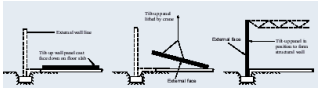
"At Bassora, where they have no timber, they make arches without any frame. The mason, with a nail and a bit of string, marks a semicircle on the ground, lays his bricks, fastened together with a gypsum cement, on the lines thus traced, and having thus formed his arch, it is carefully raised"
William Eton, Survey of the Turkish Empire 1799

- Concrete weighs about 150 pounds per cubic foot

A Turn of the century discovery here

- Robert Aiken constructed concrete buildings from panels cast on site and lifted into place with derricks in 1908
- In the late 1950's mobile crane availability made building warehouses of 20 foot tall, 20 ton panels simple, a builder could set 12 panels per day
- Today panels over 40 tons are common, an experienced tilt-up contractor can place 30 such panels per day
- Still a favorite for warehouses, "big box" stores, some low rise office buildings. But has also been used for libraries, fire stations, hotels, parking ramps….most everything but generally built by a builder specializing in tiltup.
  - A good source: The Tilt-Up Design and Construction Manual by Hugh Brooks, published by the TCA

- Tiltup concrete is effectively a site-based precasting process.
- A casting slab is poured, often it becomes the slab-on-grade floor slab or part of the parking lot
- A box is built to act as the edge forms for the panel
- Reinforcing and embedments are placed within the edge forms
- Blockouts for doors, windows are installed
- Concrete is poured, vibrated, screeded
- After curing, (7-10 days) the panel is lifted with a crane, and set into place

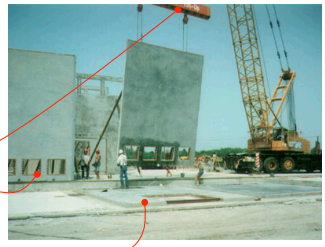


Tiltup slab/panel fundamentals

- Form the panel on a casting slab by forming its edges. Brace the edges of the form for precision, place a form release agent on the casting slab, install reinforcing and embeds, pour, cure, tilt and c

Tilting up

- Reinforce, place, cure and lift into position



Brace-in-place

- Panels cast on top of each other to save space
- Adjustable steel bracing columns

- System advantages
  - Transportation size limits don't apply - whatever can be lifted can be made
  - Transportation costs don't apply - no storage problems onsite
  - Rapid building enclosure
  - Easy to cast insulated concrete sandwich panels - two pours
  - No formwork marks on the completed panels
  - Fire and durability advantages of concrete construction

Ideal Tiltup projects

- Generally tiltup is good for:
  - Buildings with mostly flat exterior surfaces having less than 50% windows and openings
  - Most walls extending to footings (as opposed to stacking panels or lintles)
  - Less than 30 foot panel height (but 60 feet is becoming more common)
  - With enough floor area so the panels can be cast in a single layer. Wall area should not exceed approx. 80% of floor area (sequential casting in a stack is possible, or make thin 3" disposable casting slabs-on-grade for more casting capacity)
  - Walls divided into panel sizes / weights matching crane capacity (80,000 pounds / 900 square feet)

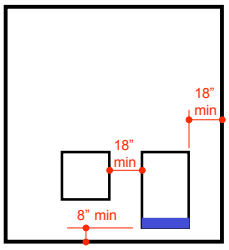
- Ripley's panel stats:
  - Heaviest tiltup panel ever set, 155 tons each…over 2,000 cubic feet
  - Tallest tiltup panel 91 feet high spire panels for a church
  - Tallest load-bearing panel 60 feet
  - Tallest free-standing wall panel 40 feet

- System disadvantages:
  - Generally not for small projects (<6,000 s.f.) on tight sites
  - Must be good weather for site-casting
  - Needs a building with a big floor area, all panels must be able to be cast on the floor, ideally at the same time or in a production-line sequence so the cranes & rigging crews (the expensive part $6,000/20-30 panels per day) don't sit idle onsite
  - Some limits to dimension of panels, proportion of panels
  - Joints between panels often made large (2") to compensate for less precision in panels
  - Concerns for process efficiency can override design concerns

Rules of thumb for sizing

- Panel sizes should be around 80,000 pounds max, crane capacity should be approx twice the weight of the heaviest panel.
- Panel weight determined by its area in feet (less doors / windows) multiplied by its thickness gives the volume of concrete, multiplied by 150 pounds per cubic foot gives total weight.
  - A panel 40 feet by 26 feet has an area of 1,120 square feet, times 6 inches of thickness (1040 x .5) = 520 cubic feet of concrete times 150 pounds per cubic foot equals 78,000 pounds
- Panel thickness can be estimated by dividing the height of the panel in feet by 4 to get the panel thickness in inches. (a 24 foot tall panel would be 6" thick, a 40 foot tall panel would be 10" ….)

