
# Structural system

- The thickness of the sheets varies from 0,75-1,50 mm, although in practice this is most typically between 0,75 and 1,20 mm.
- The sheets are in most cases hot-dipped galvanized with a layer thickness of 275 g/m2 on each side, which corresponds to an average layer thickness of approximately 20 µm per side.
- Headed studs can, under certain conditions, be **welded-through the sheet** to an underlying steel floor beam (*)

# Structural system

- In practice the terms ‘shallow’ and ‘deep’ composite slabs are often used.
- The shallow slabs vary in depth between 16-100 mm, allowing spans of up to 3,6 m (unpropped) and 6,5 m (propped).
- Deep slabs (approximately 200 mm depth) can reach spans up to 5,5 m without the need for propping.

# Structural system




Shallow and deep composite slabs.

# Design

There are two key phases for the design of a composite floor:
– the execution phase, when the concrete has not yet cured;
– the final phase.

During execution, the thin profiled steel sheeting – regardless of whether it is propped or unpropped – acts as formwork for the concrete.

For both the ultimate and serviceability limit state, the composite slab has to meet the same requirements as other floor types, such as hollow core slabs or cast in situ concrete slabs.

In practice it is conventional to use design tables provided by the steel sheeting supplier for the dimensions of composite slabs.

The maximum span of the floor can immediately be determined from tables based on the loads, boundary conditions and slab thickness.

# Design

Design table for composite floors for normal concrete without additional reinforcement for an imposed load of 5 kN/m2. The self-weight depends on the type of sheeting, as this affects the dimensions of the cross-section. 'Propped' corresponds to one row of props

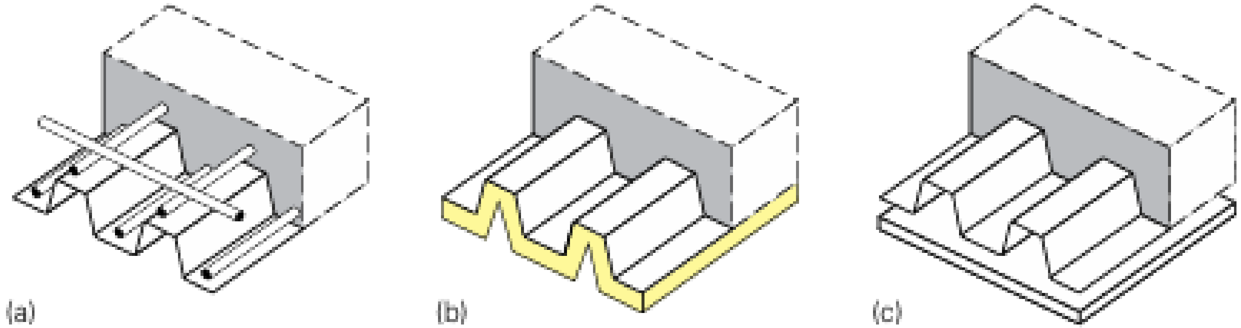
| floor type | floor thickness (mm) | self-weight (kg/m$^2$) | maximum span (m) | | | |
|---|---|---|---|---|---|---|
| | | | single-span | | multi-span | |
| | | | un-propped | propped | un-propped | propped |
| shallow composite slab $h_{sheet}$ ≈ 50 mm | 100 | 205 | 2,5 | 3,0 | 2,5 | 3,3 |
| | 120 | 255 | 2,4 | 3,4 | 2,4 | 3,4 |
| | 150 | 325 | 2,3 | 3,4 | 2,3 | 3,4 |
| shallow composite slab $h_{sheet}$ ≈ 100 mm | 150 | 235 | 3,9 | 4,5 | 3,9 | 4,8 |
| | 175 | 295 | 3,7 | 5,2 | 3,7 | 5,5 |
| | 200 | 355 | 3,5 | 5,5 | 3,5 | 5,5 |
| deep composite slab $h_{sheet}$ ≈ 210 mm | 295 | 345 | 5,6 | 7,3 | 5,6 | 8,1 |
| | 315 | 390 | 5,4 | 7,8 | 5,4 | 8,6 |
| | 330 | 425 | 5,3 | 8,2 | 5,3 | 9,0 |

# Fire Resistance

The fire resistance of composite slabs that have been designed for normal temperature (with no extra fire protective measures) has been shown by tests to be at least 30 minutes

If the requirement is 60 minutes or more, calculations or experiments should be performed

However, in the case of a 60 minutes requirement, shrinkage reinforcement combined with steel sheeting is usually sufficient to meet the safety requirements




Without additional measures the fire resistance of a composite slab is 30 minutes. The fire resistance can be increased by (a) additional reinforcement; (b) insulating coating; (c) fire resistant ceiling.

