

Materials

- Standard shapes
 - W sections, C channels, Structural T, Angles, Pipes, Tubes, Rods and Plates
- Fabricated members, Built-up sections
 - Adding plates to beam flanges,
 - Stiffeners to beam webs
 - Built up girder plates: Weld together steel plates

Materials



Raw steel used to fabricate structural steel members can be purchased from a steel mill or steel service center. Material purchased from a steel service center is usually more expensive, but may be quicker to obtain and can be ordered in smaller quantities. The material for the case study project was ordered directly from a mill and delivered in two batches approximately 4 and 5 weeks after the mill order was placed. Once the material arrived at the fabricator's shop it was organized and stored in the yard.

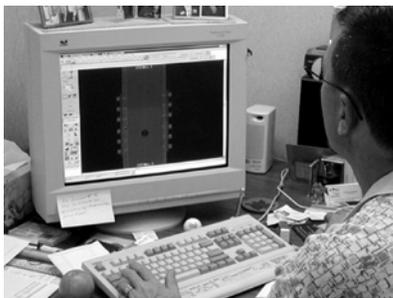
Estimating Steel

- Unit of measure:
 - Lb, hundredweight (cwt), tons
- W 18 x 55 Grade 50
 - W section, depth: 18"
 - 55lb/LF
 - Yield strength 50,000psi
- Weight of steel: 490 lb/cf
- Estimate LF of sections and multiply by nominal weight of sections (steel handbook)
 - Nominal weight +/- 2%
- Typical connections
 - Bolts and welds
- Take into account main members and detailed sections
- Cost of drawing, fabrication, delivery, welding and painting, erection

Players

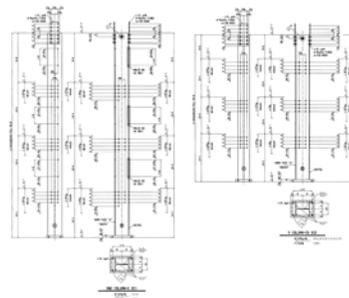
- Supplier provides steel based on
 - Total linear footage of steel, wt/ft, shape and grade of steel: Base price of steel
- Steel Fabrication (Sub/supplier)
 - Prepare shop drawings (5-10% of base price)
 - Fabricate steel (50-100% of base price)
 - Shop painting (8-12% of base price)
 - Field painting (Table 11.3: sqft/ton)
 - Shipping costs
- General Contractor (Usually sub-contracts the whole process)
 - Erection on site (Specialized equipment, expertise, safety issues)

Detailing Process



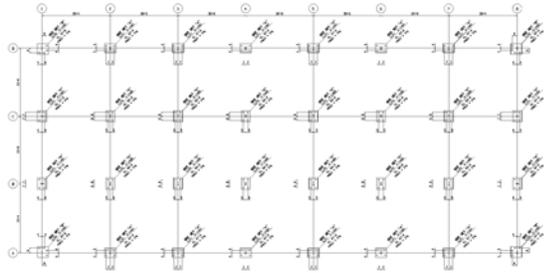
During the detailing process, the detailer develops shop drawings for each structural steel member in the structure. Each member is assigned a unique piece mark for identification and tracking. The detailer also prepares a list with a description of the structural steel members.

Shop Drawings



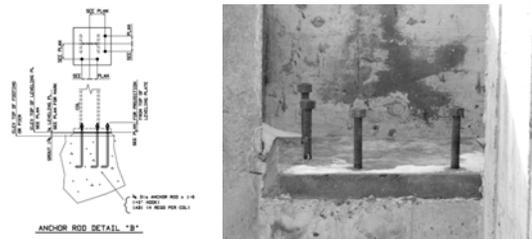
These are shop drawings of columns 3C1 and 3C2 for the case study project. Shop drawings convey precise information to the fabricator, and other project parties about how each steel member in the structure is to be fabricated.

Anchor Rod Plan



One of the first drawings prepared by the detailer is the anchor rod plan. This plan guides the foundation subcontractor in the placement of anchor rods. It contains horizontal and vertical information for placement of anchor rods, as well as dimensions and elevations of leveling plates (if used).

