Construction Management of STEEL CONSTRUCTION

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PROJECT MANAGEMENT•SCHEDULING•ESTIMATING

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INTRODUCTION

1.1 Manual Overview

This educational manual was developed for the American Institute of Steel Construction (AISC) to present the principal project management activities and issues for procuring and implementing steel construction. The manual was developed for use in undergraduate university level construction management programs. It should also be useful in project management courses in construction engineering, civil engineering, architectural engineering, and architecture programs.

The manual is intended as a supplemental text which may be incorporated into junior and senior level project management, estimating, and scheduling courses. The manual was developed in two educational modules: Module One addresses project management activities and Module Two examines scheduling and estimating issues that pertain to steel construction.

Both educational modules have been designed to help students understand the unique roles and relationships of the general contractor, steel fabricator, erector, specialty contractors, suppliers, architect, structural engineer, and owner in the construction of a structural steel building frame. While the manual has been specifically developed to address steel construction, many of the issues presented are also applicable to the management of other construction subcontracts. Therefore, this manual may serve as a detailed case study of steel construction which will help students achieve a broader understanding of construction project management, estimating, and scheduling practices. It is hoped that faculty teaching this material, will find this steel case study useful as they present the principles of project management, estimating, and scheduling in their courses.

Most construction management and construction related programs require students to take courses in construction science, technology, materials, and structural design. It is assumed that by the time students are enrolled in project management, estimating, and scheduling courses, they will have obtained sufficient understanding of the technical terminology and also have a general understanding of steel design and construction practices. This manual is not intended as a technical guide to steel, but focuses instead on the project management aspects of steel construction. Students may wish to consult other general texts on structural design and construction methods should they need additional technical information. AISC has developed numerous publications which address the technical and design aspects of steel. These publications may be obtained by contacting the AISC publication's department. See Appendix D for a listing of AISC services.

To help students gain a better understanding of the text, a steel construction project case study has been included. This building is a steel framed seven-story midrise medical office building. This project is described below under the case study description. Project documents from the case study are included in Appendix A.

To assist faculty in using this manual as a supplemental text in their courses, several open-ended questions are provided at the end of the two modules. These questions are intended to be used for in-class discussion.

The development of this manual was sponsored by a grant from the AISC Education Committee and was prepared by Mr. Tim Mrozowski, A.I.A., Dr. Matt Syal, CPC, and Mr. Syed Aqeel Kakakhel

of the Building Construction Management Program at Michigan State University. AISC appointed two advisory committees to provide input and oversee the development of the manual. The Industry Technical Committee included fabricators, erectors, contractors, and educators who provided input into industry practices. The Educational Advisory Committee consisted of construction management and engineering faculty who advised and reviewed the manual for both industry practice and educational use.

1.2 Case Study Description

This text uses a steel framed midrise office building as a case study. The building is a seven-story structure and is approximately 240 ft long by 150 ft wide. It contains approximately 256,900 sq ft of floor area and required 1,330 tons of structural steel, exclusive of the metal deck and metal stairs. The project was completed in 1998.

The case study project has a 30 ft x 30 ft typical bay size. Floor framing consists of W24 x 68 primary beams and W16 x 26 secondary beams. First floor interior columns are W14 x 159 and are reduced in size for upper floors. Columns are spliced at every other level. The floors are constructed of metal decking and concrete. Composite action is achieved by utilizing shear studs. Connections for the project are a combination of simply framed and moment connections. Exterior walls consist of panalized brick with metal stud backup and glass.

The project is located in an urban setting and is part of a large hospital complex. Site access was limited on the north, west, and east sides of the structure because of adjacent roads and buildings. Steel was delivered to the project on trucks, unloaded by crawler crane and erected immediately. Only limited minor steel components were stored on the site. A single 230 ton crawler crane was used to erect the steel and was repositioned as necessary during erection.

The steel was erected in three sections, each having multiple erection sequences. The building was roughly divided into three sections with all structural steel erected from foundation to roof for a section. At the completion of one frame section, the erector began the next section. Metal deck was purchased by the fabricator and erected by a separate metal deck installer hired by the steel erector.

Project documents are included in Appendix A and are referenced throughout the text.

Photos of Case Study Project

1.3 Introduction

Steel has been an important component of buildings, bridges, and other structures for more than a century. Its use has allowed designers and contractors to construct both simple and complex structures in efficient, time saving, orderly, and economical ways. While procurement and construction management of structural steel have many similarities to the procurement of other building materials, steel construction has some unique characteristics. For example, structural steel is largely fabricated off-site. On-site erection and assembly are done rapidly. Coordination of all parties is important in achieving the potential schedule advantages of steel construction. Steel construction also requires that the fabricated components fit properly at the site. Close dimensional tolerances require dimensional accuracy, review, and approval by several parties. The purposes of this manual are 1) to give students interested in construction management an understanding of the roles of the various participants, 2) to provide an understanding of the various steps in the process and, 3) to provide an understanding of project management activities including scheduling and estimating of steel construction.

Steel is used in many different components of buildings such as doors, equipment, reinforcement for concrete, and structural steel. This manual focuses on the management and use of structural steel framing systems for buildings. Structural steel is typically acquired, fabricated and erected by the steel contractor. The steel contractor may be a single contractor, but more typically is a lead company such as a fabricator who subcontracts portions of the steel construction to lower tier subcontractors, such as steel erectors or metal deck installers.

While the steel contractor is responsible for fabrication and erection of the structural steel frame, the steel contractor may also be required to furnish and install other miscellaneous metal items which are attached to the frame, but not classified as structural steel by AISC. The AISC Code of Standard Practice defines the elements included in the broad categories of "Structural Steel" plus "Other Steel and Metal Items" and is reprinted below in Figure 1-1.

Definition of Structural Steel (AISC 1994)

"Structural Steel," as used to define the scope of work in the contract documents, consists of the steel elements of the structural steel frame essential to support the design loads. Unless otherwise specified in the contract documents, these elements consist of material as shown on the structural steel plans and described as:

Anchor bolts for structural steel
Base or bearing plates
Beams, girders, purlins and girts
Bearings of steel for girders, trusses or bridges
Bracing
Columns, posts
Connecting materials for framing structural steel to structural steel
Crane rails, splices, stops, bolts and clamps
Door frames constituting part of the structural steel frame
Expansion joints connected to structural steel frame
Fasteners for connecting structural steel items:
Shop rivets

Definition of Structural Steel (AISC) cont'd

Permanent shop bolts
Shop bolts for shipment
Field rivets for permanent connections
Field bolts for permanent connections
Permanent pins
Floor Plates (checkered or plain) attached to structural steel frame
Grillage beams and girders
Hangers essential to the structural steel frame
Leveling plates, wedges, shims & leveling screws
Lintels, if attached to the structural steel frame
Marquee or canopy framing
Machinery foundations of rolled steel sections and/or plate attached to the structural frame
Monorail elements of standard structural shapes when attached to the structural frame
Roof frames of standard structural shapes
Shear connectors–if specified shop attached
Struts, tie rods and sag rods forming part of the structural frame
Trusses

Other Steel or Metal Items

The classification "Structural Steel," does not include steel, iron or other metal items not generally described in Paragraph 2.1, even when such items are shown on the structural steel plans or are attached to the structural frame. These items include but are not limited to:

Cables for permanent bracing or suspension systems
Chutes and hoppers
Cold-formed steel products
Concrete or masonry reinforcing steel
Door and corner guards
Embedded steel parts in precast or poured concrete
Flagpole support steel
Floor plates (checkered or plain) not attached to the structural steel frame
Grating and metal deck
Items required for the assembly or erection of materials supplied by trades other than structural steel fabricators or erectors
Ladders and safety cages
Lintels over wall recesses
Miscellaneous metal
Non-steel bearings
Open-web, long-span joists and joist girders
Ornamental metal framing
Shear connectors if specified to be field installed
Stacks, tanks and pressure vessels
Stairs, catwalks, handrail and toeplates
Trench or pit covers.

Figure 1-1 *Definition of structural steel and other metal items. AISC Code of Standard Practice (AISC 1994)*

There are many potential benefits in the use of structural steel for the owner. Some of these include:

1. Steel construction can substantially reduce construction time for the frame because of off-site fabrication and the ability to construct in all seasons. This savings reduces on-site management and overhead costs, and improves cash flow.
2. Structural steel can be designed with large spans and bay sizes, thereby providing more flexibility in space arrangement and rearrangement for the owner.
3. Steel can be easily modified and reinforced if the owner chooses to expand the facility, or if architectural changes are made.
4. Relative to other structural systems, steel is lightweight and can reduce foundation costs.
5. Steel is a durable, long-lasting material and is recyclable.

Careful project management and design of structural steel construction can help to ensure that these benefits are achieved. Section 1.4 below outlines the principal steps in the project delivery process for structural steel.

