13. Concrete Construction

14. Sitecast Concrete

15. Precast Concrete
Chapter 13
Concrete Construction

Hoover Dam
CONCRETE

Happy marriage between concrete and steel – rcc!

LIFE

Happy marriage between loving couple – sweet life!
CONCRETE

Cancer of Concrete
– Corrosion induced by moisture, oxygen and salts ingressed into concrete

LIFE

Cancer in Humans –
Also caused by inhaling cancer sticks for fun first and then by force of habit – can’t kick it!
A philosophy professor stood before his class and had some items in front of him.

He picked up an empty mayonnaise jar and proceeded to fill it with gravel. He then asked the students if the jar was full. They agreed that it was.

So the professor then picked up a box of sand and poured them into the jar. He shook the jar lightly. The sand, of course, rolled into the open spaces between the rocks. He then asked the students again if the jar was full.

They agreed it was. The students laughed. The professor picked up a box of cement and poured it into the jar. Of course, the cement filled up everything else.
"Now," said the professor, "I want you to recognize that this is your life. The gravels are the important things - your family, your partner, your health, your children - things that if everything else was lost and only they remained, your life would still be full. The sand are the other things that matter like your job, your house, your car. The cement is everything else, the small stuff.

"If you put the sand and cement into the jar first, there is no room for the pebbles or the rocks. The same goes for your life. If you spend all your time and energy on the small stuff, you will never have room for the things that are important to you. Pay attention to the things that are critical to your happiness. Take care of the gravels first - the things that really matter. Set your priorities. The rest is just sand."
But then a student then took the jar which the other students and the professor agreed was full, and proceeded to pour in a glass of fruit juice. Of course the juice filled the remaining spaces within the jar making the jar truly full.

No matter how full your life is, there is always room for fun!
Concrete History

1824; Aspdin patented Portland Cement - named after English Portland limestone

1850s; reinforced concrete (late 1900s applied to building construction)

1920s; prestressed concrete
Concrete

Rocklike Material

Ingredients

- Portland Cement
- Coarse Aggregate
- Fine Aggregate
- Water
- Admixtures (optional)
Concrete – Proportion Vs Cost

<table>
<thead>
<tr>
<th>Volume</th>
<th>Cement</th>
<th>Water</th>
<th>Fine Aggregate</th>
<th>Coarse Aggregate</th>
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<tr>
<td>10%</td>
<td>CEMENT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15%</td>
<td></td>
<td>WATER</td>
<td></td>
<td></td>
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<tr>
<td>25%</td>
<td></td>
<td></td>
<td>FINE AGGREGATE</td>
<td></td>
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<tr>
<td>59%</td>
<td></td>
<td></td>
<td></td>
<td>COARSE AGGREGATE</td>
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<table>
<thead>
<tr>
<th>Cost</th>
<th>Cement</th>
<th>Fine Aggregate</th>
<th>Coarse Aggregate</th>
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<tbody>
<tr>
<td>70%</td>
<td>CEMENT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10%</td>
<td></td>
<td>FINE AGGREGATE</td>
<td></td>
</tr>
<tr>
<td>20%</td>
<td></td>
<td>COARSE AGGREGATE</td>
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Concrete Properties

- Versatile
- Pliable when mixed
- Strong & Durable
- Does not Rust or Rot
- Does Not Need a Coating
- Resists Fire
Portland Cement

- **Generic Term**
- **Man Made Product**
- **Fine gray powder**
- **Glue (Binder)**
- **Curing - Hydration (a chemical process)**
Cement Uses

- Site Cast Concrete
- Concrete Block (CMU)
- Precast Concrete Products
- Mortar
Cement Types

- **Type I**: Normal (most applications)
- **Type II & V**: Moderate and High Sulfate Resistance
- **Type III**: High Early Strength
- **Type IV**: Low Heat of Hydration
- **Type 1A, IIA, IIIA**: Air Entrained
Cements in India