Form panel edges and holdouts for doors, windows



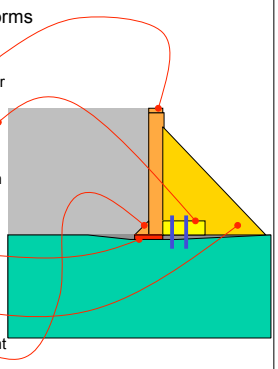
- Steel doors generally are formed using their steel or hollow metal frame. A styrofoam block is often added to the bottom of the frame to make a recess for the door threshold.
- Doors having wood or aluminum frames are formed as holdouts with simple boxes. The fragile aluminum or wood frame is installed after the panel is tilted up.
- Openings are generally kept 18" apart and 18" from the panel side. Door openings are held 8" above the bottom of the panel for reinforcing/panel continuity.

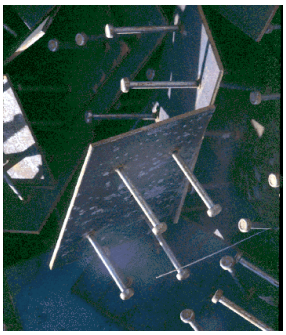
Reinforcing:

- Spacing of the bars must not exceed 3x panel thickness
- Lap splices are generally about 24" but are specified by engineer
- Shear hooks (when required) are generally a 90 degree bend plus end extension of 12x bar diameter
- Panels over 10" thick need rebar grids at both faces (within 2")
- Panels under 10" thick usually have rebar in the middle of the panel thickness
- Parallel bars must be 1 bar diameter apart, 1.33 x largest aggregate diameter apart or 1" apart, which ever is greater
- Place at least one #5 bar around panel openings, more where specified by the engineer

Edge forms

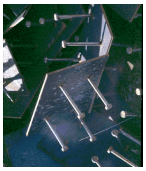
- Generally wood
  - Dimension lumber with strips of plywood added to meet full 6" or 8" panel thickness
  - Cleated to casting slab. (drill hole and use 1/4" wood dowels for connector, gives enough shear but won't spall slab when removed)
  - Assumes casting slab is fairly flat, else shim and seal with compressed foam gasket
  - 2-3 re-uses possible
  - Brace edge forms to slab to prevent distortion when pouring
  - Apply 3/4" chamfer strips to joint between side form and slab

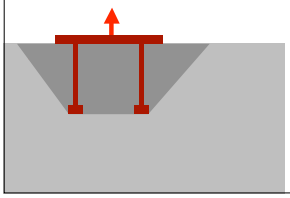




Embedments

- Embeds is the name of the miscellaneous steel parts partially sunken (embedded) in the tiltup (or sitecast or precast) to connect steel, precast or tiltup structural parts.
- Here the Embed is a steel plate with shear studs (a.k.a. Nelson studs) welded to the plate

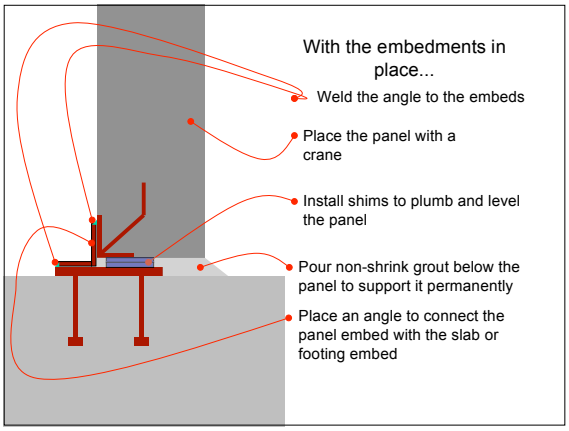




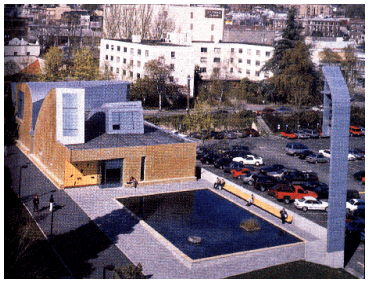
- The studs will be sunken into the concrete. As the concrete cures around the studs, the head of the stud prevents the plate from being easily pulled from the concrete… a wedge of concrete would have to be removed for the plate to fail...if tied into the rebar, the whole concrete piece would have to fail to break the connection

Embeds 2

- Here the plate with the shear studs has been cast into the footing, the tiltup panel, if it has a matching embedded plate or angle can be welded to the foundation here.

