1. Estimate the depth of steel open-web joists at 1/20 of their span for heavily loaded floor or widely spaced joints (1/24 of their span for lightly loaded floors, roofs or closely spaced joists):
   - Typical joists spacing ranges from 2 to 10 feet (depends on the spanning capability of the roof or floor decking material).

2. Estimate the depth of steel beams at 1/20 of their span and girders at 1/15 of their span:
   - The width of the beam or girder is usually 1/3 to ½ of its depth.
   - Composite beams and girders use the same ratios but include the overall depth of the beam plus deck and topping.
   - Triangular steel roof trusses at ¼ to 1/5 of their span.
   - Rectangular trusses at 1/8 to 1/12 of their span.
K → 60’
  (8” to 30” deep)

LH → 96’
  (18” to 48” deep)

DLH → 144’
  (52” to 72” deep)

Willis Faber & Dumas
Building (1970-75)
Foster Associates
Steel Connections | Overview

Overview
Bolted Connections
Welded Connections
Comparison

- Shear Connections
- Moment Connections
- Column Splices
Steel Connections | Overview

Connections are the glue that holds a steel structure together.

Historically, most major structural failures have been due to some form of connection failure.

- Type of loading
- Strength and stiffness
- Economy
- Difficulty or ease of erection
• connections typically use transitional elements such as steel angles, tees, or plates.
The strength of a connection depends on:

- the size of the members
- the connecting tees, angles or plates
- the configuration of bolts or welds
It is a common practice to weld shop attachments and to bolt field attachments.

End-plate connections are always shop welded.
Bolting is the preferred method of connecting members on the site.

Staggered bolt layout allows easier access for tightening with a pneumatic wrench when a connection is all bolted.
Slotted holes allow for thermal expansion / contraction

Oversize holes allow for tolerance in assembling the frame
Steel Connections | Welding vs. Bolting

WELDING

Advantages:
- Eliminates need for punching or drilling.
- Simplifies complicated joints.

Disadvantages:
- Greater level of skill required for welding than bolting.
- More expensive than bolting.
- Weld inspection is required and is expensive.

BOLTING

Advantages:
- Easy method of connecting members on the site.
- Field-bolting is cheaper than field-welding.

Disadvantages:
- Requires drilling or punching through all plies.
Three types of steel framing connections

- moment connections (1)
- shear connections (2)
- semi-rigid connections (3)

American Institute of Steel Construction (AISC)
Shear connections are the most prevalent type of connections in a steel frame building.

Shear connections are called simple connections – Since they are assumed not to transfer bending moment, thus allowing end rotation of the member.

Shear connections may be made to the web of the supported member while the flanges remain unconnected.
**Steel Connections | Moment Connections**

- Moment connections are also called rigid connections.
- Moment connections carry a portion or the full moment capacity of the supported member thus preventing any end-rotation of the member.
- Moment connections are typically designed to also carry the shear component of the load.

The Royal Ontario Museum
Toronto, Canada
Daniel Libeskind
Moment connections provide continuity between the supported and supporting members.

Relative rotation between the supporting and supported members is negligible.

The flanges of the supported member are attached to either a connection element or directly to the supporting member.
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Simple frame connections

AISC Type 2

- resist only shear
- free to rotate under gravity loads
- shear walls or diagonal bracing is required for lateral stability of the structure
AISC Type 2

- bolted connection
AISC Type 2

- coped beam-girder connection to level for floor or roof decking
Steel Connections | Shear Connections

- single tab shear connection

- welded shear connection
Shop-Bolted Double Angle | Field-Bolted Beam to Girder or Column
- The double angles are then field-bolted to the web of the girder.
- The holes on the beam and the girder may be offset with respect to each other for ease of fastening.
- Some rotation is possible in the gap between the beam flanges and the column web.
- This is a shear connection since the double Angles are fastened to the web, and transfer the load in shear.
- The bolts on the beam web are in double shear. Those on the girder web are in single shear.
Double angles are shop-welded to the web of the beam.
Double angles are shop-welded to the web of the beam.

If the beam and girder have different depth, the top flange of the beam is coped to meet flush with the top flange of the girder.