- 33 grade ordinary Portland cement
- 43 grade (OPC)
- 53 grade (OPC)
- Rapid hardening Portland cement
- Portland slag cement
- Portland Pozzolana Cement
- Hydrophobic cement
- Low Heat Portland cement
- Suphate Resisting Portland cement
Aggregates

- Approx. 3/4 volume
- Must be:
  - Clean, Strong
  - Resistant to freeze-thaw
  - Chemically stable
  - Properly Graded
    - mix distribution & installation space
- ASTM laboratory tests

Taking Samples for Testing
Lightweight Aggregates

- Substituted for sand / crushed stone

- **Structural Lightweight**
  - Density approx. 80% of reg. concrete
  - Purpose: Reduces dead weight
  - Often made from shales

- **Nonstructural Lightweight**
  - Density 20-25% of regular weight
  - Purpose: Insulating material - under roofs
Lightweight Aggregates

If lightweight aggregates provide for lower dead weight of the structure, why aren’t they always used?

- Generally cost more
- Mix production / aggregate H2O control
- Placement considerations / Mix design
Air-Entraining

- Causes microscopic air bubbles in concrete
- Usually 2-8% of volume

Properties:
- Improved workability
- Increased freeze-thaw resistance

Common uses: Paving & Exposed concrete
Admixtures
used to alter concrete properties

- Air-entraining admixtures
- Water-reducing admixtures
- High range water-reducers - superplasticizers
- Accelerating & retarding admixtures
- Fly ash
- Workability agents
- Fibrous admixtures
- Coloring agents
Qualities Desired Depend on

Intended Use / Design considerations:
- Structural Element; Strength & Stiffness
- Floor Slabs; Smoothness & Abrasion Resistance
- Exterior Paving; Smoothness, Abrasion Resistance, & Weather Resistance
- Tanks & Dams; Water-tightness .......

Placement conditions
Requirements for Quality Concrete

- Proper Selection of Materials
- Correct proportioning, mixing, & material transport
- Careful placing and consolidation
- Skillful finishing
- Adequate curing
Concrete Mix Design

Science
Establishes Materials & Proportions
A process to establish the desired Workability of wet concrete
Physical properties of cured concrete
Acceptable Cost
Coordinated / Approved by Engineer
Concrete Compressive Strength

Specified by 28 Day Compressive Strength

- Measured in pounds of compressive strength per square inch (psi)

Primarily Determined By:

- Amount of Cement
- Water-Cement Ratio
- Other influencing factors:
  - Admixture(s)
  - Aggregate Selection & Gradation

Strength Ranges: 2000 - 22,000+ psi
Effect of Water-Cement Ratio
If a low water cement ratio is desirable for quality concrete, why would one ever want to add excess water?

Concrete with High W/C ratio is easier to place.

Balance; workability with desired qualities

Often accomplished w/ admixtures
Concrete Measurement, Transport & Testing

- Unit of Measure - Cubic Yard (27 cf)
- Plant Certification
- Transport (transit mixed)
- Slump Test
- Test Cylinders
- “In Place” Coring, if Required
Batch Plants
Transit Mix Truck (Ready-Mix Truck)
Sample collected

Slump Cone Filled

Cone Removed and Concrete Allowed to ‘Slump’

Slump Measured
Measuring the Slump
Test Cylinders Filled with a Sampling of the Concrete Mix
Test Cylinders Curing and then strength tested (upper right)
## Building Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Tension</th>
<th>Compression</th>
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</thead>
<tbody>
<tr>
<td>Wood</td>
<td>700 psi</td>
<td>1,100 psi</td>
</tr>
<tr>
<td>Brick</td>
<td>0 psi</td>
<td>250 psi</td>
</tr>
<tr>
<td>Steel</td>
<td>22,000 psi</td>
<td>22,000 psi</td>
</tr>
<tr>
<td>Concrete</td>
<td>0 psi</td>
<td>2,000 to 22,000+</td>
</tr>
</tbody>
</table>
Concrete Placement

