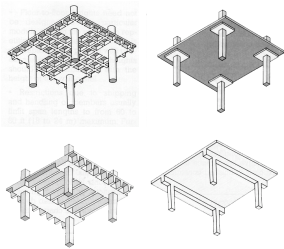


Concrete Framing systems

Design choices

- Site Cast Concrete gives a designer a lot of freedom in the design and construction of walls, columns and surface textures. When it comes to spanning, concrete offers the same one directional system types offered by timber, laminated wood, steel, and precast concrete, that is beam spanning from column to column with some form of joist or decking in between.
- This is enough for many designers, but some need the two directional spanning capacity that site cast concrete can offer. The following is an overview of concrete framing systems and some characteristics of each.

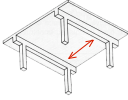
Basic flavors



All diagrams from Allen "Architects Studio Companion"

- Basically, there are 4 types of slabs an architect chooses from when considering a system for a project.
- Slabs are usually flat, can be reinforced to span one way or two ways. Their span usually depends on their depth, but there is a point where the extra concrete in the depth works against the slab due to its weight.
- Joist slabs usually can span farther and carry heavier loads because they eliminate concrete not contributing to the slabs strength. (hence the joists)

One way flat slabs

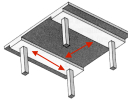


Span min 6'
Span max 18'
R.O.T. Slab depth 1/22th
of span
Postten rot Slab depth
1/40th of span

Min thick for 2hr = 5"
Min thick for 3hr = 6 1/2"

- The one way slab spans between beams or columns. It requires a structural bay (spacing between columns in both directions) that is within 20% of being square.
- It is usually used for light loading applications where it's thin structural depth gives a low floor to floor height. When heavily loaded it requires the beams below the slab, It is more desirable to NOT have these beams as they take additional labor to form and pour.
- Costs
 - 25x25 6" 40psf load about \$13.80 per sq.ft.
 - 25x25 6" 125psf load about \$17.20 per sq.ft.

One way flat slabs w/slab bands

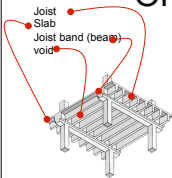


Span min 6'
Span max 18'
R.O.T. Slab depth 1/22th
of span
Postten rot Slab depth
1/40th of span

Min thick for 2hr = 5"
Min thick for 3hr = 6 1/2"

- Here the beams have been flattened out to reduce floor to floor depth. It still requires a structural bay (spacing between columns in both directions) that is within 20% of being square.
- It is usually used for light loading applications where it's thin structural depth gives a low floor to floor height. When heavily loaded it requires the beams below the slab, It is more desirable to NOT have these beams as they take additional labor to form and pour.
- Costs
 - 15x15 40psf load about \$13.36 per sq.ft.

One way joist slabs

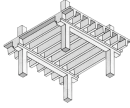


Span min 12'
Span max 45'
R.O.T. Slab depth 1/18th
of span
Postten rot Slab depth
1/36th of span

Min thick for 2hr = 5"
Min thick for 3hr = 6 1/2"

- To address heavier loading conditions, its necessary to remove the concrete that's acting as dead weight - working against the slab that comes along with an increase in the uniform thickness of a slab.
- This one way joist slab does just that, using prefab formwork set on a plywood deck voids are formed between the joists which make the slab lighter, and stiffer.
- The joists bear into beams (called **bands**) spanning from column to column. These **bands** give this system the ability to move columns off the grid, (as long as they still fall under the **bands**) allowing for more plan flexibility.
- Costs
 - 25x25 12" 40psf load about \$14.10 per sq.ft.
 - 25x25 12" 125psf load about \$16.50 per sq.ft.

More on one way joist slabs



- The slab is formed with rented fiberglass forms to make the voids between the joists. These forms are available from 8 to 20 inch depths, and in 20 & 30 inch widths.
- The joists between the voids are usually 4 to 8 inches wide, and the slab above the voids is usually 3 to 4 1/2 inch thick.
- There is usually not much reinforcing in the slab, and not much in the joist, most of the steel is concentrated in the band carrying the joists.
- The void gives places for lighting, ducts are harder to place here because it is almost impossible to put a hole big enough for a duct through the joist band.
- You might guess this is a tough system to meet with partitions going perpendicular to the joists and curved partitions are also pretty difficult.







Magic disappearing beams!

Here the beam and slab are partially integrated, the top reinforcing for the beam is placed in the slab

- Cast in place concrete is the only form of construction which can absorb primary spanning members into the slab without seriously affecting the beams performance.

Here the beam has become much wider, but also much thinner. It is more fully engaged with the slab to reduce floor to floor height

In this thicker two way slab, the extra formwork required for the slab band has been completely eliminated, fully absorbing the beam into the slab!