PROJECT MANAGEMENT

1.4 Stages of Procurement and Implementation of Structural Steel for Buildings

Initial Decision. The procurement and implementation of structural steel for buildings begins with the owner's decision to use steel as the primary structural system for the building. This decision is generally made early in the design process in conjunction with the architect and structural engineer for the project. In projects which use the services of a construction manager, or in design-build projects, the construction entity may play a strong role in recommending the structural system. The construction manager or design-build firm advises the owner on material availability, costs, suitability, and scheduling aspects of the structural frame types. In many cases, the construction manager or design-build firm consults with steel fabricators for preliminary pricing, scheduling, and layout information that is used in deciding which structural system to utilize. Refer to figure 1.2 at the end of this section for an illustration of the development and management steps for structural steel construction.

Schematic Design. Once the decision is made to use a structural steel frame, the architect and structural engineer proceed with schematic design layouts for the building. The architect and structural engineer work closely to coordinate the functional spaces of the building with the structural components. The architect develops the overall building concept and also determines locations and sizes of spaces. The structural engineer develops the structural concept in consideration of the architectural layout and examines many factors such as structural loads, material strength, economy of beam span, lateral stability, and repetitiveness to determine column and beam spacings.

Contract Documents. Upon completion of the schematic design studies, the architect and structural engineer proceed with design development and contract documents for the project. The structural engineer is primarily responsible for engineering of the structural steel frame and development of the detailed structural contract documents. The structural documents include: foundation plans and details, structural floor framing plans, roof framing plans, column schedules, structural details, structural notes, and design loads, as well as the structural specifications. The specifications are typically bound into the architect's project manual, which includes the specifications for all materials and processes for the entire project.

Bidding. After completion of the contract documents, the owner and architect prepare the bidding documents. Bidding documents are used together with contract documents to obtain bids from contractors for the construction of the building. The owner and architect solicit bids from qualified contractors, using these documents. Bids for structural steel may be in the form of subcontract prices, which are included in the general contractor's lump sum proposal, or the owner may divide the project into separate prime contracts with the steel contractor bidding directly to the owner. When the owner employs a construction manager or design-build firm, the construction entity usually takes the lead role in preparing the bidding documents and managing the bidding process for the owner.

During the bidding process, the general contractor defines the subcontract workscopes and solicits subcontract prices from steel fabricators, erectors, and specialty contractors. The general contractor may wish to subcontract the complete structural steel package to a single steel subcontractor, or may choose to divide the steel portion of the project into multiple subcontracts. In the case of a single subcontract, the general contractor will identify a qualified steel fabricator or erector to obtain a bid for the complete structural steel package. Refer to Section 1.9 for a discussion of subcontract workscopes.

The steel contractor (fabricator or erector) will solicit lower tier subcontract prices for the various portions of the steel package. Typically the fabricator, (who is not also an erector) would seek lower tier subcontract prices for steel erection, metal deck supply and installation, and shear studs, as well as other specialized aspects of the steel portion of the project. The steel contractor may also be charged by the general contractor with furnishing the miscellaneous fabricated steel items used throughout the project. Examples of these items are loose lintels, plates, and bolts installed by the mason, or steel pipe railings and metal stairs. If these items are to be included in the steel contractor's subcontract, the general contractor should specifically include these in the subcontract workscope.

The bidding steel contractor needs to obtain the bidding documents, construction drawings, and specifications in order to determine the requirements for the project. The steel contractor reviews the contract documents and contractual conditions to determine the scope of the work. The steel contractor always needs to be provided with the complete contract documents.

The bidding steel estimator conducts a quantity takeoff to determine the quantities of the various shapes and sizes of steel elements to be used for the project. Special conditions, connections, finishes, and fabrication requirements are noted. The steel fabricator will frequently consult with steel mills and/or steel service centers on pricing, availability and time of delivery of steel shapes to be used in the project. Steel joist and metal deck suppliers will also be consulted. The steel contractor will have a systematic approach for taking off and recording the quantities. The material takeoffs are frequently computerized with specialized industry spreadsheets. Refer to Module Two for a discussion of steel estimating.

The bidding steel contractor is often required to provide input into the preliminary project schedule by the general contractor. The steel contractor evaluates ordering and delivery times from the mill, fabrication durations, erection sequence, and erection duration. Other elements considered are shop drawing and approval times, shop capacity, delivery times for purchased items such as metal deck and steel joists, and project conditions. As necessary, the steel contractor consults with lower tier subcontractors in preparing recommendations. The steel contractor makes recommendations to the general contractor regarding the schedule for steel construction. The general contractor incorporates these recommendations into the overall project schedule.

The steel contractor compiles pricing and scheduling information for the specified workscope and submits this information to the bidding general contractor. The general contractor evaluates competitive pricing from various steel subcontractors based on price, quality, and schedule, incorporating the selected steel subcontractor pricing into the lump sum bid.

Contract Award and Subcontracts. If the general contractor is awarded the contract by the owner, the detailed subcontract for steel construction will be prepared. The steel subcontract will specify the detailed terms of the building's steel portion. Workscopes, pricing, and scheduling requirements must be well-defined and based on the original workscope, along with any negotiated changes in the building or project conditions.

Ordering Steel. Under normal conditions, upon execution of the steel subcontract, the steel fabricator immediately places an order with the steel mill for production and furnishing of the structural steel shapes. On expedited projects, the steel fabricator may purchase shapes directly from a steel service center, (which warehouses common steel shapes), or may fabricate from shapes stocked in the fabricator's inventory.

Erection Drawings and Shop Drawings. When ordering steel, the fabricator simultaneously begins to prepare anchor rod setting plans, shop drawings, and erection drawings for approval by the structural engineer. The shop drawings may be prepared in-house or the steel fabricator may subcontract their preparation to a steel detailing firm. The shop drawings are used to illustrate how the steel fabricator intends to comply with the contract documents, as well as the dimensional and detailed aspects of the fabrication. The erection drawings indicate the detailed configuration of the steel frame and locate each member of steel with piece marks.

Shop drawings are typically submitted to the general contractor who reviews and then transmits them to the architect and structural engineer for review of compliance with the original design concept. While shop and erection drawings are generally required by the contract documents and serve the architect, structural engineer and owner, they are also essential documents used by the steel fabricator for fabrication and erection of steel. Development and approval of shop drawings are detailed and tedious processes for all parties involved with the project, but are also extremely important and beneficial in making certain that the building is properly fabricated and fits together smoothly during the erection process. Generally, the contractor, architect and engineer will "redline" or mark required changes to the original shop drawings and return them to the fabricator.

The length of time for approval of shop and erection drawings is normally specified in the contract, and typically is two weeks. After any necessary modifications are made by the fabricator's detailer, shop drawings are resubmitted for final approval by the fabricator. To streamline the shop drawing process, the steel fabricator frequently issues the steel shop drawings in stages. Anchor rods and setting plans, along with a preliminary set of nonstandard AISC connections usually come first, followed by column and beam submittals. The general contractor or construction manager will typically require a drawing submittal schedule. The contractor, architect, and structural engineer are usually able to approve these partial elements of the steel frame. This process of partial submission allows the fabricator to begin fabrication of early structural elements and main members, which can expedite delivery of the finished steel members.

Simultaneously during the shop drawing process, the steel fabricator manages and coordinates the shop drawing process for the purchased or subcontracted items, such as steel joists, metal deck, shear studs, and metal fabrications. It is important that the shop drawing process is coordinated by all parties and the drawing submittal schedule and "approval turn around" are well defined so that the project is not delayed.

Fabrication and Delivery. Following approval of the initial batch of shop drawings and delivery of the mill steel, the fabricator will begin to fabricate and finish the steel elements. The time and sequence of fabrication will be a function of the fabricator's shop practice and capacity, other fabrication projects, and the erection sequence for the building. Fabrication involves handling of the stock members, cutting them to size, punching and drilling for connections, and preparing the connections, as well as shop painting or finishes when required. Though each project is unique, the fabricator will frequently have fabricated adequate portions of the steel for the building before erection begins. During fabrication or at the drill line, each piece is marked and identified for its precise location in the structural frame and stored or readied for delivery to the project site. Under normal conditions, steel items should be delivered to the site in the sequential order in which the steel will be installed by the erector.

Erection. Steel erection begins when the steel has been fabricated and the foundation is completed to a point where it is ready to receive steel. Steel erection is conducted by the steel erector. Some fabricators may have their own erection crews or subsidiary companies; others will subcontract this work to a separate erection company. The erection company works closely with the general contractor and the fabricator to erect the steel in accordance with the established sequence of erection and delivery.

The order of erection is typically shown on the erection drawings or on a separate sequence diagram. The erector typically prepares an erection plan which specifies the erection practices and safety measures which will be employed for the approval of the general contractor. The erection contractor usually furnishes equipment and cranes for erecting the frame; in some instances, the general contractor may furnish a crane and receive a credit from the erection company for its use. Erection of steel is generally fast paced and requires careful planning. Steel is fabricated to close tolerances. Precise layout and accuracy are important in making certain that the frame fits together properly. The steel erector may subcontract installation of a metal deck and shear studs to separate lower tier subcontractors, as these specialty firms may be more efficient at installing these items.