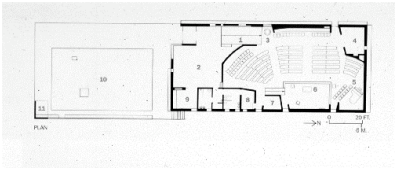


St. Ignatius Chapel

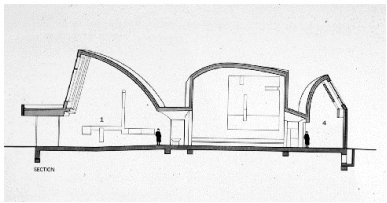


In the Chapel of St. Ignatius in Seattle, Steven Holl employed a form of site - cast precast concrete called tilt-up construction.

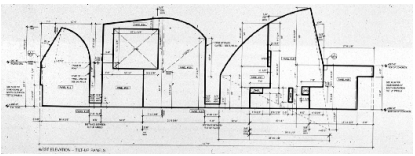
Common in wharehouses and shopping centers, this construction method is seldom seen in smaller scale construction



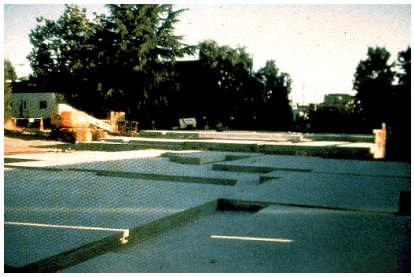
- The chapel has a deceptively simple plan using concrete wall elements, separated by light, with steel trusses spanning across to modulate the space.



- The section begins to reveal the spatial complexity possible with this simple construction method.

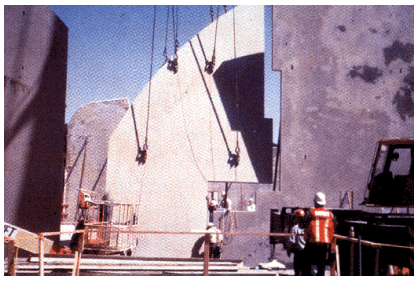


- The wall panels are carefully designed to both collect light and be at an appropriate scale for the interior space… and not be too heavy to pick up with the crane.
- The advantage to site casting these flat panels is that they can be larger than is possible to ship on the road.

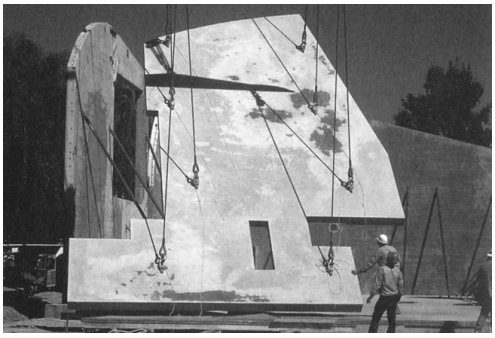


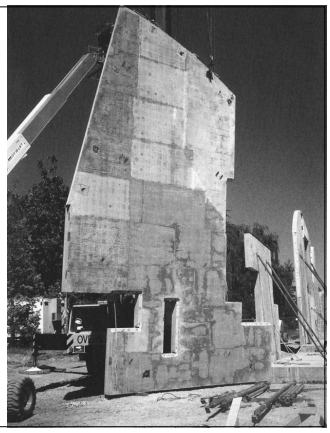
- The panels are also carefully designed to fit on the floor slab all together.
- Not as simple as tilting the panels up from where they were poured, but still easier than transporting.

- After curing, the mildly reinforced (no prestressing) panels are picked up with a crane using two spreader bars to carefully transition the panels from horizontal to vertical.

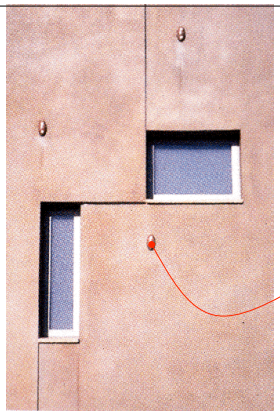


- By letting out one pair of lines, the crane can transition the panel to vertical. Lifting points for the slab are designed with the weight distribution of the slab in mind.

