Concrete

Limitless Shapes & Surface Textures
Concrete Production

- Cement
- Sand
- Coarse agg
- Water
- Batching
- Mixing
- Placing
- Finishing
- Transporting
- Curing
Sitecast Concrete
Concrete Construction - Options

- **Cast off Site (Precast)**
  - Construct components prior to installation
  - Transport components to the project (if cast “off” site)
  - Assemble / Erect the concrete elements

- **Cast on Site (Site Cast)**
  - Labor, Material, & Equip. brought to the site, and
  - Concrete elements constructed in-place

- Combination
Types of Concrete Elements That Must be Cast on Site

- Caissons & Pile Caps
- Footings (Spread & Strip)
- Slab-on-Grade
- Slab Toppings
- Elements too large or heavy to Transport
- Irregular or Special Elements (typically)
- Structures Requiring Full Structural Continuity
Concrete Frame Construction

Major Cost Components (Labor, Material, & Equipment)

Formwork, Reinforcing, Concrete
Types of Concrete Elements

- Slab-on-Grade
- Columns
- Walls
- Floors & Roofs
- Other (stairs, panels, etc.)
Slab-on-Grade (SOG)

Level surface of concrete supported on the ground
Slab-on-Grade (SOG)

Loading:
- Carries little or no structural stress except,
- Transmission of superimposed loads

Thickness & Reinforcing determined by:
- Capacity & consistency of the soil
- Loads imposed (People, cars, airplanes, equipment, etc.??)

Thickness; 3” to 18”+

Reinforcing Options; none, WWF, re-steel
Casting a SOG

- Strip Topsoil
- Cut/Fill/Compact Subsoil (Subgrade)
- Install Underground Utilities (if req’d)
Casting a SOG (cont.)

Installation of Crushed Stone

- SOG inside of Buildings - typical
- Sidewalks (rarely)
- Paving (depends)

Primary Purpose:
- Drainage
- Structural Fill
Casting a SOG (cont.)

- Install Formwork
  - Edge Forms
  - Construction Joints
  - Formed Control Joints
  - Expansion joints
Expansion Joint
Casting a SOG (cont.)

- Apply termite protection
- Install moisture barrier
Placing Termite Protection
Casting a SOG (cont.)

- Install Reinforcing
  - Lightly loaded - Light gauge WWF
  - Heavily loaded - heavy gauge or reinforcing
Reinforcing Purpose - Prevent cracking from
- Shrinkage,
- Temperature stresses
- Concentrated loads,
- Frost heaving
- Ground Settlement

Slab-on-Grade with Vapor Barrier & WWF
(Note lapping of WWF)
Casting a SOG (cont.)

Place Concrete

- Chute, Wheelbarrows & Buggies
- Concrete Bucket, Conveyor Belt, Pump
Laser-screed
Often used for ‘superflat’ floors
Casting a SOG (cont.)

Consolidate & Finish

- Straightedge (Strike off)
- Float Finish
- Hard Trowel Finish
- Broom Finish
Finishing
Rotary Power Trowel
(Rider - Double Blade)
Application of Curing Compound
Control Joint (tooled)

Joints

Control Joint (sawed)

Note the Broom Finish
Slab-on-Grade – Pavement
Concrete Paving Machine
Elevation Setting
Casting a Concrete Wall

**Footing (Wall Support)**
- Size determined by Engineer
- **Keyways**
  - A groove—often formed by 2X lumber
  - Forms a mechanical connection
- **Waterstop (depends)**
- **Reinforcing Dowels**
  - Structural connection
  - Transfers stresses to Fdn
Footing – excavated and reinforced
Waterstop, Keyway, & Wall Reinforcing Dowels
Fig. 10-15  Structural systems for various height office buildings.

Fig. 10-16  Shear lag in the windward and leeward sides of a framed tube.
Fig. 10-29 Typical layouts of high-rise buildings with shear wall-frame interaction.
Figure 7  Steel structural systems and the number of storeys
Casting a Concrete Wall
Formwork Components

Form “Facing” Material
- Spans between Support System
- Provides “Surface”/ Appearance
- Can be “faced” w/ Liner

Form Support System
- Intermediate Supports (Studs)
- Primary Supports (Walers)

Form Ties
- Hold the 2 “faces” together

Bracing (Positions/Aligns Form)
Support System Spanning Horizontal
Casting a Concrete Wall

Materials

- Stick Built of Lumber & Plywood
- Standardized prefabricated panels
- Prefabricated steel, fiberglass
- Insulated Concrete Forms

Choice Depends on:

- Number of uses, Irregularity of wall
- Wall finish & tie spacing,
- Availability & Cost
Stick Built Formwork

