What are the basic questions?

- What “materials” are used to make rebar?
- How is rebar made?
- How is rebar used?
  - ASTM Specs
  - Typical framing systems
The following presentation has been aired on Public Television stations nationwide.
Production of Reinforcing Bars

Today’s Reinforcing Steel is 100% Recycled
Fabrication
New Techniques and Materials

- Couplers
- End Anchors
- Corrosion Protection
- High Strength Reinforcing Grade 100 & 120
Specifications
Reinforcing Steel Specifications

Bar Specifications
- A615 – Plain carbon steel
- A706 – Low alloy steel
- A1035 – Low carbon/chromium steel

Coated & Corrosion Resistant Steel
- A775 – Epoxy coated rebar
- A767 – Galvanized rebar
- A1055 – Galvanized & Epoxy coated
- A955 – Stainless steel
**Reinforcing Steel Specifications**

Metrification ........ or not ?

- ASTM Specifications in inch-pound units
  - Soft SI conversations are shown for reference
- Majority of reinforcing steel marked in soft SI
- Industry talks in inch-pound units
- Design community works in inch-pound units
- Construction is performed in inch-pound units
What is bar size?

- Inch-pound bar size designations represent 1/8” inch fractions

<table>
<thead>
<tr>
<th>Inch-Pound Units</th>
<th>SI Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bar Designation</td>
<td>Nominal Diameter</td>
</tr>
<tr>
<td>#3</td>
<td>3/8”</td>
</tr>
<tr>
<td>#4</td>
<td>4/8”</td>
</tr>
<tr>
<td>#5</td>
<td>5/8”</td>
</tr>
<tr>
<td>#6</td>
<td>6/8”</td>
</tr>
<tr>
<td>#7</td>
<td>7/8”</td>
</tr>
<tr>
<td>#8</td>
<td>8/8”</td>
</tr>
<tr>
<td>......</td>
<td>#9, 10, 11, 14, 18</td>
</tr>
</tbody>
</table>
## Reinforcing Steel Specifications

<table>
<thead>
<tr>
<th>ASTM A615</th>
<th>Grade 40 (Grade 280)</th>
<th>Grade 60 (Grade 420)</th>
<th>Grade 75 (Grade 520)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Yield</td>
<td>40,000 (280)</td>
<td>60,000 (420)</td>
<td>75,000 (520)</td>
</tr>
<tr>
<td>Strength, psi (MPa)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum Tensile</td>
<td>60,000 (420)</td>
<td>90,000 (620)</td>
<td>100,000 (690)</td>
</tr>
<tr>
<td>Strength, psi (MPa)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bar Designation</td>
<td>Minimum Percent Elongation in 8”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#3</td>
<td>11</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>#4, #5</td>
<td>12</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>#6</td>
<td>12</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>#7, #8</td>
<td>-</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>#9, #10, #11</td>
<td>-</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>#14, #18</td>
<td>-</td>
<td>7</td>
<td>6</td>
</tr>
</tbody>
</table>
## Reinforcing Steel Specifications

<table>
<thead>
<tr>
<th>ASTM A706</th>
<th>Grade 60 (Grade 420)</th>
<th>Grade 80 (Grade 555)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Yield Strength, psi (MPa)</td>
<td>60,000 (420)</td>
<td>80,000 (555)</td>
</tr>
<tr>
<td>Maximum Yield Strength, psi (MPa)</td>
<td>78,000 (540)</td>
<td>100,000 (690)</td>
</tr>
<tr>
<td>Minimum Tensile Strength, psi (MPa)</td>
<td>80,000* (550)</td>
<td>105,000* (725)</td>
</tr>
</tbody>
</table>

* Tensile strength shall not be less than 1.25 times the actual yield strength

<table>
<thead>
<tr>
<th>Bar Designation</th>
<th>Minimum Percent Elongation in 8”</th>
</tr>
</thead>
<tbody>
<tr>
<td>#3, #4, #5, #6</td>
<td>14</td>
</tr>
<tr>
<td>#7, #8, #9, #10, #11</td>
<td>12</td>
</tr>
<tr>
<td>#14, #18</td>
<td>10</td>
</tr>
</tbody>
</table>

Bar Designation: Minimum Percent Elongation in 8”

- 14: #3, #4, #5, #6
- 12: #7, #8, #9, #10, #11, #14, #18
- 10: #14, #18
Reinforcing Steel Specifications

- Tensile Requirements
- Bending Requirements
  - Withstand bending without cracking
- Permissible Variation in Weight
  - At least 94% of nominal weight
- Deformations
  - Orientation, size, spacing, height
- Marking
  - Mill, bar size, type, grade
- Finish
Time for a Field Trip!
Manual of Standard Practice

- Material Specifications for Reinforcing Bars
- Welded Wire Fabric (WWF)
- Bar Supports
- Notes to Architects/Engineers
- Estimating Reinforcing Materials
- Detailing Reinforcing Materials
- Fabrication of Reinforcing Materials
- Placing Reinforcing Bars
- Contract Components
- Concrete Joist Construction
- APPENDICES

