Thermobile – Nitinol Toy
History

The Material
Steel

Industrialized
Systems in
Steel

Composite
Columns

Longer
Spans in
Steel

Fireproofing
of Steel
Framing

Details of
Framing

The
Construction
Process
Chapter 11
Steel Frame Construction
Steel Framing Characteristics

**Advantages**
- Light in proportion to its strength
- Strong & Stiff (Span, Vertical towers)
- Quick to erect
- Precise & predictable material
- Recyclable

**Disadvantages**
- Tendency to corrode - depending on the environment
- High Temperatures (fires) - Loss of strength/deformation
Cast & Wrought Iron ⇒ Steel

**Cast Iron** (till mid 1800s)
- First structure late 1700s (Bridge in England - still in use)
- Brittle, difficult to work with

**Mid 1800s -**
- manufacturing processes developed to inexpensively produce steel
Eiffel Tower
Completed 1889

- 18,000 pieces of wrought iron ("steel grade")
- 2,500,000 rivets

  4 men to install a rivet;
  one to heat the rivet, one to hold it,
  one to shape the head, one w/ sledgehammer

Construction time - Fdn - 5mo, Tower 21mo.
Steel

- Any range of alloys or iron with less than 2% carbon
- Carbon content (too much - brittle CI; too little - soft)
- Ordinary structural steel (mild steel) <1%

Strength
- Yield strength
- PSI
  - Typically - 36,000psi to 65,000psi +
- 250 MPa

Unit of Measure - Tons
Steel Production

Produced at a Mill (Structural or Steel Mill)

Mini-Mills; produce most structural steel

Production of Structural Shapes:

- Hot Steel passes through a series of rollers
  - I.E. Hot Rolled
- Cut to Length & Cooled
- Numerous Standard shapes (sizes)
Steel Alloys

- **Mild Structural Steel (Grade 50) - widely used**
  - Grade 50: 50,000 psi yield strength

- **Higher strengths** (becoming more common)

- **Weathering Steels**
  - Weathers forming a protective coating
  - Painting / protective coating not required

- **Galvanized Steels** (protective coating)
Oxidized Coating of Weathering Steel

Building with Weathering Steel
Structural Shapes
Wide Flange

- **Size Range**
  - Depth: 4” to 40”
  - Weight: 9#/ft to 730#/ft

- **Uses - Beams & Columns**

- **Proportions - Shape**
  - Tall & Narrow - Beams
  - Square - Columns & Piles
Beams
Tall & Narrow

Piles
Square
Wide Flange Designations

W 12 X 26

W = Wide Flange Designation

12 = Nominal Depth (inches)

26 = Weight (lbs.) per foot

W12x26 - 12’-0” long weights:
12’ x 26#/lf = 312#
Steel Angles

USES

- Short beams supporting light loads
- EX - Lintels
- Connectors
- Veneer / Skin Support
- Edge support (edge angle)
- Diagonal bracing
Steel Angle Designations

L 4 X 4 X 1/2

L = Angle Designation
4 X 4 = Size of the legs (inches)
1/2 = Thickness of the legs (inches)

NOTE: Legs can be equal or unequal
Channels (C Shaped)

Uses

Truss members, bracing, lintels, etc.

Designations

C 9 X 13.4

- C = Channel Designation
- 9 = Nominal Depth (inches)
- 13.4 = Weight / ft. (lbs.)
Open Web Steel Joists

Mass produced steel trusses

Common Uses
- Floor Support
- Roof Support

Joist Spacing Depends on:
- Load
- Span capability of deck
- Typically 2 to 10 feet

Spans; K-series (up to 60’), LH(Longspan) to 96’, DLH(Deep Longspan) to 144’
Joist used for floor support
Bottom Chord Anchored
Joist

Joist Seat
Joist Seat Welded to Support Beam
Steel Trusses

- Heavier Members
- Can Carry Larger Loads &
- Span Greater Distances
- Typically Specially Fabricated