- Not a Liquid - an *Unstable* mixture
  - Will segregate if handled improperly
- Deposit in Formwork (methods)
  - Direct From the Truck
  - Bucket
  - Pump
- Consolidate Mix
- Apply Finish (if Required)
Placement Today - Direct From the Transit Mixer, or
Concrete Bucket being Filled
Placement of a Wall with a Crane & Concrete Bucket
Placement with a Concrete Pump
Placement with a Concrete Pump
Placement with a Conveyor
Concrete Segregation

- Segregation - Mix “Separates”
- Results - Non-uniformity & Unsatisfactory properties
- Common Causes
  - Excessive Vibration
  - Dropping From Excessive Heights
  - Moving Concrete Horizontally
Improperly Consolidated - “Honeycomb”
Improperly consolidated Concrete
Improperly consolidated Concrete
Segregation at the bottom of the pour
(also note the trash at the bottom of the wall)
Extensive Reinforcing *Can* Make Placement & Consolidation Difficult
“Cold” Joint

First lift hardened prior to the placement of the 2nd lift
Concrete Curing

**Must be kept Moist** -

Moisture Needed for:
Hydration
(Development of Strength)
Methods to Keep Moist

Formwork

Application of H₂O

Covering

Curing Compound
Curing - Temperature Extremes

**Hot Weather**
- Premature Drying / Accelerated Curing
- Ice Substituted for Water
- Early or Late Placement Times

**Cold Weather**
- Hydration proceeds much slower
- Risk of Freezing
- Blankets (Cover), Temporary Heat
Underside of Slab being protected during cold weather
Top of Slab being protected during cold weather
Concrete Formwork

- Temporary Structure
- Shapes and supports wet concrete
- A negative of the final concrete shape
- Must be designed to support:
  - Concrete & Reinforcing &
  - Construction Loading
  - w/o excessive deflection and
  - Be easily stripped once concrete is cured
Concrete Formwork

Quality of the finished concrete surface

- Quality of the form material

- Structural Strength (including the form tie and framing spacing)
Formwork Materials

TYPES:
- Wood
- Metal
- Plastic/Fiberglass
- Cardboard

Wood - Panelized

Steel Wall Form

Round Steel Column Form
Concrete Reinforcing

Concrete - No Useful Tensile Strength

Reinforcing Steel - Tensile Strength

- Similar Coefficient of thermal expansion
- Chemical Compatibility
- Adhesion Of Concrete To Steel

Theory of Steel Location

“Place reinforcing steel where the concrete is in tension”
Reinforcing Steel

Sizes
Eleven Standard Diameters
3, 4, 5, 6, 7, 8, 9, 10, 11, 14, 18
Number refers to 1/8ths of an inch

Grades
40, 50, 60

Steel Yield Strength (in thousands)
India : Fe 250, Fe 415 & Fe 500 MPa
Reinforcing Markings

Why put “markings” on the reinforcing steel???
Reinforcing Support

Chairs or bolsters

Properly position the steel
Reinforcing Special Coatings

Galvanized or Epoxy Coated
Exposure to Salts or Sea Water

Epoxy Coating
Reinforcing Steel Manufacture

- Process - ASTM Standards
- Hot-Rolled
- Round Cross Section
- Surface Ribs - Better Bonding
- Standard Lengths - 60 ft.
- Shipped to Fabrication Shops
Welded Wire Fabric (WWF)

- **Type of Reinforcing**
- Grid of “wires” spaced 2-12 inches apart
- Specified by wire gauge and spacing
- **Typical Use** - Horizontal Surfaces
- Comes in Mats or Rolls
- **Advantage** - Labor Savings
WWF – Sheet (mat)
Reinforcing Fabrication