Safety is an extremely important aspect of steel construction. Safety issues are discussed in Section 1.12.

During the erection process the frame will be plumbed; temporary bracing and guy cables may be installed to maintain structural stability during erection. Erection will continue until all of the structural steel members have been installed and the structural frame is essentially complete. Metal fabrications and miscellaneous steel items, if included in the steel subcontract, are installed as necessary, based on the overall project schedule and applicable safety standards. With the completion of the frame, the steel subcontract is ready for contract closeout.

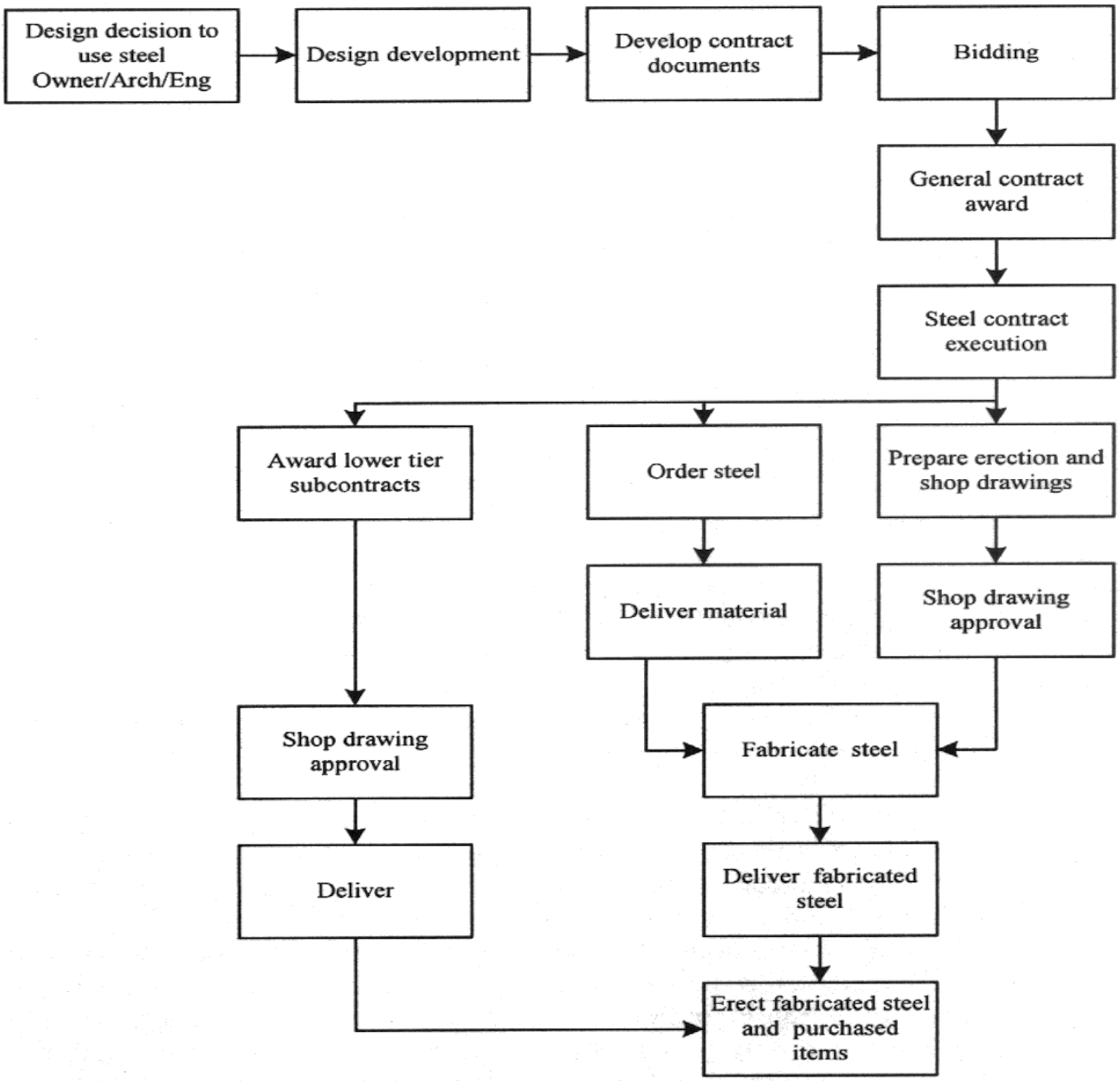

Figure 1-2 Stages of steel project management

1.5 Responsibilities of Industry Participants in Steel Construction

Many parties have responsibilities in the successful procurement and implementation of steel construction for buildings. As previously discussed, the entire process begins with the owner's decision to use a steel frame. The architect and engineer, together with the construction manager or design-builder make recommendations to the owner. The structural engineer plans and designs the steel frame. The contractor, construction manager or design-builder coordinate the bidding and construction process. Steel suppliers, steel fabricators, detailers, erectors and specialty lower tier subcontractors fabricate and install the work. Finally, building inspectors and testing agencies also have important roles to ensure quality. Listed below are the principal participants in planning and delivery of steel structures, together with a brief description of their primary responsibilities:

Owner

The owner is the entity, agency or organization which owns and operates the completed facility. The owner's primary responsibilities are to employ an architect, to furnish a design program, furnish the contract documents, provide relevant information to the contractor, provide a site upon which to build, and pay for the work. The owner may also, under some contract forms, furnish the property and other insurances. In a general contract form, the owner has a direct contract with the architect and general contractor, but will not have a direct contract with steel subcontractors. In some construction management contracts, or when multiple prime contracts are awarded, the owner may have a direct contractual link to the steel contractor.

Architect

The architect designs the project based on the owner's design program, developing the schematic layout showing the space layout and overall building concept. The architect will utilize either an in-house structural engineer or an outside consulting engineer to develop the structural concept for the building. The architect also develops the construction documents for the architectural portions of the building and coordinates the work of mechanical, electrical, structural and other specialty engineering and design disciplines for the project. The architect usually assists the owner in developing the bidding documents, soliciting bids from contractors, and awarding the contract for construction. During construction, the architect will have a contract administrative role conducting activities such as reviewing applications for payment, observing the work, processing change orders, and reviewing shop drawings.

Structural Engineer

The structural engineer is responsible for the detailed structural design for the structural steel portions of the project. As part of this process, the structural engineer develops detailed structural steel contract documents and specifications. Other important functions of the structural engineer are to review steel shop drawings for consistency with the design intent and to review the structural assembly during the construction phase. The structural engineer also has contract administrative duties, similar to those of the architect, described above. The structural engineer may be either an employee of the primary architectural and engineering firm, or an employee of an outside consulting firm, or of the owner.

General Contractor

The general contractor (GC) has a contract with the owner to coordinate and construct the entire project. As part of this responsibility, the general contractor will define subcontract workscopes, solicit competitive subcontract prices, schedule and coordinate the work of all subcontractors, and construct certain portions of the building with the contractor's own work forces. Under this project delivery system, the general contractor has a direct contract with the steel subcontractor and becomes ultimately responsible for the subcontractor's work through the general contractor's contract with the owner. Other duties of the general contractor are to obtain payment from the owner, pay subcontractors, develop a safety plan, review and transmit shop drawings, provide the primary building layout lines, and furnish general condition items for the project.

Construction Manager

The construction manager (CM) is a professional management person/ organization employed by the owner to oversee and manage the project. The CM is usually hired early in the project, preferably prior to the design stage, and provides advice to the owner regarding systems selection, scheduling, budgeting, and coordinating bid packages for the trade contractors. During the construction phase, the CM will oversee the work and perform many of the coordination functions of the general contractor. In some instances the CM may assist the owner in selecting the design architect and structural engineer.

Design-builder

Design-build is an alternative approach to both the general contract and the construction management methods of project delivery, where the design-builder is responsible for furnishing both design and construction services. Generally, the design-build team will be led by the construction entity which uses in-house or outside consulting architectural and engineering professionals to furnish the design services. Because the design-builder is responsible for delivering a given project within an established quality level and within a specific schedule, the design-builder is in a position to select and evaluate building systems which are within the owner's budget and satisfy other project constraints. The design-builder works closely with the steel contractor in the initial project planning phase as they select and define the structural system. This early input by steel constructors is extremely helpful in establishing a workable schedule and in meeting the overall project requirements.

Steel Contractor

The steel contractor is the lead subcontractor, having general responsibility for all aspects of fabrication and erection of the structural steel frame. The steel contractor may be a fabricator, erector, or in some cases, both a fabricator and erector. The steel contractor is usually a subcontractor to the general contractor, or may on some construction management projects have a direct contract with the owner.

Steel Fabricator

The steel fabricator is responsible for fabrication of primary steel components to the point that they are ready to erect by the steel erector. This process includes material takeoff, ordering of steel shapes, developing shop drawings, layout and fabrication of the elements, and delivery to the site.

