Floor slab construction

Introduction

When developing a scheme for a structure, the choice of floor slab construction is critical to the columns, foundations, walls and overall stability. As such, the floor slab's form should be selected with care and consideration.

This Technical Guidance Note provides information about a number of common floor construction forms that are currently available. It focuses on concrete based solutions: some acting compositely with steel elements, such as reinforcement and/or steel members. Descriptions of each flooring system together with their key features (which cover topics such as buildability, aesthetics and compatibility of other elements e.g. building services) are included. Please be aware that floor slab technology is continually evolving and that new floor slab solutions continue to become available as a result.

ICON LEGEND

- Floor construction
- Applied practice
- Further reading
- Web resources

Floor construction

This note covers nine different types of concrete slab floor construction that are in current use to a greater or lesser extent. Each have unique features, which this note attempts to identify and explain. These features have an overall impact on the structural form they are installed into and can be summarised as follows:

Buildability
The ease with which a floor slab can be constructed.

Aesthetics
What visual impact does the floor (usually its soffit) have if it is exposed?

Sustainability
What impact does the floor construction system have on the environment?

Health and Safety
Closely related to buildability, does the floor slab provide a safe working platform both during and after its construction?

Cost
Cost is measured against any modifications required to the frame structure and construction methods, due to the choice of floor slab. An example is the need to include fully fixed moment connections, as well as the extent of any temporary works such as propping.

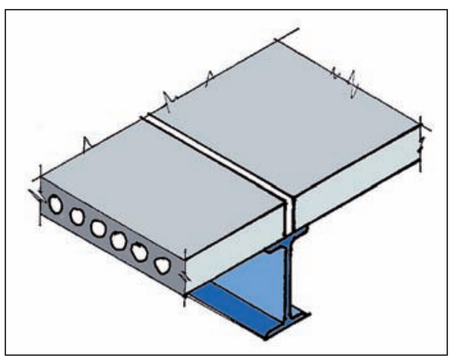

Figure 1
Precast hollowcore planks
(*in situ* concrete not shown for clarity)

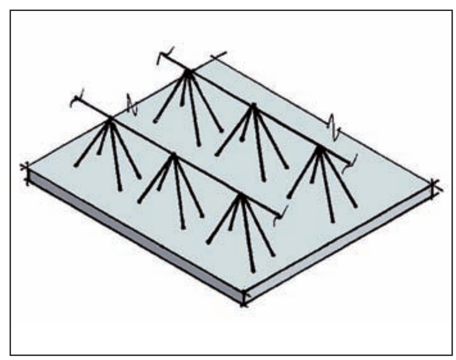

Figure 2
Precast concrete permanent formwork
(*in situ* concrete not shown for clarity)

Building services integration
The easier the distribution of building services can be incorporated into the floor structure, the less complex it becomes when they are installed. This factor can in some instances override many of the other aspects listed here.

Adaptability
How easy is it to carry out modifications to the floor slab and how does it adapt to complex shapes and geometries and varying load conditions due to change of use?

Precast hollowcore concrete planks

Precast concrete planks (Figure 1) are typically 1200mm wide and can span up to 15m. Reinforced with prestressed steel tendons, they are typically supported off of steel beams but can also form part of an *in situ* or precast concrete frame. Their span/depth ratio is very low due to the prestressed method of reinforcement, but the creation of large voids post installation in the slab can be problematic.

Key aspects:
- Propping isn't required and slabs provide a safe working platform once erected, but the supporting beams may need to be restrained due to temporary destabilising load conditions
- Rapid erection and simple installation of reinforcement to structural topping (if present) for continuity
- Usually have a very smooth and polished finished to their soffit, making it possible for them to remain exposed
- Potential damage during delivery and may require significant cranage as part of installation
- In order to create a diaphragm the planks must be grouted at their edges and can also