First published - 1927
Reinforcing Bar Markings

- Main Ribs
- Letter or Symbol for Producing Mill
- Bar Size #36
- Type Steel:
  - S for Billet-Steel (A615M)
  - I for Rail-Steel (A995M)
  - R for Rail-Steel (A985M)
  - A for Axle-Steel (A985M)
  - W for Low-Alloy Steel (A706M)
- Grade Mark
- Grade Line (One line only)

*Bars marked with an S and W meet both A615 and A706

GRADE 420
Tying Reinforcing Steel

• Tying does not add to the strength of the finished structure
• Specifications typically require that a specified number of intersections by tied
• Criteria for tying:

“The mats, cages, or bars will not displace during casting, screeding, and finishing operations”
“At the time of placement, all reinforcing bars shall be free of mud, oil, or other deleterious materials.”
“Reinforcing bars with rust, mill scale, or a combination of both should be considered as satisfactory, provided that the minimum dimensions, weight, and height of deformations of a hand-wire-brushed specimen are not less than the applicable ASTM specification requirements”
Field Bending of Reinforcing Steel

- To correct bars partially embedded in concrete due to incorrect fabrication, incorrect placement, accidental misalignment or design change

- Not field fabrication

- In-situ bending is prohibited unless shown on drawings or specifically authorized by the engineer
Field Bending of Reinforcing Steel

- Limited to bar size #11 and smaller
- Bend diameters must conform to ACI 318
- Bar sizes #3 through #5 and if were previously unbent, can be bent cold
- Bar sizes #3 through #5 and if were previously bent, must be heated prior to straightening and re-bending
- Bar sizes #6 through #11 must be heated prior to straightening and/or bending
## Field Bending of Reinforcing Steel

<table>
<thead>
<tr>
<th>Bending Condition</th>
<th>Bar Size</th>
<th>Reduction in Yield Strength</th>
<th>Reduction in Ultimate Tensile Strength</th>
<th>Reduction in Elongation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold</td>
<td>#3 &amp; #4</td>
<td>-</td>
<td>-</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>#5</td>
<td>5%</td>
<td>-</td>
<td>30%</td>
</tr>
<tr>
<td>Hot</td>
<td>All Sizes</td>
<td>10%</td>
<td>10%</td>
<td>20%</td>
</tr>
</tbody>
</table>

Source: Concrete International January 1992 - Khosrow Babaei and Neil M. Hawkins
### Field Bending of Reinforcing Steel

<table>
<thead>
<tr>
<th>Bar Size</th>
<th>Minimum Temperature</th>
<th>Maximum Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>#3 &amp; #4</td>
<td>1,200 F</td>
<td>1,250 F</td>
</tr>
<tr>
<td>#5 &amp; #6</td>
<td>1,350 F</td>
<td>1,400 F</td>
</tr>
<tr>
<td>#7, #8 &amp; #9</td>
<td>1,400 F</td>
<td>1,450 F</td>
</tr>
<tr>
<td>#10 &amp; #11</td>
<td>1,450 F</td>
<td>1,500 F</td>
</tr>
</tbody>
</table>

*Source: Concrete International January 1992 - Khosrow Babaei and Neil M. Hawkins*
Field Cutting of Reinforcing Steel

- Bolt cutters for bar sizes #10 to #16
- Abrasive saw on any bar size
- Cutting torch on any bar size
  - Tests indicate no more than 3/8” from end of bar is affected by heat
- Flame cutting of epoxy-coated bars will damage the coating, proper repair is necessary
Epoxy Coated Reinforcing Bars

- Nylon slings or other padded material to lift bars
- Lift and set bars into place
  - Bars are not to be dragged into place
- Minimize walking on bars
  - Set up a walkway
- Bars to be visually inspected for damage after placement
Splicing Reinforcing Steel
Reinforcing Steel Splicing Options

- Lap Splices
- Welded Splices
- Mechanical Splices
  - Deformation Dependent
  - Non-Deformation Dependent
Deformation Dependent

• Bolted
Bolt heads shear off when proper values are reached.
Non-Deformation Dependent

- Tapered Thread
Framing System
Constructability

• Efficiency in design and construction
• New tools and techniques
Economical Concrete Construction

- Formwork
- Concrete
- Reinforcement
Economical Concrete Construction

Typical Conventionally Reinforced Cast-In-Place Concrete Frame Costs

- Formwork: 50%
- Concrete: 30%
- Reinforcing: 20%
Economical Concrete Construction

Minimizing material quantities can lead to “inefficient” designs.
Economical Concrete Construction

Designing to minimize quantities of concrete and reinforcement leads to false economy.
Economical Concrete Construction

Optimizing design and utilization of formwork holds the key to true economy.
Economical Concrete Construction

Keep Formwork

1. Simple

2. Repetitious

3. Standard
   • Form sizes
   • Lumber dimensions
Economical Concrete Construction

Material savings does not offset forming costs
Column Considerations

- Make column same size throughout
  - Vary concrete strength
  - Vary percentage of reinforcement
- Use fewer, larger bars
- Utilize mechanical couplers
- Consider Grade 75 (Grade 80) reinforcement
Column Considerations

- Space columns uniformly
- Use fewest column sizes
- When column size must change, reduce one dimension at a time
Beam - Column Intersections

Plan View

Isometric
Floor Framing Systems

Make beams wider than columns

Size beams and joists the same depth
Floor Framing Systems

- Select one floor framing system
- Use shallowest system
- For most buildings floor framing costs dominate
- Vertical element costs become more significant in taller buildings or in moderate to strong seismic zones
Two-Way Flat Plate

Plate Range:
12 to 25 ft.