Steel Erector

The steel frame is erected by the steel erector. The erector may be a separate subcontractor or may be part of the steel fabrication company or a subsidiary. The erector works closely with the general contractor and fabricator to establish the erection sequence and to assemble the frame.

Lower Tier Subcontractors

Specialty lower tier subcontractors are frequently used by the erector to install metal decking and shear studs. Using these lower tier subcontractors frees up the erector's crew to install the main steel elements. Other specialty companies may be hired by the fabricator to fabricate special components, such as handrails or stairs, as part of the steel fabrication or miscellaneous metals subcontract. Generally, lower tier subcontractors have direct contract with either the fabricator or the erector.

Steel Suppliers

Steel for larger projects will be purchased directly from the steel mill. Steel is rolled and produced by the mill from the mill order for the specific project. On smaller projects or projects requiring an expedited schedule, the steel fabricator may order steel from a steel service center (warehouse). Both the mill and the service center must supply steel which meets the material characteristics specified and national testing standards.

Detailers

Shop drawings, anchor rod layouts and erection drawings are developed by detailers under the direction of the steel fabricator. These detailers may be independent companies or may be employed by the steel fabricator. The primary job of the detailer is to prepare detail drawings for fabrication and erection in compliance with the project requirements, fabricator standards, erector standards, and AISC specifications.

Proper communication and coordination among the participants are essential for the timely completion of structural steel. The following parties were involved in the case study project:

1. Owner
2. Architect
3. Structural engineer
4. General contractor
5. Steel contractor (fabricator/erector)
6. Steel suppliers
7. Lower tier sub contractors (sub-subcontractors)
   - Deck supplier
   - Joist supplier
   - Deck erector
   - Shear stud supplier/installer
   - Miscellaneous metals and special fabrication supplier

Figure 1-3 shows the contractual lines of responsibility for a typical project which uses structural steel. Note that in the case study project, the steel contractor had both fabrication and erection capabilities and that there was no separate lower tier erection subcontract.

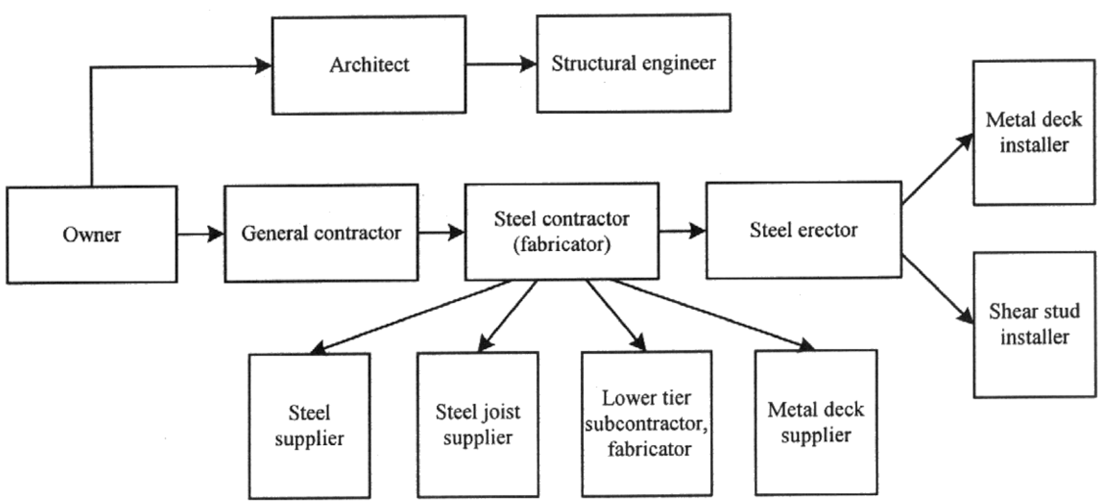

Figure 1-3 Lines of responsibility on a steel project.

1.6 Contract Documents Overview

The words "Contract Documents", in the context of a construction agreement, are legal terms of art with a special connotation. The precise documents which comprise the "Contract Documents" can vary from contract to contract. Because of this, the term "Contract Documents" is often defined in the opening paragraphs of a project contract or general Conditions. This definition should be reviewed on each new set of bidding documents. It almost always includes more than a single document or sheaf of documents.

Normally, contract documents for structural steel consist of the contract, the general and supplementary/special conditions, the drawings and specifications, addenda issued prior to contract execution, and modifications issued after contract execution. The contract may be a subcontract between the general contractor and the steel contractor, or in some instances the contract may be directly with the owner. Some subcontracts may also incorporate certain responsibilities and provisions of the general contractor's prime agreement with the owner. The contract documents are generally prepared by the architect and structural engineer. The general and supplementary conditions define the general contractor's broad overall responsibilities and are often incorporated by reference into the steel subcontract. The structural drawings and specifications are prepared by the structural engineer and define the required materials and products, installation requirements, and contract administrative requirements for the project.

Structural Steel Drawings. The structural steel drawings that are prepared by the structural engineer indicate the sizes and arrangement of the structural steel elements that make up the structural steel frame. Generally, they consist of foundation plans, structural floor and roof framing plans showing column and beam sizes and locations, column schedules, general structural notes, and various special and general details. The structural drawings usually include general details consisting of typical details for column base plates, column and beam splices and connections, floor and roof openings, composite beam and metal deck details, and lintel schedules. Also included are details that illustrate special or nonstandard structural conditions designed for the project. Figures 1-4, 1-5, and 1-6 show sample structural steel drawings.

The AISC *Code of Standard Practice* requires the owner's authorized representative, usually the structural engineer of record, to provide complete contract documents "Released for Construction." Plans provided as part of a contract bid package are considered to be "released for construction" unless otherwise noted. This is necessary to assure that the owner receives adequate and complete bids, and to enable timely completion of shop drawings and fabrication. The "released for construction" contract documents are assumed to provide complete structural steel design plans clearly showing the work to be performed and providing the information required by Section 3 of the *Code of Standard Practice*. When it is necessary for a project to be advertised for bidding before the requirements of Section 3 can be met, the owner's authorized representative must provide sufficient information in the form of scope, drawings, weights, outline specifications, and other descriptive data to enable the fabricator and erector to prepare a knowledgeable bid.