Anchor Rod Details



The anchor rod detail on the left depicts how anchor rods and leveling plates were placed for the case study project. A leveling plate is a steel plate fixed on top of a foundation on which a structural column can be placed. The leveling plate is leveled and grouted prior to installation of the column. Although this is one method for setting columns, practices may vary with other erectors. On the right is a photograph of the anchor rods and leveling plates in place for the case study project.

Fabrication



Structural steel members are fabricated by precisely cutting, shearing, punching, drilling, fitting and welding in order to produce the configurations detailed in the shop drawings. Each member is labeled with a piece mark, length, and job number for identification.

Piece Mark



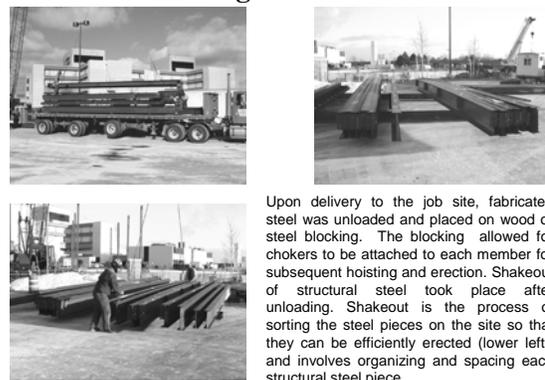
Once fabricated, each finished structural steel member is labeled. In this case the fabricator labeled each steel member with its piece mark, sequence number, and the last two digits of the job number. Specific labeling practices may vary by fabricator. Notice that this time the label color is yellow to differentiate it from previous labels. Labeling of the steel pieces is crucial because it will help identify members on the job site.

Transportation



Once the on-site crane was fully set up, the fabricator loaded the steel members for sequence 1 onto trucks and transported them to the job site. Structural steel was delivered by sequence throughout the erection process. It took a total of 29 truckloads to deliver all of the structural steel for the project.

Unloading and Shakeout



Upon delivery to the job site, fabricated steel was unloaded and placed on wood or steel blocking. The blocking allowed for chokers to be attached to each member for subsequent hoisting and erection. Shakeout of structural steel took place after unloading. Shakeout is the process of sorting the steel pieces on the site so that they can be efficiently erected (lower left), and involves organizing and spacing each structural steel piece.

Storage



After fabrication, finished structural steel members are stored in the fabricator's storage yard. The more organized the yard, the easier it will be to transport steel to the site. In this case structural steel was stored according to erection sequence. Sequences define areas of the frame and are used to organize their delivery and erection. The practice of planning and storing by sequence improves the efficiency of loading, delivery, offloading and erection.

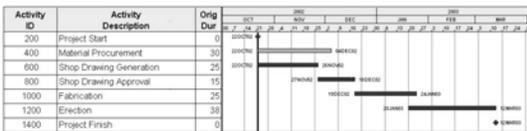
Case Study Project



Description of the structural steel frame:

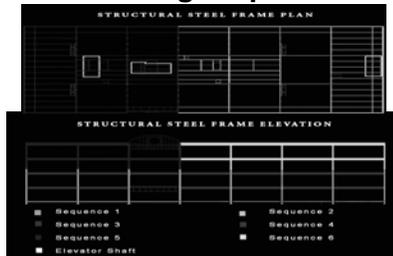
- Office building use
- 4 Stories
- 80,000 square feet of building construction area
- Approximately 400 tons of structural steel or 10 pounds per square foot
- Approximate fabrication and erection cost 9 dollars per square foot
- Standard bay size of 30ft by 30ft
- 3 by 7 bays
- 964 pieces of structural steel
- Built in 2003

Structural Steel Construction Phase Schedule



As seen on the schedule, material procurement occurs early in the process, even before shop drawings are generated. This is done so that a steel mill has enough time to produce the required steel. Material procurement includes: quantity surveying, placing the mill order, delivery of steel from the mill and storage of the steel in the fabrication shop. Detailing includes the creation of shop drawings of each piece in the structural frame. Shop drawings are submitted to the contractor and structural engineer to ensure that they comply with the engineer's design. Upon approval of shop drawings and arrival of steel from the mill, steel pieces are precisely fabricated. Once structural steel members are fabricated they are taken to the yard, loaded on trucks and transported to the job site for erection.