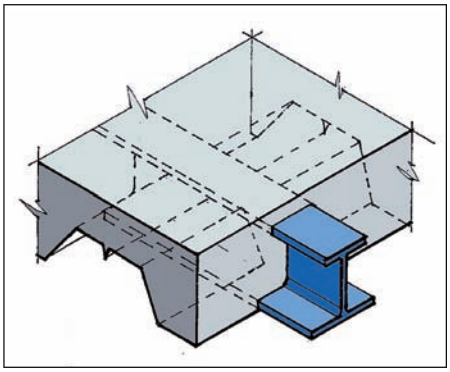

Figure 3
Asymmetric steel beams incorporated into slab depth

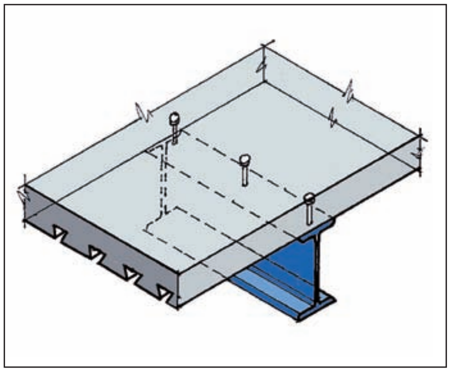

Figure 4
Composite steel beams with metal deck formed slab

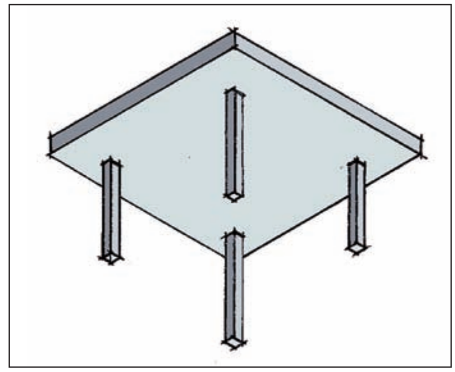

Figure 5
Two way spanning flat slab

receive a structural topping slab and have stitch reinforcement over their supports. Progressive collapse can be mitigated with perimeter ties
- Building services integration can be problematic requiring early coordination, along with provision of trimmer beams to support larger voids
- The presence of down-stand beams interrupts the passage of building services' horizontal distribution. However, use of 'slimflor' beams permit a level soffit and some manufacturers have systems that allow heating distribution along the voids

You can find more detailed guidance in *Technical Guidance Note 24 (Level 1): Precast concrete planks.*

Precast concrete permanent formwork
Precast concrete permanent formwork (Figure 2) has reinforcement projecting from its top surface. As the formwork/ flooring is placed, it requires propping before *in situ* concrete is poured onto it. It can span up to 5m, requiring floor support beams at reasonably close centres, which are sometimes referred to as 'secondary beams'. There are two typical types of this formwork; one with standard reinforcement which usually needs to be propped, and one that is prestressed which can span greater distances without the need to be propped.

Key aspects:
- Permanent formwork solution that reduces the amount of temporary works materials required to create the floor slab
- Provides a smooth and polished finish to its soffit which, with up to 2400mm wide planks, can give an aesthetically acceptable exposed finish
- Requires propping prior to the placement of *in situ* concrete for longer spans
- Has a shallower form factor when compared to traditional reinforced concrete slabs
- Diaphragm created once concrete has been cast
- Provides a working platform, though this is interrupted with the reinforcement that projects from it, which can present a trip hazard
- Can be damaged during delivery and installation
- The presence of down stand beams in the structure interrupts the passage of building services' distribution

Asymmetric steel beams incorporated into slab depth
Asymmetric steel beams (Figure 3) feature a wider bottom flange that supports a reinforced concrete floor slab within its depth. The slab is formed from a metal deck that acts as permanent formwork. This creates downstand free soffit and facilitates the building services' horizontal distribution. For longer spans, beams require partially rigid connections at supports to address deflection and vibration issues.