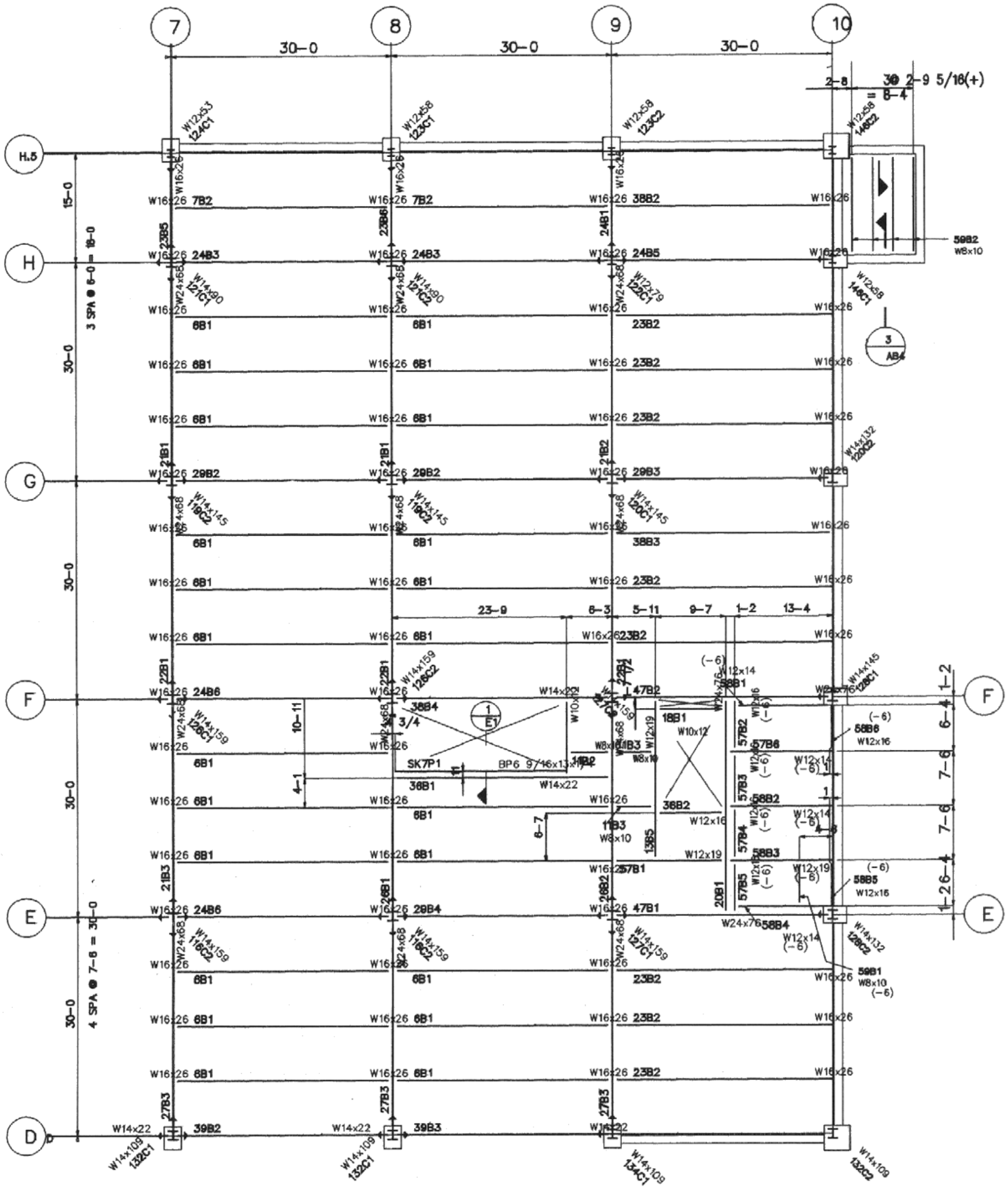

Figure 1-4 Representative structural framing plan

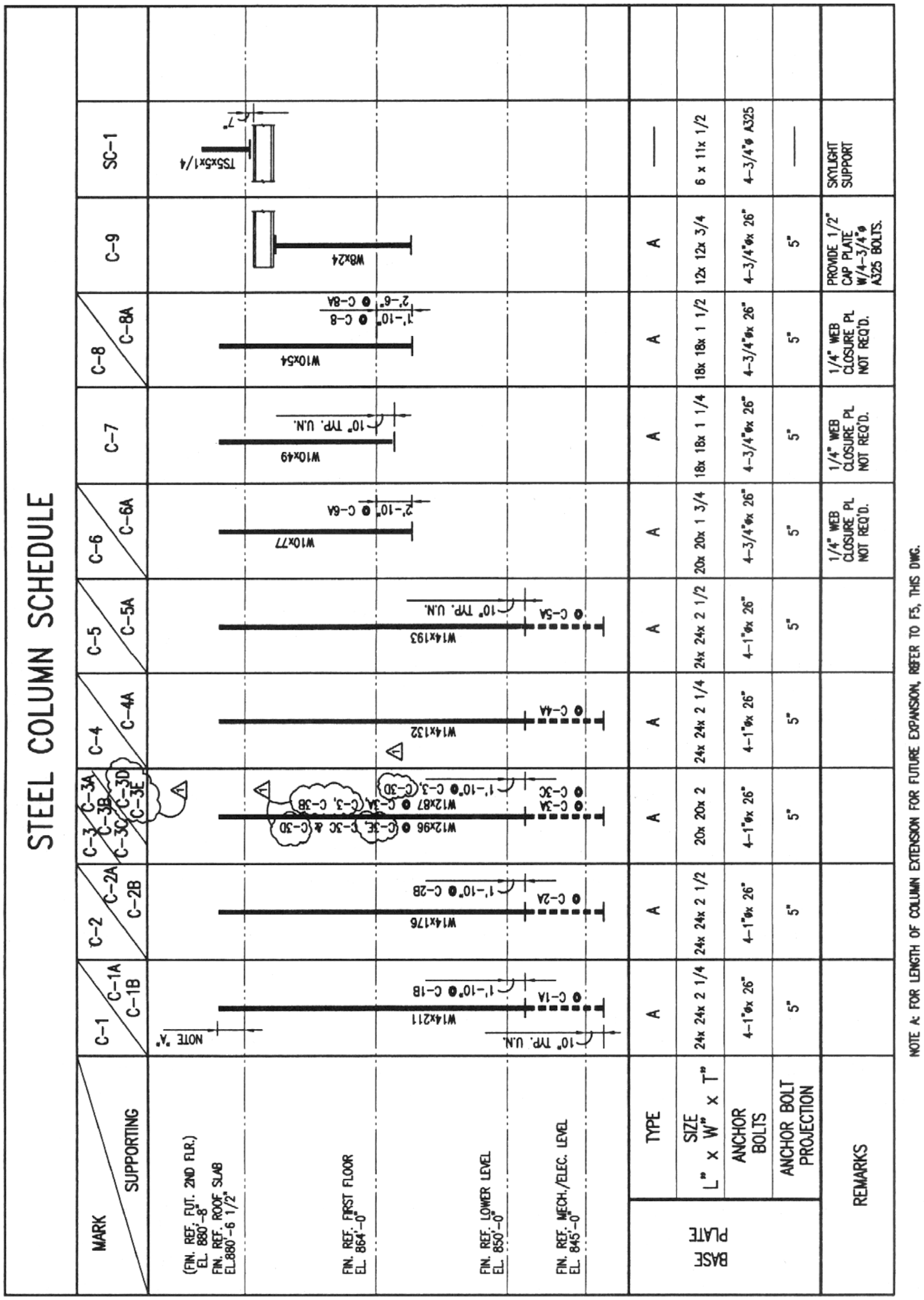

Figure 1-5 Representative column schedule

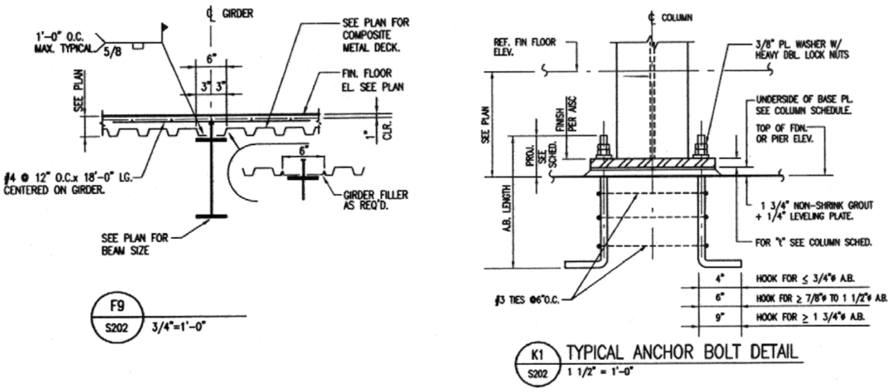

Figure 1-6 Typical details

The column schedule will usually indicate the column size and critical vertical dimensions such as elevations of base plates, column splices, and top of a column. If included, the beam schedule indicates beam sizes, structural reactions usually in kips, spacing and size of shear connectors if composite beam deck interaction is required. Any special requirements, such as beam camber or special connections may also be included.

Typical connection details may be addressed in the structural drawings. Frequently, however, the detailed design and layout of the beam-to-beam and beam-to-column details are left to the fabricator and the steel detailer. The detailer will develop the connection details as part of the shop drawing process and these connections will be reviewed by the structural engineer during the shop drawing approval process. This has the advantage of giving the fabricator flexibility to fabricate connections in a manner most suitable to the fabricator's standard shop practices and equipment. The 1997 edition of the American Institute of Architects (AIA) A201 General Conditions of the Contract for Construction requires that any design service required of the contractor be specifically set out in the contract documents, and further requires that the contract documents specify all performance and design criteria that the service must satisfy. In some instances, the contract documents will require that the components which are designed by the fabricator will be certified by a licensed engineer. However, in all instances, the architect or its designee, usually the structural engineer of record, must review and approve all submittals, including those prepared by a licensed engineer retained by the contractor, and take responsibility for the adequacy of the performance or design criteria required by the contract documents.

The structural engineer also develops the steel specifications. The specifications indicate administrative procedures, material requirements, and installation requirements for the project. The AISC Code of Standard Practice and Specification should be incorporated into division 5 or comparable specification sections which deal with Structural Steel.

1.7 Specifications

Specifications for structural steel are prepared by the structural engineer and are typically bound into the architect's project manual that includes all the specifications for the building. Although different specification formats may be used, many engineers use the Construction Specifications Institute (CSI) Masterformat or the AIA Masterspec format. These formats use a unified construction index system which places all products and materials into 1 of 16 divisions. Figure 1-7 below lists the 16 divisions. Structural steel and other associated metal products are classified in Division 5.

1	General Requirements	9	Finishes
2	Site Work	10	Specialties
3	Concrete	11	Equipment
4	Masonry	12	Furnishings
5	**Metals**	13	Special Construction
6	Wood and Plastics	14	Conveying Systems
7	Thermal and Moisture Protection	15	Mechanical
8	Doors and Windows	16	Electrical

Figure 1-7 Unified Construction Index divisions

Under the unified construction index, all products and materials carry a five-digit section code that establishes their division number and distinguishes them from other categories of materials within the division. For example, structural steel has a section code of 05120 and steel joists have a section code of 05210. Figure 1-8 below indicates the sample section codes for items in Division 5 Metals.

05010 Metal Finishes
05120 Structural Steel
05210 Metal Joists
05300 Metal Decking
05400 Cold Formed Metal Framing
05500 Metal Fabrications
05520 Handrails and Railings
05700 Ornamental Metalwork
05715 Prefabricated Metal Stairs
05800 Expansion Control

Figure 1-8 CSI Division 5 specification items

Each specification section is divided into 3 parts: Part 1 General, Part 2 Products, and Part 3 Execution. For example, Section 05120 Structural Steel: Part 1 General, includes administrative procedures such as quality control and shop drawing requirements. Part 2 Products, lists the acceptable materials, and Part 3 Execution, indicates the installation requirements. See Appendix B for a sample structural steel specification for the case study.