Hoisting Sequences

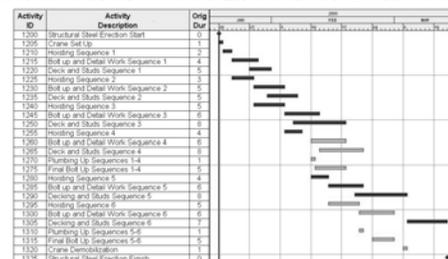


During detailing, the steel frame was divided into 6 sequences illustrated on the erection drawings. Sequences represent the order in which a zone or section of the frame will be erected. They are designed to improve efficiency of the erection process. Planning the sequences allowed for parallel construction operations to take place. For example, while the erection crew erected sequence 2, the decking crew placed metal deck at the previously placed sequence 1. In this way the deck placed at sequence 1 formed a work platform and reduced the potential fall distance when the steel contractor erected sequence 3 which was above sequence 1.

Safety Concerns

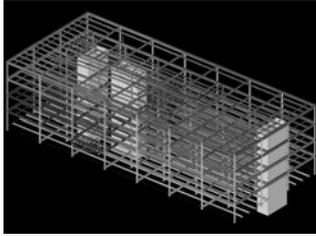
- All employees must have fall protection at 15 feet, except for deckers in controlled decking zones and connectors [§.760(a)]
- **Controlled decking zone** (CDZ) means an area in which certain work (for example, initial installation and placement of metal decking) may take place without the use of guardrail systems, personal fall arrest systems, fall restraint systems, or safety net systems and where access to the zone is controlled.
- Controlling contractor to provide erector with a safe site layout.
- Minimizes employee exposure to overhead loads through pre-planning and work practice requirements.

Structural Steel Erection Schedule



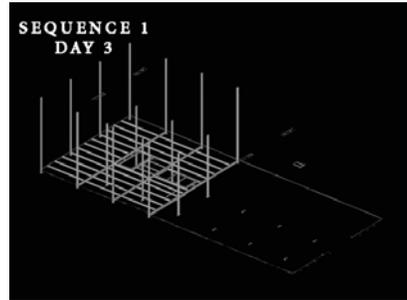
This is a detailed schedule of the erection process of the structural steel frame. In this project an average of 40 pieces of steel were hoisted per day. Hoisting, bolt up, detail work, decking and stud activities are performed by sequence. Hoisting consists of lifting and placing steel members into their appropriate position and temporarily fastening them using several bolts and/or welds. Plumbing up refers to the vertical alignment of the frame. Final bolt up refers to tightening the bolts which connect the components of the structure.

STRUCTURAL STEEL ERECTION BY SEQUENCE

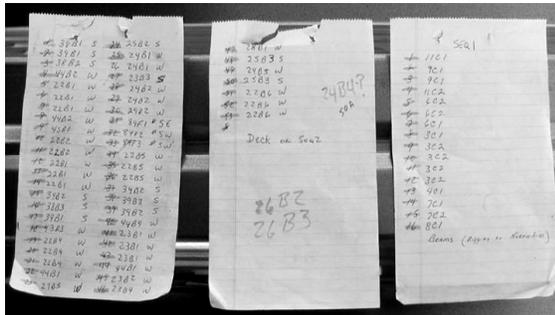


The following is an animation of the structural steel erection process by sequence. The six sequences will slowly appear along with the working day in which hoisting of each sequence was completed. The last images to appear are of the masonry stair and elevator shafts. They were built after the frame was erected. The steel frame was connected to the vertical shafts to provide permanent lateral stability of the frame.

SEQUENCE 1 DAY 3

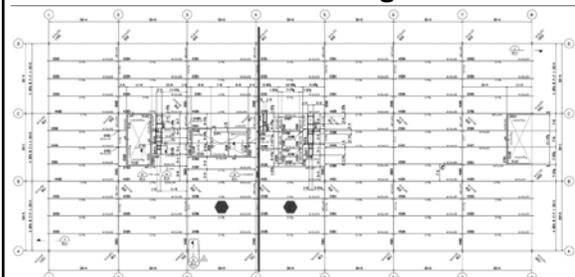


Erection Order



The erection crew foreman used the erection drawings to determine the exact order in which structural steel members were to be erected. The first pieces hoisted during this project were the columns in sequence 1 (right sheet), then girders and beams (left and center sheets).