The double angles are then field-bolted to the web of the girder.

This is a shear connection since the double angles are fastened to the web, and transfer the load in shear.

The bolts on the girder web are in single shear.
Double angles are shop-welded to the web of the beam.

If the beam flanges are too wide to fit in between the column flanges, the beam flanges will be copeled.

This is a shear connection since the double angles are fastened to the webs of the beam and column.

The vertical segment of the weld transfers the load from the beam web to the column web.

Welding all around the outstanding leg will inhibit the flexibility of the connection.

The weld at the top is limited to a weld-return.

The weld at the bottom is optional.
Shop-Welded Double Angle | Field-Welded Beam to Column Web
End plate is shop-welded to the web of the beam.

Holes in the end plate are drilled in the shop.

This is a shear connection as the end plate is fastened to the web of the girder (beam flanges are not secured against rotation)

The bolts attaching the end plate to the girder web are in single shear.
Shop-Welded Double Angle | Field-Welded Beam to Column Web
The angles are pre-drilled or punched in the shop before they are welded to the flanges of the girder.

The bottom angle is called the seat.

The seat is where the girder transfers its load to the column in bearing.

The top angle provides stability to the girder.

The seat angle is larger and thicker since it transfers the load from the girder to the column.

Unlike others, this shear connection is not made to the web.

The bolts attaching the seat angle to the column flange are in single shear.
Shop-Welded Seat (Unstiffened) | Field-Bolted Seat to Column Flange
Shop-Welded Single Plate | Field-Bolted Plate to Beam or Column

- The single plate is pre-drilled or punched and then shop-welded to the web of the girder.
- The beam may be swung into place instead of lowered into place.
- The top flange of the beam is coped to match the girder elevation.
- This is a shear connection since the single plate is fastened to the web of the beam.
- The bolts shown are in single shear.
- This connection can transfer a small amount of moment to the supporting member.
Shop-Welded Single Plate | Field-Bolted Plate to Beam or Column
AISC Type 1

- Hold their original angle under loading
- Develop specified resisting moment
- Constructed with plates welded or bolted to the beam flanges and the supporting column
Steel Connections | Moment Connections

- stable joints, transfer actions into matrix
- continuous structure
- works in either tension or compression
Steel Connections | Moment Connections

- AISC Type 1
- welded
- The top and bottom flange plates are pre-drilled and then shop-welded to the column.
- The single plate is shop-bolted to the web of the girder.
- The top and bottom flange plates are field-bolted to the girder flanges.
- The single plate is field-welded to the column web.
- The flange plates are cut to fill the space between the column flanges.
- These corners are left open and are not welded.
- The single plate on the girder web transfers shear to the column.
- The flange plates prevent rotation and thus the transfer of moment forces to the column.
Shop-Welded Flange Plates | Field-Bolted Girder to Column
Shop-Welded Flange Plates | Field-Bolted Girder to Column

- The top and bottom flanges are pre-drilled and then shop-welded to the column.
- The single plate is shop-bolted to the web of the girder.
- The top and bottom flange plates are field-welded to the girder flanges.
- The single plate is field-welded to the column web.
- The flange plates are cut to fill the space between the column flanges.
- The corners of the flange plates are clipped to eliminate the development of stress concentrations at the re-entrant (back) corners.
- The single plate on the girder web transfers shear to the column
- The flange plates prevent rotation and thus the transfer of moment forces to the column, which makes this a moment connection
Shop-Welded Flange Plates | Field-Bolted Girder to Column
The end plate is pre-drilled and shop-welded to the end of the girder.

The corresponding holes in the column flange are pre-drilled.

The two transverse stiffener plates are shop-welded to secure the column flanges against the load transferred from the girder flanges.

Extended end-plate connections require tight fabrication and erection tolerances.