Part 1 General, of the specification section on structural steel 05120 typically includes:

1. Summary of the work
2. Related sections (related work specified elsewhere)
3. Performance requirements
4. Submittals (product data, shop drawings, qualification data for firms, mill test reports
5. Quality assurance (installer qualifications, fabricator qualifications, applicable reference standards, professional engineer qualifications, welding standards)
6. Delivery, storage, and handling
7 Sequencing
8. Allowances (engineers' allowance for adding steel components to the design)

Part 2 Products, of the specification section on structural steel 05120 typically includes:

1. Structural steel shapes, plates, bars
2. Cold formed steel tubing
3. Shear connectors
4. Anchor rods, bolts, nuts, and washers
5. Non high-strength bolts, nuts, and washers
6. High-strength bolts, nuts, and washers
7. Welding electrodes
8. Grouts
9. Primers
10. Fabrication requirements (addressing items such as tolerances, cambers, cutting, holes etc.)
11. Shop connections (welded, bolted)
12. Shop priming (surfaces required, surface preparation, painting requirements)
13. Galvanizing
14. Source quality control (requirements for independent testing of fabrications, welds, connections, etc.)

Part 3 Execution, of the specification section on structural steel 05120 typically includes:

1. Requirements for examination of bearing surfaces, elevations, and locations of anchorage
2. Preparation (requirements for temporary shores, guides, bracing)
3. Erection (setting base plates, erection tolerances, alignment and plumbing)
4. Restrictions on field cutting and hole enlargement
5. Field connections (bolting, welding)
6. Field quality control (testing and inspection)
7. Cleaning (touch up painting, galvanized surfaces)

Upon obtaining the contract documents and deciding to bid the work, the steel contractor reviews and correlates the plans and specifications. An important part of this review is to identify the elements which will be subcontracted. In the case study project, the steel contractor performed both fabrication and erection of the structural steel frame. Steel joists and metal deck were purchased and the metal deck and shear stud installation were subcontracted. When reviewing the specifications, it is important that the steel contractor identify any unique administrative procedures, material and finishing requirements or installation requirements that are not standard practice and which impact pricing, obtaining materials, scheduling, or quality of workmanship.

In some instances, the steel contractor may elect to exclude certain specified elements from the subcontract workscope. For example, steel contractors will frequently exclude grouting of base plates. When the steel contractor elects to exclude elements from the workscope, it is important that the general contractor is aware of these exclusions.

1.8 Steel Fabrication and Erection Subcontracts

Steel construction will usually involve the use of subcontractors and lower tier subcontractors. The steel contractor may serve as a subcontractor to a general contractor. Specialty contractors, such as metal deck installers, may serve as lower tier subcontractors to the steel contractor. Typical lower tier subcontracts found on steel frame projects include: fabrication, erection, metal deck installation, shear stud installation, metal fabrications, and furnishing of miscellaneous metals.

As with most construction subcontracts, many basic contractual issues need to be addressed. Typical clauses identifying the date, parties, and contract documents, as well as provisions for payments, insurance, and dispute resolution etc., should be incorporated. Since this manual is not intended to be a comprehensive guide to subcontracts, these basic contract components are not addressed in this manual. The reader should refer to other sources such as AGC650 or AGC655 issued by the Associated General Contractors (AGC) or the A401 issued by the American Institute of Architects (AIA) for their standard form subcontracts. The purpose of this section is to address those clauses which are unique or of special interest in steel subcontracts, for both the subcontractor and the general contractor.

Incorporation by Reference. The subcontract frequently incorporates all or portions of the prime contract by reference. This has the effect of binding the parties to the conditions of the prime contract, as if they were physically attached to the subcontract. It is important for both of the contracting parties to obtain copies of the incorporated documents and to understand their impact. Occasionally, the terms of the subcontract may conflict with the incorporated terms of the prime contract. This could be handled by the use of a “precedence” clause (a clause indicating which document will govern in case of a conflict in documents.)

Scope of Work. The scope of the subcontractor’s work should be clearly defined in the subcontract. This definition should include the general conditions or services which the subcontractor must provide, and those which the general contractor will provide for the steel contractor. The general contractor may use CSI specification sections to indicate work included in the subcontract. However, care should be taken when describing workscopes that incorporate work from portions of multiple CSI sections or divisions. For example, the general contractor may require the mason to furnish steel lintels specified in Division 5 Metals, and installed by the mason under Division 4 Masonry. In this instance, it would be important to indicate clearly to the miscellaneous metals contractor that lintels were not in the project workscope. Standard workscopes are discussed more fully in Section 1.9 of this manual.

Use of General Contractor’s Equipment. Under most subcontracts, the subcontractors furnish and utilizes their own equipment for completing the work. For steel work, there may be rare occasions, such as in high-rise buildings or on restricted sites, where the general contractor will provide cranes or lifting devices for the project, charging the subcontractor for their use. Scaffolding may also be provided by the general contractor on some renovation projects. When the subcontractor uses any portion of the contractor's equipment, it should be only by written agreement that clearly defines the terms of use.

When the erector is to use the crane provided by the general contractor, the erector will typically want to use its own crane operator. It is also important that the erector has full access to and use of the crane during the erection period, so that the erection operation can proceed as planned and the schedule is not disrupted by other competing lifting activities which may use the crane. The general contractor should recognize the erector's need to proceed with the work and that crane access is important in maintaining the erector's schedule.

Layout Responsibilities. The general contractor establishes the main axis lines for the project. Generally, each of the subcontractors has responsibility for laying out their own work and examining construction in-place before installing their portion of the project. With steel construction, the steel fabricator typically furnishes the general contractor with anchor rod setting plans and setting plates that are used to set the anchor rod locations. Prior to shipping fabricated steel to the site, though normally not contractually required to do so, the steel contractor may wish to field check the actual anchor rod placements and plate elevations. The steel contractor should notify the general contractor if they are not installed in accordance with the setting plans. If checking of anchor rods can be accomplished early, then the foundation contractor will be able to relocate and correct the placements prior to arrival of steel at the site. If improper placement of anchor rods is not discovered until the steel arrives, delays, productivity loss, and additional costs may be incurred from having to modify the steel components or anchor rods.

Schedule and Time Requirements. Time and schedule are very important on most projects. The owner will frequently seek protection from the general contractor for delays caused by the contractor or subcontractors. As a consequence, the general contractor will include protective clauses in the subcontract. The general contractor's prime contract may contain a "time is of the essence clause" that makes time a material aspect of the contract. The owner-contractor agreement may also contain a liquidated damage's clause providing for compensatory damages due to delays.

The general contractor typically establishes the overall construction schedule for the project. This schedule should incorporate early input from the major subcontractors for the project and from subcontracts that have the potential for significantly impacting the schedule. The general contractor may establish the right, in the subcontract, to change the schedule and require the subcontractor to perform in accordance with the adjusted schedule. Another form of protection which the general contractor may use is to include a liquidated damages clause in the subcontract, which provides for compensatory damages in the event that the subcontractor's work delays the project. In some instances, the steel contractor may be delayed in the start of erection because the building is not ready for erection of steel. The general contractor may use a "no damages for delay" clause that prohibits the subcontractor from seeking damages from the general contractor. The steel contractor may wish to exclude or negotiate these protective clauses based on the project conditions.

The best form of protection from delays is a proper set of "released for construction" contract documents prepared in accordance with Section 3 of the *Code of Standard Practice*, coupled with early coordination and frequent communication between the general contractor and the subcontractors. The steel contractor's early input into the schedule and agreement as to the sequence of construction and erection is an important element in avoiding delays. Early ordering of steel and commencement of shop and erection drawings, as well as a smooth process for approval of shop drawings, and a clear "request for information" (RFI) process can all help to alleviate delays caused by the steel contractor. Refer to Manual Module Two for a detailed discussion of scheduling steel construction.

1.9 Structural Steel Workscopes

The structural steel subcontract typically includes the fabrication, delivery, and installation of structural steel framing (05120), steel joists (05200), and metal decking (05300). This workscope may also include other items such as metal fabrications (05500), ornamental metals (05700), handrails, and railings (05520). The general contractor should be precise in indicating which specification sections are to be included in the steel subcontract. A single subcontract is frequently awarded for the complete structural steel frame and a separate subcontract awarded for the metal fabrications, loose lintels, handrails etc.

Careful definition of the workscope by the general contractor is extremely important in ensuring that all components for the project are assigned and accounted for and that no items are double counted. One method for assigning workscopes is to assign all work specified under a particular CSI specification section number. Frequently, the subcontractor's work includes work from several specification sections. This will cover most of the elements for the project. However, the contractor should proceed cautiously because certain elements may be indicated on the plans that are not specified in the project manual. The contractor should carefully correlate the plans and specifications to ensure that all project elements are properly assigned.