Erection Drawings



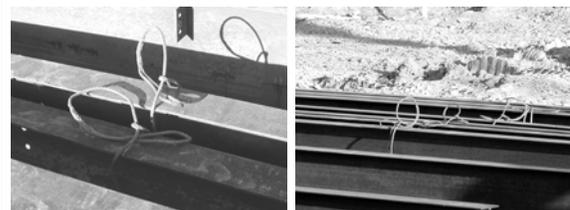
This is the erection drawing (e-drawing or e-sheet) of the first floor framing for the project. The numbers one and two inside the red hexagons on each side of the red line indicate the sequence number for each part of the structure. The piece marks on the drawing match those on the beams, girders and columns and are used to locate and orient each member during erection.

Erection Crew



Seven people formed the erection crew used for this project. The crew consisted of one foreman, two ironworkers hooking steel (upper left), two ironworkers connecting steel (upper right), a crane operator (lower left), and an oiler (lower right).

Chokers



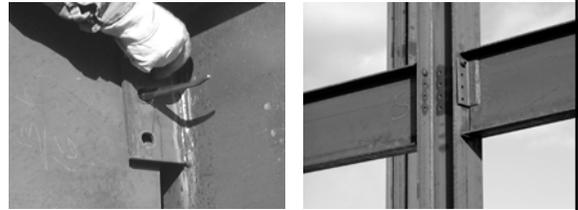
A choker is a rigging assembly used to attach a load to a hoisting device. It is usually made of wire rope or synthetic fiber. Chokers are used to hoist beams into position. They are positioned at the center of gravity of the beam so that the beam remains level when hoisted.

Multiple Lift Rigging



Multiple lift rigging is a process used to hoist several pieces of steel simultaneously. This is accomplished by utilizing a rigging assembly that facilitates the attachment of up to five independent loads to the hoist rigging of a crane. In this project up to four beams were hoisted at a time. Multiple lift rigging speeds the lifting process by reducing the total number of lifts required for the frame.

Preliminary Bolting



The connector uses pins to align the holes between structural steel members being connected. Then he places several bolts and temporarily tightens them with his spud wrench. At least two bolts per connection are used to temporarily fasten each connection.

Sequence 1 Columns



The first structural steel members hoisted were the columns. This is a view of sequence 1 after the columns were set. Notice that all columns have a splice on the top.

Beams



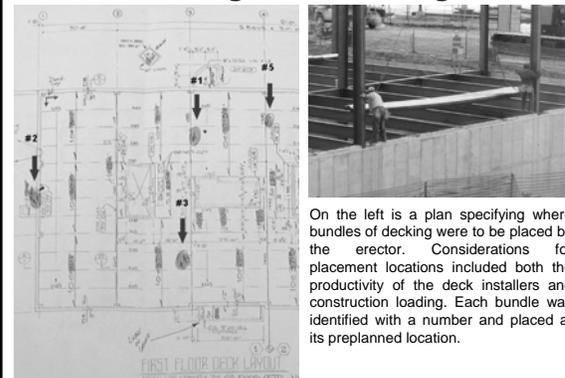
Main girders are hoisted after the columns. Beams are then hoisted and connected to the girders. On the left is a photograph of the first bay to be hoisted. On the right is a photograph of the first three bays in place.

Metal Decking



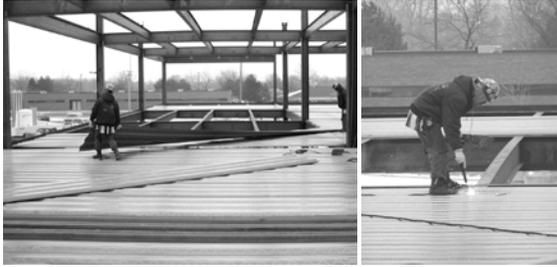
This is the metal decking used in the project. The erector had the responsibility of unloading and hoisting metal decking to pre-established positions on the frame.

Hoisting Metal Decking



On the left is a plan specifying where bundles of decking were to be placed by the erector. Considerations for placement locations included both the productivity of the deck installers and construction loading. Each bundle was identified with a number and placed at its preplanned location.