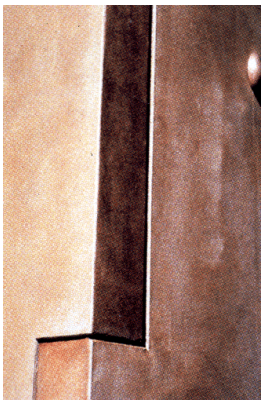




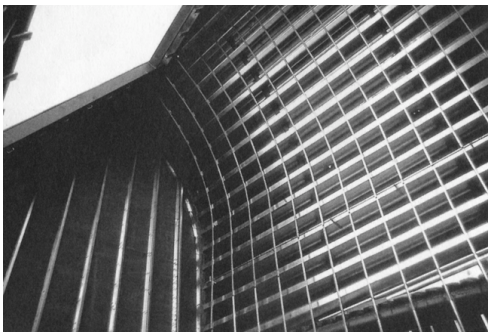
- The panels are permanently stabilized by welding steel trusses between opposing panels.

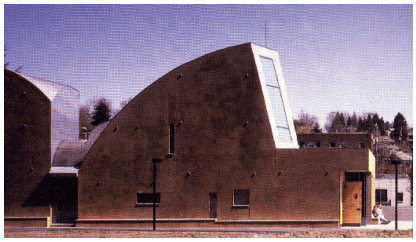


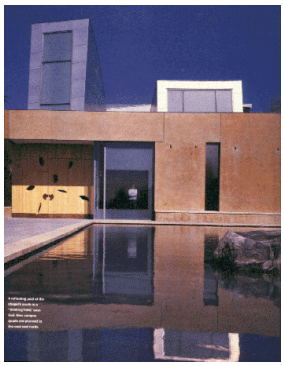
- Holl positions window openings along the panel joints, interlocking most panels together, not trying to hide the joint, but to form it in a way that the mechanical engagement between panels is apparent.
- Bronze covers, mark the pick up points for each

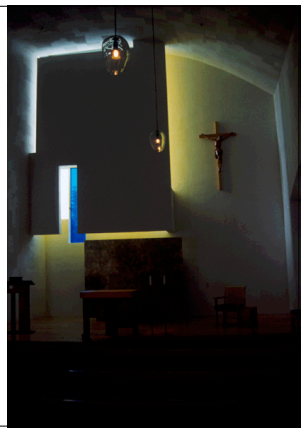


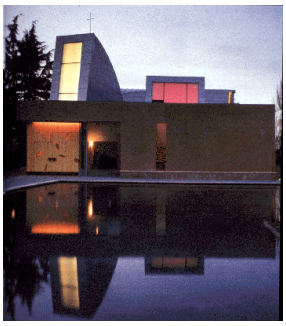
- At the buildings corners, the panels form a simple overlapping joint.









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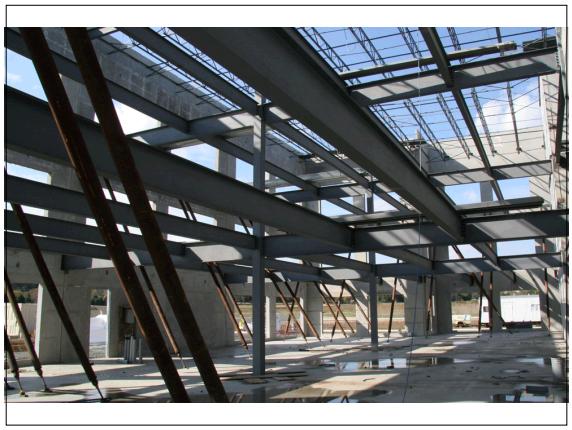

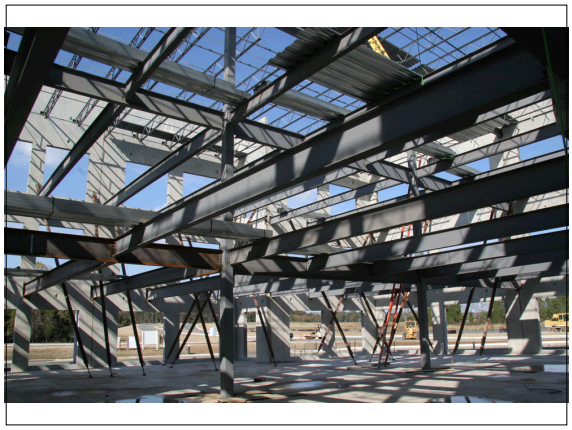

A 8" thick panel (incl 2" polystyrene), steel trowel finish in-place cost is est. at $9.78/s.f.