The assigned specification sections indicate to the subcontractors the detailed administrative, product, and installation requirements of their portion of the work. The subcontract provisions indicate the contractual and procedural requirements which bind the subcontractor and the contractor.

A typical workscope for structural steel includes the supply and furnishing of all labor, materials, tools, scaffolding, apparatus, supplies, welding rods, equipment, machinery, transportation, supervision, insurance, taxes, permits and fees when required, technical services, and all operations as required for the satisfactory performance and completion of the work in accordance with the contract documents. Other items typically included in the workscope are listed below:

1. Allowances and/or unit prices as specified in the technical section
2. Sales and use taxes
3. Liability insurance for own forces, vehicles and operations
4. Testing as specified
5. Attendance at project coordination meetings
6. Submittal of shop drawings, product data, samples, design data, test reports, certifications, manufacturers' instructions, field reports
7. Extra materials as specified
8. Warranties as specified (as well as warranties required by the general conditions)
9. Delivery to the site of materials and equipment
10. Safety provisions
11. Unloading of materials at the site

12. Detailed layout of the work specified
13. Storage provisions for materials and equipment
14. Hoisting of workers, material and equipment required by the work
15. Scaffolding required by the work
16. Electric cords as necessary to convey temporary electricity for the work
17. Provisions for temporary electricity
18. Provisions for temporary task lighting
19. Cost of cutting and patching work
20. Protection of other work from damage
21. Cleanup of waste and debris
22. Submittal of project record documents

Some items typically furnished by the general contractor and commonly excluded from the subcontractor's work are listed below:

1. General layout of the project
2. Temporary sanitation facilities
3. Proper access to and around the site
4. Material testing unless specified to be by the subcontractor
5. Trash dumpster
6. Final cleaning

Source: adapted from Construction Industry Research Committee's (CIRC) Recommendations for Subcontract Workscopes (1986).

1.10 Overview of Scheduling

An important aspect of the general contractor's job is to prepare a construction schedule that permits the project to progress smoothly and to complete the project in the time allotted by the owner in the contract. Structural steel is a large and important early component of the building and has many sub-activities that need to be coordinated.

Scheduling, timely delivery, and erection of the fabricated components, involve a broad range of activities including ordering mill steel, preparation and approvals of shop drawings, fabrication, applying coatings, delivery to the site and erection. Each of these activities has its own nuances and variables that should be considered in preparing the steel portion of the schedule. These activities must be well organized, coordinated, documented, and communicated with the many parties to avoid delays. Shop drawings, for example, prepared by an independent detailer are reviewed by the fabricator, contractor, architect, and structural engineer. Initial drawings may need to be revised for final approval. All parties have an important stake in maintaining the schedule and should work within the schedule limits for delivery and approval for shop drawings.

The steel contractor should be consulted as the general contractor prepares the overall project schedule. The steel contractor needs to have input on likely durations for the various structural steel related activities. Refer to Module Two for a discussion of scheduling.

1.11 Site Organization, Logistics, and Equipment

The general contractor must consider many factors in laying out the site to support the construction operations. First, the general contractor must pro-actively plan and manage the construction of the project in a timely, safe, and economical way that delivers the quality level required by the contract documents. The general contractor operates within the context of a diverse group of materials, construction processes, equipment, subcontractors, professions, personalities, governmental agencies, transportation systems, and weather. The general contractor must manage these elements for a typically limited project site. The general contractor must be able to take all of these factors into account when planning the work and the site is laid out.

Some of the critical elements to consider in the site layout are listed below:

1. Site size and configuration
2. Location of adjacent roads, buildings and utilities, subject to damage
3. Location of roads available for transporting materials and equipment
4. Likely access points to site and buildings on the site
5. Location, height, size, configuration of building being constructed
6. Soil conditions and excavation requirements
7. Relationship of building and its components to the site
8. Location of site underground utilities
9. Proposed construction methods for major building systems
10. Construction sequence and schedule
11. Erection and installation equipment requirements for major building systems
12. Material quantity, storage, and delivery requirements
13. Entrance points for workers to site
14. Worker parking
15. Tool and equipment storage requirements
16. Construction operations facilities and trailers
17. Sanitary facilities
18. Safety
19. Fire protection
20. Efficiency of materials movement and management

There are unique sets of conditions for each project, that must be considered; any of these factors may take on more or less prominence. For example, on some projects a restrictive site may dictate the construction method and the contractor's site layout will be heavily influenced by the construction equipment that will be used. In other instances, the site layout may be influenced more by limited access points, excavation and shoring requirements. The construction equipment may dictate that measures such as temporarily leaving out a portion of the foundation, may be necessary in order to move equipment into the building footprint. Site layout is complex and requires experience and expertise in balancing the many factors involved.

Structural Steel. Regardless of the interplay of the various site layout factors to be considered for an individual site, it is clear that the structural steel erection process will heavily influence the contractor's site layout, construction schedule, and the construction sequence. A poorly conceived site layout will lead to unnecessarily large erection equipment in order to handle large reaches, increased movement of materials, slower progress, increased accident potential, and increased cost.

Because the structural frame is such a dominate component in the overall building, its successful completion often sets the overall tone for the building project and subsequent trades. The lifting equipment, whether stationary towers, truck mounted mobile cranes, or crawler mounted cranes, requires adequate space for setup operation and removal. Deliveries of steel tend to be large (up to 20 tons) and transported by truck. The steel is sometimes unloaded from the truck and immediately erected in a single operation. This “just in time” delivery creates a savings of ground storage space because the need to stockpile beams and columns is eliminated, but this method requires the designation of an unloading zone. Trucks delivering steel will occupy this space during the erection process. Steel may also be off loaded in designated “lay down” areas and marshaled to the erection area as needed.

The general contractor will need to consult closely with the steel contractor and the steel erector to establish the construction schedule and construction sequence. Large horizontal structures such as industrial plants and warehouses, may require that the building be erected in sections with mobile cranes moving inside the building footprint. This process may allow for steel to be erected on one side of the building while foundations are being erected on another portion of the building (parallel construction activities). Vertical structures such as the project case study, could be erected one floor at a time for narrow footprints or could be erected in vertical sections from ground to roof level, with each section being completed before moving equipment to set steel for the next section. The case study project was divided into three areas consisting of multiple sequences that reduced the need for frequent moving of the equipment on the site. This was important because of the limited site area.

The AISC Code of Standard Practice requires that the steel erector be provided with safe, adequate access to the site, and a firm, properly graded, well drained, adequate and convenient space in which to set up and operate erection equipment. The steel erector also needs to be able to work in an area free of overhead power lines or other obstructions.

The erector may lease or own the lifting equipment for the project and will select equipment based on the following criteria:

1. Lifting loads
2. Reach required
3. Lifting heights
4. Crane radius
5. Setup and maneuvering space available
6. Mobility requirements
7. Strength of the ground base
8. Construction sequence
9. Erection sequence (i.e., horizontal or vertical sections)
10. Number of cranes to be used
11. Fabricated steel delivery points
12. Times the crane will be used
13. Costs
14. Availability of equipment

Selection of the lifting equipment is a specialized field and will generally be completed by experienced personnel within the erector’s organization or by outside consultants retained by the erector. When special site or lifting conditions are encountered, the erector may employ a consulting engineer and work closely with lifting equipment suppliers to determine suitable equipment.

Crane options for the project range from truck or crawler mounted mobile cranes, fixed tower cranes, or climbing cranes. Mobility and allowable lifting load for the required reach are important determining factors. Generally, tower cranes will have higher lifting loads for long reaches, but they have the disadvantage of lack of mobility. Mobile cranes such as truck or crawler mounted cranes will have the advantage of being able to move around the site, but have smaller lifting capacities than tower cranes. Crawler cranes may move while lifting loads; truck mounted cranes typically cannot. Truck mounted cranes can be driven to the site; crawler or tower cranes must be transported. Each crane type has various advantages and disadvantages; the erector will consider all of these factors in selecting the equipment. The reader should refer to construction equipment textbooks for detailed information on crane types.

Occasionally more than one crane will be used for a project, allowing the contractor to increase erection speed. Sometimes the erector will use cranes in a tandem to lift long elements such as long span trusses. In this instance, adequate space for movement of the cranes is necessary and the need to coordinate the simultaneous movement of separate cranes becomes important.

Figure 1-9 Crawler crane

1.12 Safety

Safety on all construction sites is a vital issue. With structural steel erection, the potential risks for exposure of workers to equipment, falls, being struck or caught between material and equipment are ever present. This manual is not intended to be a detailed guide to safety in steel construction. However, because of the importance for construction management students to be aware of general safety issues concerning steel construction, a brief discussion is provided. While the means and methods of erection are generally the erector's responsibility, they are heavily regulated by Occupational Safety and Health Administration (OSHA) and are reviewed by the general contractor. Safety is ultimately the responsibility of all parties involved with construction, and all have important stakes in maintaining a safe project site.