Key aspects:
- Shallow floor depth with uninterrupted soffit, allowing for free passage of building services' horizontal distribution
- Diaphragm created once concrete has been cast
- Cast in beam creates fire protection without additional treatment to all but the bottom edge
- Permanent formwork reduces temporary works materials
- Additional costs to fabrication and construction due to the requirement of semi-rigid connections for longer spans
- Requires much more reinforcement to address deflection and vibration criteria when compared to other floor systems
- Due to the high amount of reinforcement in the slab, it is difficult to form larger voids for vertical passage of building services' distribution
- Can also use standard UCs with base plates welded to their bottom flange that supports the formwork, be it deep metal deck or precast planks

Composite steel frame with metal deck formed concrete slab
Composite reinforced concrete slabs (Figure 4) are formed from a corrugated metal deck. This decking acts as permanent formwork working compositely with a steel supporting beam via a series of shear studs that are welded onto the top flange of the beam. Shear reinforcement can be placed under the heads of the shear studs at the point of support to facilitate the composite action.

Key aspects:
- Permanent formwork reduces temporary works materials
- Shallower steel beams than non-composite structures, which reduces the weight of the structure and the amount of steel needed to be fabricated
- Services can easily be suspended from the soffit of the decking
- Larger voids in the slab require additional trimming beams
- Can suffer from large deflection and vibration issues for longer span beams
- The presence of down stand beams in the structure interrupts the passage of building services' horizontal distribution. This can be countered by using castellated/open web steel beams
- Diaphragm created once concrete has been cast
- Fire resistance requirement often govern the thickness and reinforcement in the slab resulting in structurally inefficient floor slabs
- Propping required to decking prior to installing in situ concrete for longer spans but that can be mitigated against with deeper and thicker decks
- Difficult to install trimming reinforcement for voids due to the shallow depth of the floor slab

Two way spanning concrete flat slab
Flat slabs (Figure 5) are reinforced concrete floor slabs that are 250-350mm thick, span in two directions and contain a great

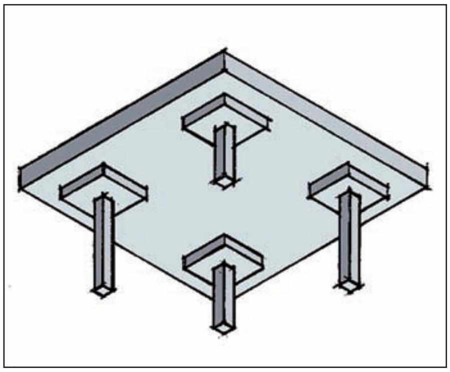

Figure 6
Two way spanning concrete slab with drop panels

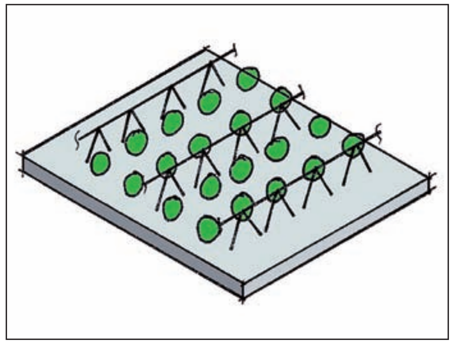

Figure 7
Concrete slab with void formers
(*in situ* concrete not shown for clarity)

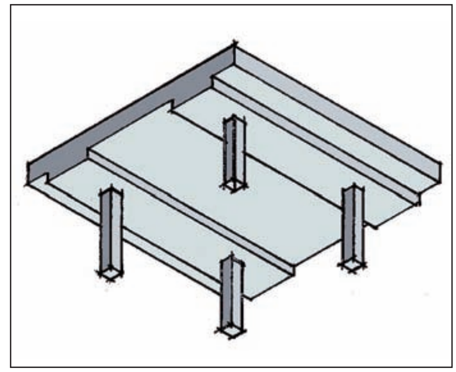

Figure 8
Concrete slab with band beams

deal of reinforcement due to their lack of depth. They have a smooth soffit with no downstand elements. All concrete is formed using temporary formwork and requires propping during construction.