Extended end plate prevents rotation and thus transfers moment forces to the column, which makes this a moment connection.
Shop-Welded End Plate | Field-Bolted Girder to Column
Field-Bolted Moment Splice | Girder to Girder or Column Connection

- All holes in this connection are pre-drilled in the shop.
- The web and flanges of each girder are pre-drilled.
- (2) Shear plates are field-bolted in each side of the webs.
- The plates that attach the (2) webs to each other are responsible for transferring shear.
- Pre-drilled flange plates are field-bolted to the top and bottom flanges.
- The flange plates are responsible for transferring bending moments across the connection.
- The bolts fastening the web plates are in double shear.
- The flange plates prohibit any rotation and so this is a moment connection.

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Structural Steel Connections | MOMENT 4
Field-Bolted Moment Splice | Girder to Girder or Column Connection
AISC Type 3

- Semi-rigid connections assume beam and girder connections possess a limited moment-resisting capacity.
AISC Type 3

- welded/bolted end plate beam-column connection
• bolted column-column connection
• shims
• welded connections
• welded butt plate connection
The plates are pre-punched and then shop-welded to the lower (larger) column.

The flange splice plates are field-bolted together.

If the two columns have the same depth, but different flange thickness, then a filler plate or shim is used to make up the difference in thickness.
Shop-Welded or Shop Bolted Splice | Connecting Two Different Columns
Field - Welded Column Splice

- A temporary plate or erection aid is either welded or bolted to the web and/or flange of the lower (larger) column in the shop.
- Flange plates may also be required for stability of the column during erection.
- This plate helps align the upper and lower columns.
- The upper and lower columns may be of different sizes.
- The flanges and webs of the two columns are field-welded to each other.
- This type of weld is called a groove weld.

Steel Columns are most economical when they extend over 2 or more stories

Groove welds
Field - Welded Column Splice
Michael Hopkins
Patera Building

- lightweight steel framework
- insulated cladding system and fully glazed end walls
Patera Building, Michael Hopkins
- all parts fit into a shipping container and assemble easily with a fork-lift truck
Patera Building, Michael Hopkins

- pin connections and cast nodes make a fully rigid joint (upper)

- mid-span joint has a three-hinge tension-only link making a rigid joint or a hinge joint depending on forces (lower)
Patera Building, Michael Hopkins

- Pin connections and cast nodes make a fully rigid joint (upper)

- Mid-span joint has a three-hinge tension-only link making a rigid joint or a hinge joint depending on forces (lower)
ING Building
Architect: Meyer & Van Schooten Architects, Amsterdam
double envelope
serves as a thermal space, provides circulation routes and garden space
ING Building auditorium--23 meter cantilever

Architect: Meyer & Van Schooten Architects, Amsterdam
double envelope

serves as a thermal space, provides circulation routes and garden space
Steven Holl’s ‘technological’ skin

Referenced by constructed form; to be discovered; an ‘occasional’ reveal

CALA service wall
between floor plank and the exterior stud in steel truss

KIASMA -service wall
Centre Pompidou, Paris France, 1978
Piano & Rogers
six storey articulated steel superstructure
Centre Pompidou, Paris France, 1978
Piano & Rogers
six clear uninterrupted floors each 166 x 448 m in plan

Centre Pompidou, Paris France, 1978
Piano & Rogers
Centre Pompidou, Paris
France, 1978
Piano & Rogers
Cast Steel Elements

Gerberette brackets
Centre Pompidou, Paris France, 1978
Piano & Rogers
Centre Pompidou, Paris France, 1978
Piano & Rogers
The section of Pompidou, showing the 48 m span with the steel trusses beam system and the basement concrete structure
The west elevation, facade system braced by diagonal steel rods
The East elevation, the escalators attached at the outer side of the building
Eames House
Charles & Ray Eames
Pacific Palisades, CA
1949
Marika-Alderton House
Yirrkala Community, Northern Territory
1991-94

Glenn Murcutt

Minerals and Mining Museum
Broken Hill, New South Wales
1987-89
Local History Museum and Tourist Office

Glenn Murcutt, Kempsey, New South Wales

1976-88
Ball and Magney House
Glenn Murcutt
Interior and Exterior Details
Glenn Murcutt
Maestri House
Blueys Beach, New South Wales
1981
Simpson-Lee House
Mount Wilson, New South Wales
1989-94
Murcutt Guest House
Kempsey, New South Wales
1992
Murcutt Guest House
Kempsey, New South Wales
1992