Metal Decking



Metal deck was placed and attached with a series of welds. Controlled deck zones were used during installation. A controlled deck zone is an area in which initial installation and placement of metal decking may take place without the use of guardrail systems, personal fall arrest systems, fall restraint systems, or safety net systems and where access to the zone is controlled.

Shear Studs



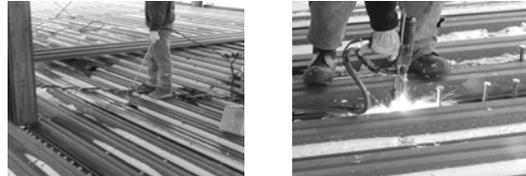
These are shear studs. The white rings are ceramic ferrules. The ceramic ferrule constrains the molten metal into which the stud is thrust automatically and a high quality fusion weld is accomplished where the weld is stronger than the stud itself.

Perimeter Safety Cables



On multi-story structures, perimeter safety cables are installed at the interior and exterior perimeters of floors and openings as soon as the metal decking has been installed.

Welding Shear Studs



Snow was removed from the locations where shear studs were to be placed (upper left). Using a stud-welding gun (an automatic welding device) the shear studs were then welded to the structural members below the metal decking. Shear studs are used to ensure a composite action between the concrete slab and structural steel beams (upper right). Whether shear studs are used is a function of the structural engineer's design.

Shear Studs



This is a view of the welded studs. Shear studs were tested to ensure that they were correctly welded to the structural steel members in compliance with the bend test of the AWS D 1.1 Structural Welding Code.

Sequence 1



Sequence 2



This is a view of the completed hoisting activity for sequences 1 (left) and 2 (right). It took approximately 5 days to hoist the 166 pieces of steel that are part of the two sequences.

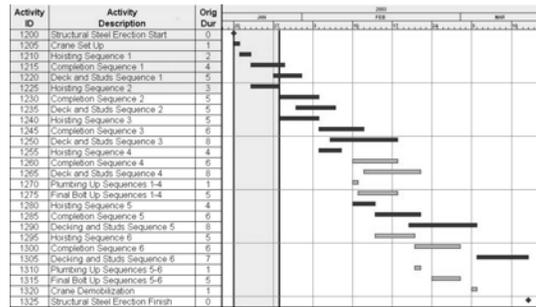
Sequence 3

Sequence 4



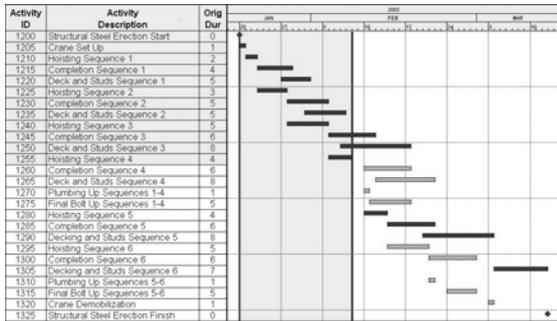
This is a view of the completed hoisting activity for sequences 3 and 4. Hoisting these two sequences took approximately 9 days in contrast with the five days it took to hoist sequences 1 and 2, because sequences 3 and 4 consisted of two floors (365 pieces of steel) and sequences 1 and 2 consisted of one floor (166 pieces of steel).

Erection Schedule



The activities in yellow were completed by the time sequence 2 was hoisted. Notice how deck and studs for sequence 1 starts before hoisting sequence 3 to provide fall protection for the ironworkers connecting steel.

Erection Schedule



The activities in yellow are the ones completed by the time sequence 4 was hoisted. Notice that deck and studs for sequence 3 were started before hoisting sequence 5 in order to provide fall protection for the ironworkers connecting steel. Plumbing up and final bolt up for sequences 1 through 4 were performed after sequence 4 was hoisted.

Temporary Bracing



Temporary bracing was placed before plumbing up the structural frame. Temporary bracing is used to provide temporary lateral stability to the structure and to plumb up the frame. The temporary bracing was removed by the erector once the structural steel frame was secured to the vertical masonry elevator and stair shafts, which were installed after completion of the steel frame.