Truss to Span a Hotel Atrium

Heavy Trusses for the Seattle Stadium
Cold Formed Steel

- Formed by rolling or bending sheet steel
- Light Steel Framing; C-Shaped - Most Common; Frequently used for partition & exterior wall framing

- Metal Decking
Joining Steel Members

Rivet

Bolt

Weld
Rivets

Installation Process

• Heat Rivet
• Insert in Hole
• “Hammer” to produce a second head
• Cool - Expands to form a tight joint

Seldom Used any more

• Labor Intensive
• Less Expensive Alternatives
Bolts

Types:

- Carbon Steel Bolts
  - Similar to ordinary machine bolts
  - Lower Strength, low load/shear connectors

- High Strength Bolts
  - Heat treated for greater strength
  - Higher shear resistance
  - Can also be used in Friction Connections
  - Can be used with or without washers
Installation - Bolts

- Drift pins
- Temporary Bolts
- Tighten Bolts
High Strength Bolts
Friction Connections

- Load transferred between members by friction
- Members clamped together
- Must be Tightened consistently and reliably
Verification of Required Tension

- **Turn of the Nut Method**
  - Tightened until snug, then turned an additional fraction of a turn

- **Tension Control Bolts**
  - Correct tension is reached when end breaks off

- **Load Indicator Washers or Direct Tension Indicators**
Tension Control Bolts

- Wrench grips both the nut & bolt
- When required torch reached
  ➔ End twists off
  ➔ Ease of installation & consistency
Load Indicator Washers

- Washer with Protrusions (Gap)

- Protrusions flatten as Bolt is tightened
- Visually inspected to ensure that protrusions are flat (gap closed)
Load Indicator Washers

Load Indicator Washers with a Visible Dye that squirts out when the washer has sufficiently flattened.
Welding

**Welding vs Bolting** (Both can achieve similar performance)

- **Welding**
  - labor intensive (especially in the field)
  - Requires a highly skilled/certified craftsman
  - Verification of Installed Quality - inspection, X-ray, etc

- **Bolting** - Quick, easy, and less labor intensive & skill req’d

- **Not uncommon to see both**
  - Welded fabrications in the shop
  - Bolted in the field
Steel Framing Connections

**Framed Connections**
- Bolts only in web, not the flanges
- Transmits only shear
- Not bending moment
- Accomplished w/
  - clip angles & bolts/welds

**Moment Connections**
- Transmit shear & moment
- Flanges must be connected
- Bolt/Weld Flanges
- May require column stiffeners
Framed Connection
Clip angles welded to column, bolted to beam
Bolted Connection
Bolted Column Splice
Moment Connection
Options for Building “Structure” Lateral Resistance

• Diagonal Bracing (or eccentric bracing)
• Shear Panels (Walls)
• Moment Connections
• Combination (common)

Most Common

Bracing and/or Shear Panels with “Framed” Connections (bolted - shear)
Concrete Moment Connections

Stairwell Shear Panels

Core Shear Panels w/ Steel Frame
Las Vegas Hotel - Alternating Truss Construction (w/ HC precast floors)
(a “form” of Diagonal Bracing)
Diagonal Bracing
Construction Process Timeline

- Preparation of Structural Drawings (Structural Engr.)
- Preparation of Shop Drawings (fabricator)
  - Detailed fabrication & erection drawings
  - Details each piece and connections
- Submission & Approval
- Order “stock” lengths
- Fabricate each piece (after Shop Drawing Approval)
- Ship to Jobsite
- Erection
Structural Steel Erection
Erect 1st Tier Columns

Column Base Plate
• Distribute Loads
• Attachment to Fdn.
• Often Shop Welded
• Holes must match anchor bolts in ftg.
Column Set to Proper Elevation

Options

- **Leveling Plate**
  - set in grout prior to column erection

- **Leveling Nuts**
  - nuts set to elevation prior to steel erection

- **Shims**
  - metal shims set to proper elevation
Anchor Bolts with Leveling Nuts
Erection Sequence