Upside Down construction

- Most construction places load carrying elements **below** the source of the load, **part** of the structural hierarchy driven by gravity and the relative difficulty of designing and constructing tension based connections.
- Another unique capability of concrete construction is the relative ease with which supporting members can be constructed / connected **above** the source of the load.

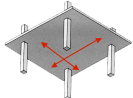
Carpenter Center for Visual Arts



Here, Architect Le Corbusier has placed the beam carrying the ramp above the ramp, using it as an integral railing

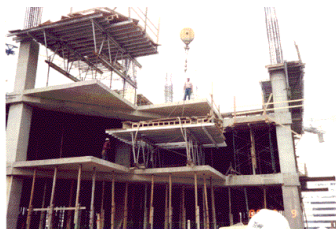
- Real efficiency! Using one act to complete two tasks!

Two way flat plate

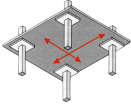


Span min 10'
 Span max 28'
 R.O.T. Slab depth 1/30th of span
 Postten rot Slab depth 1/45th of span
 Min thick for 2hr = 5"
 Min thick for 3hr = 6 1/2"

- The two way flat *plate* is more efficient structurally for light loading situations. The big difference between it and the one way slabs with beams is that it's reinforced to span two ways. This is possible because the beams are developed within the slab and span across all columns
- It still requires a structural bay (spacing between columns in both directions) that is within 20% of being square.
- It is usually used for light loading applications where it's thin structural depth gives a low floor to floor height.
- As it reaches it's maximum span, there is more concrete needed in the beam strips, so the **slab gets thicker**. This also means there is more concrete in the center which is just acting as dead weight, working **against** the slabs efficiency!
- Costs
 - 25x25 9" 40psf load about \$12.85 per sq.ft.
 - 25x25 10.5" 125psf load about \$13.85per sq.ft.



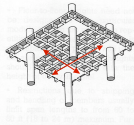
Two way flat slab with drop panels



Span min 12'
 Span max 33'
 R.O.T. Slab depth 1/30th
 of span
 Postten rot Slab depth
 1/45th of span
 Min thick for 2hr = 5"
 Min thick for 3hr = 6 1/2"

- The two way flat slab is more efficient structurally for heavier loading situations. The big difference between it and the flat plate is its extra shear resistance at the columns.
- Here the shear resistance is developed by adding extra slab thickness (and reinforcing) at the columns. This form of adding shear resistance is called **shear or drop panels**. They add significantly to the cost of formwork!
- Like the plate, it has beams are reinforced to span two ways. This is possible because the beams are developed within the slab and span across all columns
- It still requires a structural bay (spacing between columns in both directions) that is within 20% of being square.
- As it reaches it's maximum span, there is more concrete needed in the beam strips too, so the **slab gets thicker**. This also means there is more concrete in the center which is just acting as dead weight, working **against** the slabs efficiency!
- Costs
 - 25x25 10" 40psf load about \$13.30 per sq.ft.
 - 25x25 10" 125psf load about \$14.55 per sq.ft.

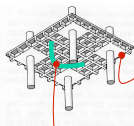
Two way joist slab...waffles anyone?



Span min 15'
 Span max 55'
 R.O.T. Slab depth 1/24th
 of span
 Postten rot Slab depth
 1/35th of span
 Min thick for 2hr = 5"
 Min thick for 3hr = 6 1/2"

- The **two way joist slab**, also called a **waffle slab** is most efficient structurally for heavier loading situations and longer spans in concrete.
- The magic of the waffle slab is that the extra depth of the slab which gives more span/load capacity **does not create dead weight** in the middle of the span. The waffles **displace** unemployeed concrete making the slab lighter and much stiffer!
- It behaves a little like a space frame made of concrete.
- The best part is columns don't have to line up! This gives exceptional flexibility in column layout!
- Costs
 - 25x25 10" 40psf load about \$18.55 per sq.ft.
 - 25x25 10" 125psf load about \$19.35 per sq.ft.

More about Waffles



- The waffles are formed by placing fiberglass pans or domes on a plywood deck. The pans displace concrete leaving the void when they are stripped.
- Pans aren't usually placed near the columns or bearing walls to allow the concrete to fill in solid at columns and bearing walls, places of maximum shear transfer.
- Slab thickness above the pans is usually 4 to 6 inches
- The pans are usually rented, and come in standard heights from 8 to 24 inches deep and from 19 to 52 inch widths. This gives the engineer a joist width choice between 5 and 8 inches wide
- You can see one of the difficulties for an architect using this system, wall partitions that have to meet the slab can really only fall on the joists. This makes curved partitions very hard to build.