Key aspects:
• Continuous flat soffit that allows free passage of building services' distribution
• Trimming beams not required for voids as all reinforcement is contained within the depth of the slab
• Services can easily be suspended from the soffit of the slab
• Can have smooth finish to soffit of slab either by careful use of formwork or post casting treatments
• Easy to install reinforcement, but can be quite dense
• Formwork and propping required, which leads to extensive temporary works
• Can require the use of shear einforcement around column heads to resist punching shear due to shallow depth of slab
• Larger amount of *in situ* concrete required than other flooring systems, resulting in a heavier structure
• Can have deflection and vibration issues, especially for longer spans, requiring additional reinforcement
• Void placement adjacent to columns is difficult due to reduced resistance to punching shear if they are installed
• The end span of a flat slab tends to be the most critical due to the lack of continuity, resulting in reduced stiffness at the end support

Concrete slab with drop panels
Concrete floor slabs with drop panels (Figure 6) address the issue of punching shear at the heads of columns found in flat slabs. By creating a localised thicker section of slab around the column head, the need for shear reinforcement is negated. The presence of drop panels also reduces the amount of reinforcement within the slab, due to stiffening of the supports, and can reduce slab thickness when compared to flat slabs.

Key aspects:
• Easy to form voids without the need for downstand trimming beams during construction
• Removes the need for punching shear reinforcement
• Interrupted soffit that limits passage of building services' distribution
• More complex formwork than its flat slab counterpart due to the presence of the drop panels
• Difficult to provide voids near columns due to presence of drop panels
• The drop panels create supports that reduce the amount of reinforcement in the slab

Concrete slab with void formers
Much of a reinforced concrete slab is not efficiently engaged. Most of the work is carried out by both the reinforcement within it and the outer surfaces of the slab. In recognition of this, there are products that remove the bulk of the concrete from the middle of the slab by replacing it with lightweight plastic or polystyrene void formers (shown in Figure 7 as small green spheres). This reduces the overall weight of the structure significantly, but usually leads to the introduction of large amounts of shear reinforcement around column heads. This is because the slab's resistance to punching shear is reduced due to the reduction in concrete.

Key aspects:
• Can be delivered and installed in large modules
• Significant reduction in concrete leading to a lighter structure
• Reduced amount of reinforcement due to reduction in self-weight of slab
• Provides a smooth and polished finish to its soffit
• Light plant required to lift and install slabs into place due to reduced self-weight of units
• High amount of shear reinforcement required around column heads due to lack of concrete
• Can suffer from large deflection and vibration issues for longer spans, requiring additional reinforcement
• Can be damaged during delivery
• Can produce a thick floor slab reducing the floor to ceiling height
• The presence of down stand beams in the structure interrupts the passage of building services' horizontal distribution
• Difficult to provide voids near columns after construction due to dense reinforcement around columns

Concrete slab with band beams
Band beams (Figure 8) are horizontal elements that are wider than they are deep. The slab spans one way onto the band beams, which reduces the thickness of the slab and complexity of reinforcement. The band beams provide a thickened element that resists both shear and bending between columns.

Key aspects:
• Simple reinforcement in the slab, making it easier to design and construct
• Reduces the need for punching shear reinforcement
• Stiffer supports reduce the amount of reinforcement in the slab
• The band beams create supports that reduce the amount of reinforcement in the slab
• Heavy construction when compared to other forms of floor slab described in this note other than flat slab
• Difficult to provide voids near columns after construction due to the presence of dense reinforcement around column heads
• The presence of down stand beams in the structure interrupts the passage of building services' horizontal distribution
• Formwork and propping required, which leads to extensive temporary works

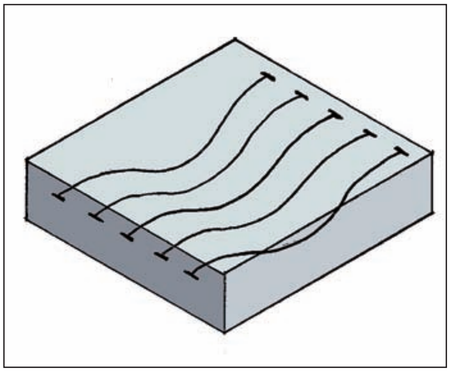

Figure 9
Post-tensioned concrete slab

Post-tensioned concrete slab

Post-tensioned concrete slabs (Figure 9) contain steel cables, known as 'tendons' that are plotted and installed within the concrete slab in such as a way as to use the compressive strength of the concrete. This is achieved through the application of tension to the tendons during the curing process of the concrete with strand jacks at the perimeter of the slab. This significantly reduces the depth of the slab and can be used in the floor slab forms identified in Figs 5, 6 and 8. Any reinforcement over and above the tension cables is typically found at the column heads to resist shear and at the anchor points for the tendons, to prevent them from bursting due to localised stresses.