- Erect Columns
- Install beams and girders
- Plumb structure
- Complete (weld or tighten) all connections - including diagonal bracing
- Grout column base plates
- Install edge angles & decking (or netting/plank)
- Start next tier
Column Base Plate Grouted

Temporary cables used to plumb the structure

Grouted **AFTER** 1st tier erected & plumbed
Edge Angles

- Forms the Slab “Edge”
- Anchorage of exterior “skin”
Multi-Story Structural Frame

Tower Crane
SS Frame w/ Roof Joists
Metal Deck w/ shear studs
Edge angles
Diagonal bracing to be installed
Beam Coping
Metal Decking

- A sheet of steel that has been corrugated to increase its stiffness

Span capability primarily based on:

- Thickness (gauge) of the sheet
- Depth & spacing of the corrugations
- Singular or Cellular
Metal Decking

Cold Rolled Sheets of Metal
Metal Decking - Uses

- Permanent Formwork for Concrete
- Floors
- Roofs
- Roof Deck
Metal Deck Uses
Roof Support
Atrium Roof
“Curved”
Roof Deck - Exposed & Painted
Metal Decking Attachment

- **Mechanical fastener** (self-tapping screws)
- **Welding** (common for floor deck)
Decking being ‘Puddle-Welded’
Composite Metal Decking

- Works in combination w/ concrete fill
  - Bonds to the concrete
  - Serves as tensile reinforcing
Composite Metal Decking

Often in combination w/ Shear Studs

- Creates a shear connection between deck & frame
- Increases carrying capacity
- Produces lighter, stiffer, & less costly frame
Decking w/ Shear Studs
Fireproofing

Codes Limit the Use of Exposed Steel

HOW? - Height & Area limitations
WHY? - Fire/heat reduces yield strength

Taller & Larger Buildings w/ Steel must be Protected
Structural Steel exposed to Fire / Heat
Encasement with a fire resistant material

- Concrete or Masonry
  - Adds dead weight
- Plaster
  - Costly/labor intensive
  - Exterior or humid applications
- Drywall
  - Also serves as finish mat’l
- Spray-on Fireproofing
- Combination
- Intumescent Mastics & Paints

Structural Steel Fireproofing Methods
Spray-on Fireproofing Mixture

Cementitious or fiber & binder mixture
Sprayed to the required thickness
Greater thickness = greater Resistance
“Bagged” Fireproofing Material & Pump
Note the thickness is greater on the columns
Often the metal decking does not require additional fire protection

Note- Composite deck
Protection during Fireproofing operations
Longer Spans

Rigid Steel Frames

Depth of Beams & Columns varies with magnitude of bending forces
Trusses
Angle
Tubular

Longer Spans
Castellated Beam
Opryland Hotel
Nashville, TN
Arches
Space Frame
Three dimensional structure - carries loads similar to a two-way slab
Rock -’n’- Roll Museum
Seattle
Frank O. Gehry & Assoc. (FOGA) Architect
“free-form curvilinear structure”
ENR 2/28/00
Rock -’n’- Roll Museum as seen from the Space Needle
Some of the ‘Exterior’ Skin for the Rock - ’n’ - Roll Museum
**Fabric Structures**

**Tensile & Pneumatic**

**Vancouver Convention Center**
Tensile Structure
Masts, and cable

**UNI Dome**
Pneumatic Structure (air supported)
Built 1975
Failed 3 times
- Mechanical failure
- Strong storm (winds & power failure)
- Melting snow and high winds
University of Iowa
Air Dome
Football Practice Facility
University of Iowa Air Dome
(Inside)
University of Iowa
Air Dome
Exterior Steel Restraint
‘Netting’
Fans to Provide the Internal Pressure necessary for Support of the Structure
CAUTION
Door Under Pressure
Use Revolving Doors

University of Iowa Air Dome
Entrance Door
Steel & the Building Codes

Without Fire Protection:
- Building heights & areas severely limited

With Proper Fire Protection:
- Unlimited Building Heights & Areas Permitted for most occupancy groups