This slide shows the typical reinforcement cage for a simple span concrete beam. The tension bars resist tension from moment which will occur in the bottom of the beam in this case; the stirrups resist shear which is highest near the supports under distributed loads (more on shear design later); and finally the compression bars (called that because they are in the compression zone of the beam) help support the top of the cage and improve the mechanical performance of the beam in some ways that we will discuss later.
Floor Framing Plans

This is the type of system we will learn in this class.

The is the first step of the load path for the one-way slab system.
This is the second step of the load path. The last would be into the columns and then down to the foundations.

Joists make the slab stiffer and allow the flanges of the slab to be thinner. The disadvantage is that the forming can be more difficult. There are pan form systems that allow these to be cast with relative ease, but they limit the contractor to specific dimensions and cannot be flexibly applied for a wide range of applications.

A system similar to the joist system.
This is the most flexible of all concrete floor systems and is thus widely preferred by contractors. They require minimal forming which can often be rearranged easily to accommodate unusual column locations or varying column spacing. There are two disadvantages: (1) The slab must be thicker because it does not have any beams to make it stiffer; and (2) punching shear – the tendency of the columns to punch a hole through the concrete slab.

Drop panels and column capitals reduce punching shear (which is probably the most common collapse mode of all concrete structures). However, special forming is required which increases cost.
Slide 12

**Flat Slab with Drop Panels**

![Flat Slab with Drop Panels](Image)

*Photo courtesy of the Godden Collection, Earthquake Engineering Library, University of California, Berkeley*

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Slide 13

**Forming for a Drop Panel**

![Forming for a Drop Panel](Image)

*Photo courtesy of Mehdi Setareh (VPI) and Robert Darves (Uni. of Michigan)*

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Slide 14

**Waffle Slab**

![Waffle Slab](Image)

*Photo courtesy of Mehdi Setareh (VPI) and Robert Darves (Uni. of Michigan)*

**Typical example of a waffle slab.**

Standard pan forms make these relatively easy to make. The resulting floor is relatively thick and requires a higher floor to floor height to accommodate the space.
This is the system we will learn in this course.

The moment resisting frame works because of the rigid joints between columns and beams. This causes moment transfer from the beams into the columns.
This is the resulting moment diagram for columns in a moment resisting frame.

Shear walls are a desirable option for many cases.
Shear Walls

Floor slabs act as rigid membranes, carrying lateral load to the shear walls.

Shear Walls

Shear walls can be placed in the building interior to allow an open facade.

Shear walls have the disadvantage that they are harder to put openings in (it can be done, but the openings cannot be too big and they reduce the strength of the wall – they are also hard to design when they have openings). Shear walls are often moved to the interior of the building so that they do not interfere with exterior windows. They are often used around the stair wells and mechanical shafts.
Optimal building design starts from the top down (we follow the load path). Building construction necessarily begins from the bottom up.
Step 1 (after excavation and site grading) – Footings are cast.
Slide 27

Footings

Example of a pad footing (forming).

Photo courtesy of Mehdi Setareh (VPI) and Robert Darvas (Univ. of Michigan)

Slide 28

Wall Footings

Example of a strip footing. A strip footing supports a wall rather than an individual column.

Photo courtesy of St. Mary's Parish, Southbridge, MA

Slide 29

Wall Footings

Photo courtesy of St. Mary's Parish, Southbridge, MA
Step 2 – The column rebar cage and forming are put in place. Lap splice ensure continuity of reinforcement from the footings into the columns. Column reinforcement will extend through the slab above into the next level of columns.
Building project at UW-Madison – Vilas Communication Hall.
Slide 36
Casting of columns accomplished using a pump truck.

Slide 37
This is an example of highly versatile column formwork. These forms have a high initial cost to purchase and must be well maintained, but have several advantages: (1) they are reusable; (2) they can accommodate a wide range of column dimensions; (3) they quality of the interior surface will provide a good finish; and (4) they assemble very quickly reducing labor costs.

Slide 38
Step 3 – A slab on grade is cast to provide a surface to support formwork and shoring.
**Slide 39**

Girders and Slab

- Slab & Beam Forms
- Slab & Beam Reinforcement
- Shoring

**Slide 40**

Girders and Slab

- Negative Moment Reinforcement for Beam
- Positive Moment Reinforcement for Beam

**Slide 41**

Girders and Slab

- Shear Reinforcement
- Ties to help anchor hooks on negative moment bars
Slide 42

Slide 43
Step 4 – Beams and slab are cast as a monolithic (single) unit.

Slide 44
This photo shows “flying forms” (top) and reshores (underside of slab). Reshores are shores added after the removal of formwork. Their purpose is to distribute construction loads placed on a fresh slab into slabs beneath.

Another example of shoring and formwork.
Note the congestion of the joint. There are three directions of reinforcement that must be accommodated at the joint. The designer needs to think about how all these will fit. Intersections will be corrected by field workers who often don’t understand the ramifications of moving the reinforcing bars from their intended position.

Casting of a waffle slab. Note that workers stand directly on the rebar and can deform it if it is a small size.
Slide 51

Casting of Waffle Slab

Casting and vibration.

Photo courtesy of Mehdi Setareh (VPI) and Robert Darvash (Univ. of Michigan)

Slide 52

Rebar Congestion

Left – Trump Tower, Chicago, Illinois
Right – Oakland Bay Bridge, California

Both photos show intense rebar congestion. For Trump Tower, there is a lot of reinforcement to resist wind loads. For Oakland Bay Bridge, the reinforcement is to resist seismic forces. The purple in the Oakland Bay Bridge photo is epoxy coated reinforcement.

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Rebar Congestion

Reinforcement for a anchorage segment of US 183 elevated freeway in Austin, Texas. This photo illustrates how complex reinforcement arrangements can become. This particular piece of the bridge will sit over a pier and also anchors large steel prestressed cables. The concentrated forces entering the segment because of this necessitate the large amount of reinforcement.
The consequence of excessive congestion – you may not get concrete all the way into the forms. This segment had to be discarded. The contractor overcame the congestion problem by designing a highly fluid mix that would flow though the congested areas.