- Shop Drawing Preparation
- Shop Drawing Review & Approval
- Cut, bend, bundle, & tag
- Ship to jobsite
Reinforcing Installation

- Hoist bundles to desired location
- Place and Secure (tie)
- Splicing Purpose
  - Transfer Loads
- Splicing Methods
  - Overlap a specified # of bar diameters
  - End to end; weld or mechanical splice
Wall Reinforcing being secured with Wire Ties
Why use Mechanical Splicing devices?
Long Bridge Pier Requiring Reinforcing Splicing
Staggered Mechanical Splices on Bridge Pier
Reinforcing a Simple Concrete Beam

- Location of Forces
- Purpose of Hooks at the end of reinforcing
Reinforcing Stirrups

- Position Beam Reinforcing
- Resist Diagonal Forces / Resist Cracking

Hooks transfer the tensile forces that remain in the steel to the concrete at the ends of the beam.

Stirrups carry the diagonal tension forces near the ends of the beam.

Bottom steel bars carry the tensile forces.
Reinforcing a Continuous Concrete Beam

- Most Beams are not simple span beams
- Location of Tension Forces Changes
  - Midspan - Bottom in Tension
  - At Beam Supports - Top in Tension
Slab Reinforcing

- "Broad" beams
- Supported by columns, beams, walls, or a combination
- Often have shrinkage / temperature steel
- One-Way Slabs
- Two-Way Slabs
Reinforcing Concrete Columns

**Vertical Bars**
- Carry Compressive & Tension Loads
- Bar Configuration - Multi-story

**Ties** - Small bars wrapped around the vertical bars
- Help prevent buckling
- Circular or Rectangular
- Column Ties or
- Column Spirals

**Installation**
Prefabrication

Cage Rebar ‘Offset’
Conventionally Reinforced Concrete

- Reinforced Concrete Members
  - Part of the member in compression
  - Part of the member in tension
- Over half of the concrete
  - Not carrying any load, it’s: Holding reinforcing in position & providing protective cover
Prestressing

Theory; “Place all the concrete of the member in compression” (take advantage of concrete’s compressive strength of the entire member)

Advantages

- Increase the load carrying capacity
- Increase span length, or
- Reduce the member’s size

Under loading, the prestressed beam becomes flatter, but all the concrete still acts in compression, and no cracks appear.

When a concrete beam is prestressed, all the concrete acts in compression. The off-center location of the prestressing steel causes a camber in the beam.
Pretensioning

- Prior to concrete placement
- Generally performed at a plant - WHY???

1. The first step in pretensioning is to stretch the steel prestressing strands tightly across the casting bed.

2. Concrete is cast around the stretched strands and cured. The concrete bonds to the strands.

3. When the strands are cut, the concrete goes into compression and the beam takes on a camber.
Prestressing - Posttensioning

- Cables positioned prior to concrete placement
- Stressed after concrete placement (& curing)
- Generally performed at the jobsite

1. In posttensioning, the concrete is not allowed to bond to the steel strands during curing

2. After the concrete has cured, the strands are tensioned with a hydraulic jack and anchored to the ends of the beam. If the strands are draped, as shown here, higher structural efficiency is possible than with straight strands
Posttensioning Installation

Install (position) unstressed steel strands
- Often Draped
- Positioned to follow tensile forces

Place and Cure Concrete

Stress steel stands w/ hydraulic jack
- From one or both ends of the stand

Anchor the ends of the stands

Trim cables (& patch)
Post-Tension Cable Strands or Coils

Coated / Sheath to prevent bonding and Precut to Length
Plastic-sheathed to prevent bonding to concrete
(note the cable is lubricated)
Draped to be positioned in “Tension” area of slab
Used in conjunction with conventional reinforcing
Cables can be ‘Bundled’
Cable attachment to Edge Form
Elongated Strands after Stressing (Jacking)
Large Conduits for Placement of Post Tensioning Cables on a Bridge