# Execution

With proper logistics, high construction speeds can be **achieved** by using composite slabs:

in high-rise buildings two to three floors per week are not uncommon.

In case of an unpropped floor, casting and curing of the concrete is not critical and assembly of the floors is on the same timeline as that of the steel frame. The packages of steel sheeting (of roughly 100-300 m2) are placed on top of the mounted beams with a single crane movement (fig.). A team of two people can lay down roughly 1000-1250 m2 of steel sheets per week.

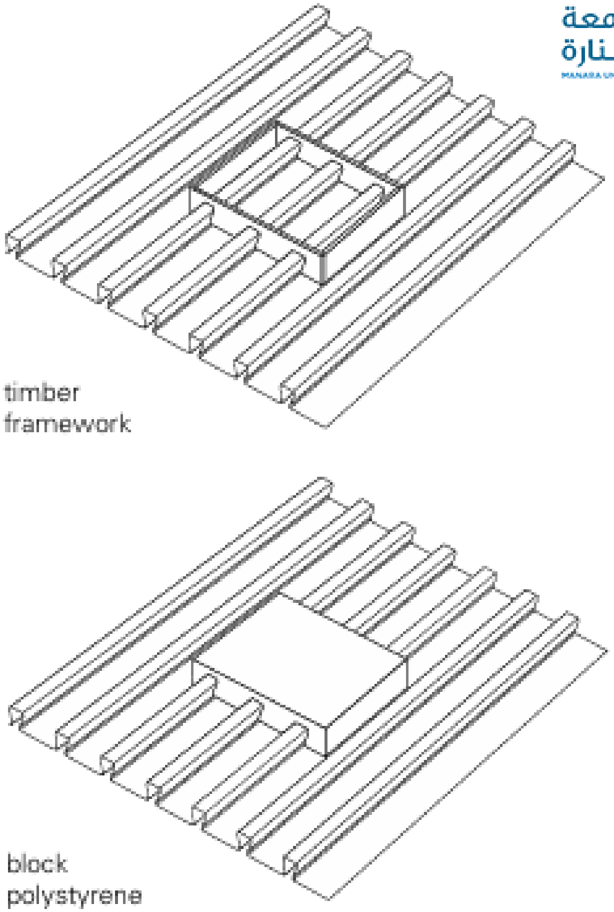
The steel sheets are fixed to the beams with shot-fired nails.

The overlaps of the sheets are fastened to each other with blind rivets or self-drilling screws and, if necessary, closed-off with duct tape in order to prevent leaking water after casting of the concrete

After assembly of the sheeting, the edges and openings are made and (if applicable) the studs are welded. The edges consist of folded steel sheets which are fixed with clips

Small recesses of 300-500 mm are made by placing a timber box or blocks of polystyrene on the floor (fig.)

Steel sheets for composite slabs are placed in packages on the steel structure, and are installed manual




Edges consist of cold-formed steel trims which are fastened by clips

**In general, composite slabs offer the following advantages during execution:**

The profiled steel sheeting acts as formwork and reinforcement, saving time during execution;

– the profiled steel sheeting are both a solid workfloor for casting of concrete (fig) and a safety screen for lower floors;

– the profiled steel sheeting may prevent lateral buckling of the steel floor beams and contribute to the stability of the steel frame during execution;

– most composite flooring systems have attachments which allow services, ceilings and lighting systems to be easily installed;

– the concrete floor can be power floated immediately after casting, depending on the weight of the power float;

– after casting and curing, the solid slab can provide diaphragm action;

The steel sheets act as reinforcement during the final (composite) phase as well as concrete formwork and a solid working floor for pouring concrete