Built in-Place
• From Stock Mat’l
• Panelized sections

Materials: (often)
• Plywood
• 2x Lumber
• “Light” tie

Tie Spacing
• Close - regular

Uses
• Limited Reuses
• “Smaller” projects
• Irregular shapes
Panelized Systems

Built in-Place with:
• Panelized Sections
• Multiple Sizes
• Rent or Buy

Materials: (often)
• Higher Quality Facing Mat’l
• Metal “support system”
• Ties appropriate for the “system”

Tie Spacing
• Spaced @ or > “Stick built”

Uses
• Multiple Reuses
• Regular shapes
Panelized System with its Own Tires

Panelized System
Metal & Fiberglass

Often Built:
• Specifically for a project
• Examples:
  – Multi-level Shear Walls
  – Exposed / Architectural

Materials: (often)
• High Quality Facing Mat’l
• Higher “quality / strength” Ties

Tie Spacing
• Larger spacing

Uses
• Multiple Reuses
• Irregular or Regular shapes
Gang Forms

Assemble formwork into large sections

- Stick built, Panels, or any other system
- Minimizes labor, increases equipment requirements,
- Increases speed of construction
- Generally used only for large, similar & repeated wall elements
Gang Forms
Gang Forms
Insulating Concrete Forms
Casting A Concrete Wall (cont)

- Layout, Install one side, anchor, & brace
- Coat w/ Form Release
Reinforcing Installed
Reinforcing Installed
Casting A Concrete Wall (cont)

Install Form Ties

“Small diameter metal rods which hold the forms together (generally remain in the wall)
Alternative form ties

Pencil-rod

Battered wall form

Taper tie

Plate washer

Plate washer

She bolts

Inside threaded rod

Coil tie

Wire structure

Coils
Casting A Concrete Wall (cont)

- Install Embeds (if required)
- Install Bulkheads
- Inspect
- Erect second side
- Plumb & Brace
- Establish Pour Hgt.
Casting A Concrete Wall (cont)

- Pour Wall (Place, consolidate, smooth/level top of wall)
- Cure (including after stripping)
- Strip, break ties, point & patch if req’d
Relationship Between Formwork Design and Concrete Placement Rate

- Faster Pour Rate = Higher Stress on the Formwork
  - Facing material
  - Form support system
  - Form Ties

Hydration Process starts:
- Upon initial mixing of ingredients

Tall Walls
- Poured in lifts
- Take advantage of set
- Minimize form design loads

Liquid "Head"
Casting a Concrete Column

Column Footing

→ Usually not a strip footing
→ Column footing, pile cap, or caisson
Casting a Concrete Column (cont.)

Layout /Establish Column Location

Fabricate & Install Reinforcing
Reinforcing for a Round Column
“Offset” Reinforcing at the Top
Casting a Concrete Column (cont.)

- Install column form, plumb & brace
- Place & Cure Concrete (sim. to wall)
- Strip (& cure)
Pouring a Concrete Column
(Workers Tied off)
Column Forms

Material

Wood
  Field fabricated or
  Standardized panels

Steel

Plastic or Fiberglass

Waxed cardboard

Typically - Ties not required
  (Column Clamps)
Column Form Materials
Sonotube – Waxed Cardboard
Column Form Material
Stripped Column

Note the spiral formwork markings
Elevated Framing Systems

**One-Way System**
- Spans across parallel lines of support furnished by walls and/or beams

**Two-Way System**
- Spans supports running in both directions
One Way Elevated Framing Systems

One-Way Flat-Slab

- Limited Depth
- Limited Spans
- Shorter Story Heights
- Underside often exposed
One Way Elevated Framing Systems

One-Way Joist System

- Span Greater Distances, Less Dead Load
- Spaced ribs or joists w/ a thin top slab
- Utilizes pans (metal, plastic, fiberglass)
One Way Elevated Framing Systems

Wide-Module or Skip-Joist System
Elevated Framing Systems

**Two-Way Framing Systems**

- Often more economical than One-Way if:
  - Bay spacing (columns) square
- Can be accomplished with a flat slab, joists, beams, etc.
- Often associated with higher loadings
Two-Way Flat Slab

- Flat slab w/ reinforcing beams

- With, or w/o Capitals or drop panels
Two-Way Waffle Slab
Elevated Framing Systems
Factors to Consider

- Bay Spacing - Square or Irregular
- Span Length
- Loading
- Ceiling Treatment
- Lateral Stability
Elevated Slab Preparation

Prior to Formwork Construction

- Prepare, submit, & approve Engineered Shop Drawings
- FRPS supporting walls/columns
Elevated Slab Sequence

- Set Beam Bottoms (if required)
- Erect Beam Sides
- Form Slab
Beam Formwork

Form Beam Bottoms & Sides
Elevated Slab Sequence

- Install Deck formwork
- Install MPE sleeves, block outs, Cast in electrical roughin
- Clean Deck &
- Apply form release
Place Reinforcing

⇒ Beam reinforcing
⇒ Slab bottom &
⇒ Then top reinforcing
Elevated Slab Sequence (cont.)