Plumbing Up



Plumbing up refers to the vertical alignment of the structure. A theodolite was used to verify the alignment of columns in the perimeter of the building. The foreman directed ironworkers on the structure to shift the frame using the temporary bracing.

Final Bolt-up



After a section of the structural frame was assembled and vertically aligned, ironworkers permanently fastened the structural steel members with additional bolts and welds. Tension controlled bolts (F1852) were used. Final bolt-up was performed using a torque wrench. The wrench stops automatically when the bolt shears at a tension control groove indicating that the required tension is reached.

Sequence 5



Sequence 6



This is a view of the completed hoisting activity for sequences 5 (left) and 6 (right). It took approximately 9 days to hoist both sequences, similar to sequences 3 and 4.

Erection Schedule

Activity ID	Description	Orig Dur
1200	Structural Steel Erection Start	0
1205	Crane Set Up	1
1210	Hoisting Sequence 1	2
1215	Completion Sequence 1	4
1220	Deck and Studs Sequence 1	5
1225	Hoisting Sequence 2	3
1230	Completion Sequence 2	5
1235	Deck and Studs Sequence 2	5
1240	Hoisting Sequence 3	5
1245	Completion Sequence 3	6
1250	Deck and Studs Sequence 3	8
1255	Hoisting Sequence 4	4
1260	Completion Sequence 4	6
1265	Deck and Studs Sequence 4	8
1270	Plumbing Up Sequences 1-4	1
1275	Final Bolt Up Sequences 1-4	5
1280	Hoisting Sequence 5	4
1285	Completion Sequence 5	6
1290	Decking and Studs Sequence 5	8
1295	Hoisting Sequence 6	5
1300	Completion Sequence 6	6
1305	Decking and Studs Sequence 6	8
1310	Plumbing Up Sequences 5-6	1
1315	Final Bolt Up Sequences 5-6	5
1320	Crane Demobilization	1
1325	Structural Steel Erection Finish	0

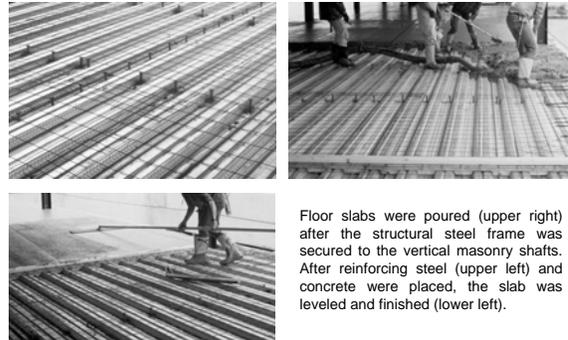
The activities in yellow are the ones completed by the time sequence 6 was hoisted. Plumbing up and final bolt up for sequences 5 through 6 was performed after sequence 6 was hoisted. Hoisting sequence 6 was the last activity that required the use of the crane. After hoisting sequence 6 the crane was demobilized.

Lateral Stability



Masonry elevator and stair shafts were installed after the steel frame was erected. The steel frame was secured to the shafts of the building at each floor providing lateral stability for the frame.

Slabs



Floor slabs were poured (upper right) after the structural steel frame was secured to the vertical masonry shafts. After reinforcing steel (upper left) and concrete were placed, the slab was leveled and finished (lower left).

Slabs



This is a view of the finished slab. At this point the structural frame of the building is complete.

Inspection



The structural steel frame was inspected upon completion by the local jurisdiction and work could proceed accordingly. Depending on frame complexity, additional periodic inspection and testing may also be required by the local jurisdiction. The design engineer also conducts contract administration and field observation activities which help ensure quality.

Fireproofing



Structural steel has to be protected from fire. Steel will not burn, but it may become soft and weak when exposed to intense heat. Building codes regulate the need for fireproofing and its required locations. There are several methods for fireproofing. The method used for this project utilized spray-on fireproofing. Spray-on material may be portland cement or a gypsum-based product and can be applied directly to structural steel members.

Finished Building



This is how the building will look after it is completed. The structural steel frame is one of the most important parts of the building. Building with steel has several advantages over other building materials. Steel can be erected year round. It is light yet strong when compared with other structural frame materials. Steel can also be adapted to almost any imaginable shape. One of the biggest advantages is that it can be erected very fast.