Key aspects:

- Significantly reduced amount of reinforcement in the slab, making construction easier
- Lighter construction when compared to traditional reinforced concrete
- Formwork and propping required, which leads to extensive temporary works
- Shear reinforcement is likely around column heads, which can reduce the ease with which voids can be installed near columns
- Specialist construction technique, which limits the number of potential contractors who can construct it
- Reduces flexibility in location of voids within the slab
- Additional anti-burst reinforcement required at tendon ends
- Fixing into soffit of slab can be a problem as the tendons must not be hit as the slab is drilled into
- Care is needed during demolition with unbound tendons, hence current practice is to bond the tendons with grout once they have been stressed

Applied practice

BS EN 1992-1-1 Eurocode 2: Design of Concrete Structures – Part 1-1: General Rules for Buildings

BS EN 1992-1-1 UK National Annex to Eurocode 2: Design of Concrete Structures – Part 1-1: General Rules for Buildings

BS EN 1993-1-1 Eurocode 3: Design of Steel Structures – Part 1-1: General Rules for Buildings

BS EN 1993-1-1 UK National Annex to Eurocode 3: Design of Steel Structures – Part 1-1: General Rules for Buildings

BS EN 1994-1-1 Eurocode 4: Design of composite steel and concrete structures. General rules and rules for buildings

BS EN 1994-1-1 UK National Annex Eurocode 4: Design of composite steel and concrete structures. General rules and rules for buildings

Glossary and further reading

Further Reading

The Institution of Structural Engineers (2013) Technical Guidance Note 24 (Level 1), *The Structural Engineer,* 90 (4), pp. 26-28

The Institution of Structural Engineers (2006) *Manual for the design of concrete building structures to Eurocode 2* London: The Institution of Structural Engineers

The Institution of Structural Engineers (2010) *Manual for the design of steelwork building structures to Eurocode 3* London: The Institution of Structural Engineers

The Concrete Centre (2009) *Economic concrete frame elements to Eurocode 2* London: The Concrete Centre

Web resources

Tata Steel Europe:
www.tatasteeleurope.com

The Concrete Centre:
www.concrete.org.uk

The Institution of Structural Engineers library:
www.istructe.org/resources-centre/library

Errata

In Technical Guidance Note No. 6 (Level 2) 'Designing a laterally loaded masonry wall' (*The Structural Engineer,* June 2013) the description variable for f_{vd} should read: 'is the shear strength of the wall..."

Technical Guidance Note No. 7 (Level 2) 'Designing a concrete pad foundation' (*The Structural Engineer*, August 2013) stated that the spread of the concentrated force from a column onto a pad footing is at an angle of 45 degrees. This is not assumed to be the case in Eurocode 2, which places a variance on this angle depending on both the strength of concrete used and the bearing capacity of the soil. For unreinforced concrete pads, the table here (taken from the *Manual for the design of concrete structures to Eurocode 2,* where further guidance on this topic can be obtained) should be referred to, when determining the spread of force within the pad footing:

Depth/projection ratios for unreinforced footings

Unfactored ground pressure σ (kN/m²)	$\frac{a}{h_f}$			
	C20/25	C25/30	C30/37	C35/45
≤200	1.2	1.1	1.1	1.0
300	1.5	1.4	1.3	1.2
400	1.7	1.6	1.5	1.4

Where:
a **is the projection from the face of the column**
h_f **is the depth of the footing**

Also, the dimensions of the pad in the Worked example should read '600, 400 and 600'.