Plate Depth:
6 to 9 in.
Two-Way Flat Plate

- Most economical short span structural system
- Minimizes floor-to-floor height
- Shortest construction time with least field labor
- Simplest formwork and reinforcing steel layout
- Greatest flexibility in layout of columns, partitions
Two-Way Flat Plate with Drop Panels

Plate Range: 20 to 35 ft.

Plate Depth: 7 to 12 in.
Two-Way Flat Plate with Drop Panels

• Very economical system for relatively square bays and multiple bays in each direction
• Uses smaller columns than Two-Way Flat Plate with longer spans
• Provides uniform clear space below slab
• Provides flexibility in layout of columns, partitions
One-Way Slab and Beam

**Beam Range:**
60 to 65 ft.

**Slab Spans:**
18 to 22 ft.

**Construction Depth:**
30 to 36 in.
One-Way Slab and Beam

- Good for concentrated and heavy load areas
- Basis for more complex framing systems
- Commonly used for parking structures and elevator and stair areas
- Excellent vibration characteristics
- Popular for use in commercial buildings
- Adaptable to custom forming situations
Standard Beams and Joist

Beam Range:
Up to 30 ft.

Joist Spacing:
24 to 36 in.

Pan Depth:
8 to 20 in.
Standard Beams and Joist

- Provides depth for stiffness and increased load bearing capacity
- Efficient use of concrete and reinforcing materials
- Standard reusable forms readily removed and re-erected
- Accommodates floor penetrations and mechanical systems
Building Value and Efficiency
Building Value and Efficiency

• Life cycle cost, not project or initial cost
• Contribution of concrete to other systems
• Sustainability and concrete construction
• Scalable, adaptable and expandable to accommodate future needs
Schedule

Accelerated Start

• Readily available materials
• Local materials
• Staging and transportation logistics are minimal
Schedule

Early Completion

- On-site adaptability
- Multi-track construction
- Concrete inherencies
**Schedule**

**Multi-Track Construction**

- Concurrent work due to concrete inherencies
- Multiple trades working off the critical path
- Jobsite safety is the key
Cash Flow

Low Upfront Cost

- Cash flow is back-end loaded
- Local materials
- Reduced lead times
- Minimal staging
Cash Flow

Floor-to-Floor

- Building for space, not volume
- Height restrictions
- Urban footprint
- Reduction in vertical material utilization and costs
Cash Flow

Operating Costs

• Reduced HVAC costs
• Low maintenance costs
• Lower insurance premiums
Inherent Systems

Unique Properties

• More than just initial frame cost
• Elimination of material and labor expenses
• Cost and time savings
Inherent Systems

Thermal Mass

- Limited fluctuations in temperature
- Savings in energy and cost
Inherent Systems

Fire Resistance

• Concrete is non combustible
• No fireproofing required
• Connections are protected
• Reduced insurance premiums
Inherent Systems

Sensitive Structure

• Vibration and heat sensitive equipment
  • Research Labs
  • Hospitals
  • Computer data facilities
Flexibility

Design

• Long open spans
• Shear wall options
• Hybrid systems with post tensioning for additional span length
Flexibility

Future Growth

- Built-in or expandable
- Large increases in initial capacity for very minimal cost
Flexibility

Adaptability

• Changes happen
• Conflicts
• Form and pour
Aesthetics

Visual Statement

- Innovation
- Freeform
- Creativity
- Color & texture
Reinforced Concrete Construction

- Cost effective
- Durable
- Safe
- Sustainable
- Adaptable
- Aesthetic
What materials are used for producing Reinforcing Bars’?

- Metal scrap from automobiles, washers, refrigerators, dryers
Assessment of Learning
(Question 1)

What is the minimum head size for “Headed Reinforcing Bars”?

• The gross area of the head shall be a minimum of 5 times the nominal bar diameter

• i.e. 4 times of nominal bar diameter of net embedment surface area
What is the minimum yield strength requirement for Grade 60 reinforcing steel?

- “60” refers to the minimum yield strength, so a Grade 60 reinforcing bar has a minimum yield strength of 60,000 PSI (60 KSI)
Is it permissible to re-bend a #8 bar partially embedded in concrete?

- Yes
- Must be heated to between 1,400 F and 1,450 F
- Doing so will lower both the yield and UTS by 10% and result in a 20% reduction in elongation
Which component of cast-in-place concrete makes the largest contribution to onsite construction costs?

- Formwork. An optimized design will minimize formwork costs.