Place, Consolidate, & Finish and Cure
Elevated Slab Sequence (cont.)

Allow Concrete to Achieve Stripping Strength

- Often 75% +/- of design strength
- Often use high-early - Time of the essence

Verify req’d strength prior to stripping

- Test to destruction one or more test cylinders
Elevated Slab Sequence (cont.)

- Strip Formwork & Re-shore
- Re-shore (May Extend 3-4 Floors Below)
- Re-shore Purpose - Support Construction Load
  Weight of the next Floor
Elevated Slab Sequence

The following group of photos shows the sequence for installation of a one-way elevated slab.

(Slab & Beam with Reinforcing & Post-Tensioning)
Columns Placed & Form Support (Scaffolding) Being Erected
Decking Support Beams Being Erected
Plywood Decking Being Erected
Plywood Decking and Beam Sides Being Erected
Plywood Decking and Beam Sides Being Erected
Plywood Decking & Beam Sides Erected
Deck Support System (Scaffolding)
Beam & Deck Reinforcing Installed
Post-Tensioning Installation
Post-Tensioning Installed
Post-Tensioning Complete and MPE Sleeves Installed
Slab Poured & Cured
Stripping & Post Shores
Stripping formwork
Formwork Stripped and Reshores Installed
Site Cast Post-tensioning Systems

- Can be used with any framing system
- Reduce member size and/or
- Extend span capacity
Innovations in Site Cast Concrete

- Lightweight Concrete and Admixtures
- Formwork Materials & Methods
- Lift-Slab
- Flying Formwork, Gang forms
- Slip Forms
- Tilt-Up
- Shotcrete
Lift-Slab

Cast slabs on the ground (“Stacked) & Jack into Place, and Anchored
Lift-slab

(Note the slab supports at the columns)
Flying Formwork

Floor Tables stacked and ready for installation
Slip Forms

“Ring” of formwork steadily pulled upward by jacking off the vertical reinforcing

USES:
“Tall”, Repetitive, Walls Shafts Stairwells Silos
Tilt-Up

Walls cast Horizontally & “Tilted” into Place

Commonly used in Warehouse, Distribution, Retail
The following group of photos shows the tilt-up sequence used for construction of a Home Depot
Panels formed and reinforced
Panels Formed and Reinforced
(Note the Inserts)
Inserts for Panel Braces, Steel Framing Anchorage, & Panel Lifting

Insert for Brace

Weld Plate for Joist Attachment

Insert for Lifting Bracket
Placement of Exterior Footing
Braces Installed Prior to ‘tilting-up’ the panels
Panel being lifted (tilted into place)
Panel being placed on shims set to proper elevation
Panels being braced
Panels braced
Panel grouted between footing & panel
Roof support structure anchored to panels
Subgrade prepared for panel structural connection to Slab-on-Grade
Slab-on-Grade perimeter poured to anchor the panel bottom.
Panels erected
Architectural Concrete

Concrete that is left exposed as finished interior or exterior surfaces.
Exposed ‘Architectural’ Concrete at the University of Iowa
Exposed ‘Architectural’ Concrete at the University of Iowa
Exposed ‘Architectural’ Concrete
(Note the rough finish)
Architectural Concrete Finishes

- Exposed Aggregate
  - clean off paste
  - & expose aggregate

- Key
  - Aggregate choice
  - Mix Placement
Architectural Concrete Finishes

- Mechanically remove the paste
  - Sand Blast
  - Bushhammer
Architectural Concrete Finishes

- Liners & Form mat’ls
  - Multiple # of Finishes

Form Liner & Bush-hammer
Architectural Concrete with “Bushhammered” Finish
Architectural Concrete with “Bushhammered” Finish
Simulated Stone Form Liner
Considerations / Challenges

Rustication Location

Form Tie Location
Form Tie Holes
Considerations / Challenges

Rusted Bar Supports
Designing Economically

Of three elements - conc., reinf., formwork -
- Formwork is generally the most expensive element
- Formwork - high % of labor

Economies - simplification & standardization
- Identical bay spacing
- Flat plate - when possible
- Standardize column & beam sizes
Fire resistant

- Assuming adequate re-steel coverage
- Most uses - Unlimited Height & Area

Resistance to lateral loading

- Rigid joints