Responsibilities of the General Contractor. The general contractor is responsible for the means and methods of the construction project. Although the general contractor frequently subcontracts to subcontractors, the responsibility for means and methods and their associated safety practices for various building components, the general contractor retains certain fundamental safety responsibilities. The broad safety duties of the general contractor include:

1. Providing an overall safety plan for the project
2. Maintaining a safe site and working environment for the general contractor's employees, as well as the employees of other contractors
3. Coordinating the work in a manner that does not expose workers to hazards from the work of other subcontractors
4. Maintaining proper supervision during the work
5. Being responsible for the safety of the general contractor's own employees and furnishing proper protective equipment etc. for their employees
6. Maintaining and operating equipment in a safe manner
7. Complying with applicable OSHA or other safety standards
8. Preventing overloading the structure during construction

The broad subcontractor safety responsibilities include:

1. Developing all required safety plans and documentation
2. Being directly responsible for safety of own employees
3. Maintaining proper supervision during the work
4. Providing proper personal protective equipment as necessary
5. Maintaining and operating equipment in a safe manner

Because of the extreme exposure that ironworkers have to the many risks of working in tall buildings and from moving large structural elements and equipment around the site, special attention must be paid to their safety during erection of steel.

Project Planning. Safety begins with close coordination with the general contractor to determine the construction sequence, site layout, location of site storage, staging areas for equipment, and the selection of hoisting and lifting equipment and methods. This is the stage of project planning where space and schedule conflicts among subcontractors can be identified and a plan to avoid conflicts can be developed. Many accidents and injuries on construction sites occur during the moving of materials. If the need to move materials around the site is reduced through proper site layout, then the risk of injury is reduced. A side benefit of this layout strategy is a reduction in time spent on moving materials and an increase in worker productivity. Proper project planning, scheduling and construction sequencing should be developed in such a way that when there is potential danger, subcontractors are not required to work in areas of other subcontractors.

The erector usually conducts weekly "tool box" meetings to discuss safety with project workers. In order to reduce the height of falls the project is typically sequenced in such a manner that metal decking is installed on lower floors before proceeding with erection of steel for the upper floors. Close scheduling and coordination among the metal deck installer, the fabricator's site representative and/or the erector is necessary in order to ensure that the project is not delayed by the metal deck.

Project Site. The AISC Code of Standard Practice calls for the owner (via the general contractor) to furnish and maintain for the steel contractor proper access roads to and throughout the site for safe delivery of materials and equipment. The general contractor must also provide the erector with a firm, properly graded, well drained, convenient and adequate space for operation of equipment. The owner, (again via the general contractor) is responsible for removing all overhead power lines and other obstructions in order to provide a safe working environment.

Erection Plan (Sequence Diagram and Erection Scheme). The steel erector and fabricator should prepare an erection plan (sequence diagram and erection scheme) that enumerates the sequence of the work, together with erection methods and safety procedures to be used. Although erection means and methods remain the responsibility of the erector, the general contractor should review the erection plan for its impact on overall project safety.

Safety Standards. The steel erector and the erector's employees must comply with OSHA standards which are applicable to the work. OSHA requirements for personal protective devices, clothing and equipment, ladders, electrical cords, material safety data sheets, safe equipment operation, accident reporting, use of water craft or aircraft, etc. all apply to steel erection activities. Special standards for fall protection are also outlined in Sub Part R of the OSHA standards and/or state construction safety standards.

Temporary Bracing. The AISC Code of Standard Practice requires that the erector design and install any temporary supports, shoring, guys, bracing, etc. necessary to maintain the stability of the structure during the construction process. In self-supporting frames which will be stable when completed, (without the interaction of other building components), the erector installs the necessary bracing to brace the frame during erection, in addition to the permanent bracing. The erector must also provide bracing for non-self-supporting structures. Non self-supporting structures require the interaction of elements other than structural steel for stability of the structure, such as masonry shear walls. Non-self-supporting structures must be clearly identified in the contract documents. The erector designs the temporary bracing system utilizing the information provided in the contract documents. A registered engineer hired by the erector may be required to furnish sealed engineering calculations for complex bracing systems. The general contractor is responsible for installing the elements other than structural steel that will ultimately brace the structure.

Removal of the erector's bracing, shoring and other temporary supports should not be undertaken by any party without the consent of the erector. Bracing remains the property of the erector and should be returned to the erector. AISC has published a design guide for erection bracing entitled "Erection Bracing for Low-Rise Structural Steel Buildings," as part of its Steel Design Guide Series.

Lifting Devices. The steel erector is responsible for selecting and furnishing hoisting and lifting devices for the erection of the frame. Crane stability must be analyzed for the loads, reach, soil conditions, and environmental loads caused by wind, earthquake, and other conditions.

1.13 Coordination and Reporting

For fast paced structural steel construction projects, coordination and reporting among the parties is essential. Many coordination and reporting activities are mandated by the project contract documents, and others are simply good management practice.

Generally, the contract documents require that the general contractor organize a preconstruction conference, in addition to periodic progress meetings where the major subcontractors are required to be in attendance (together with the general contractor, architect, and the owner's representative). Progress meetings typically will have a standard set time (such as weekly) and will normally have a set agenda. A party, usually the general contractor, is responsible for recording notes of the meeting and distributing them to those in attendance. The purpose of these meetings is to coordinate activities, identify and devise strategies to correct problems, report on progress, etc. Since structural steel is a major component of the project, the steel contractor should be an active party in these meetings.

The contract documents normally mandate that the contractor and subcontractors furnish certain reports, data, certifications and other submittals. Requirements often include:

1. Lien waivers from suppliers and contractors, affidavits of payment
2. Verification of wage statements for prevailing wage projects
3. Verification of WBE and MBE compliance (Women Owned Business and Minority Owned Business Enterprises)
4. Nondiscrimination statements
5. Civil rights awardability certifications
6. Subcontractor lists
7. Qualification statements such as "no punishable felonies"
8. Performance and payment bonds
9. Certificates of insurance
10. List of submittals
11. Schedule
12. Schedule of values
13. Shop drawings
14. Product data
15. Mill certificates and test reports
16. Engineering certifications
17. Requests for information (RFI)
18. Consent of surety

The contract documents, through the general and supplementary conditions and the general requirements, normally establish communication requirements for the parties. These documents define the required communication procedures, and notification process, as well as the RFI process.

The contract documents may also mandate that the parties participate in "partnering" for the project or implement "Continuous Quality Improvement" (CQI) or "Total Quality Management" (TQM) for the project. Partnering is a non-contractual method for fostering teamwork and partnership on projects aimed at getting all parties to focus on the common goals of project quality and success. Many large organizations have embraced partnering and other quality improvement methods requiring that all project parties cooperate and participate. Improvement of coordination and communication of the parties is an important outcome of these new contractual requirements.

1.14 Payment

Payment terms for steel construction are defined in the steel contractor's subcontract with the general contractor, or in the trade contract with the owner or CM on construction management contracts. Payment terms that should be included in the contract are: contract price, payment method (such as lump sum or unit cost), terms of progress payments, dates of applications for payment, dates of payment, interest provisions and final payment terms. If retainage is required, then the terms and provisions for release of retainage should also be included. Other special issues that should be addressed are requirements for a schedule of values and any provisions for receiving payment for materials purchased for the project, but stored off-site.

As with all general contracts, the subcontractor (steel contractor) submits a schedule of values and applications for payment to the general contractor for review and approval. The general contractor incorporates the steel contractor's payment amount together with that of the general contractor's and of other subcontractors. The general contractor submits the complete application for payment, along with necessary documentation to satisfy the owner that title to the work and materials has or will pass to the owner. Upon receiving payment, the general contractor disburses funds to the various subcontractors. Final payment less retainage is made at the completion of the steel work, punch list items, and closeout activities. Late payment, nonpayment, and "pay if paid" issues (which are concerns in all subcontracts) are magnified for steel contracts because of the relatively high proportion of the cost of the steel subcontract relative to the total project cost.

Payment may be based on a lump sum with periodic progress payments, or on unit cost methods. Small renovation projects may be based on time and material or cost plus methods. When the payment method is based on a unit cost (such as price per pound of steel delivered and erected), the quantities of materials are based on the gross weight of materials as shown on the shop drawings.

The AISC Code of Standard Practice addresses the standard methods which are to be used for the calculation of weight of structural steel for unit price contracts. The Code of Standard Practice defines the weight of steel as 490 lbs per cubic ft and uses the gross weight and overall lengths of the members, as shown on the shop drawings. The weight of material removed from the member such as by drilling, punching, and coping is ignored. The weight of weld material is ignored, but the weight of bolts is usually included. The AISC Code of Standard Practice may be referred to for a comprehensive discussion of this subject.

While many of the mentioned payment issues are common to most construction subcontracts, several payment issues require closer attention when applied to structural steel contracts. The schedule of values, release of retainage, and payment for materials not yet stored on site, all present some unique concerns. Structural steel construction is usually an early activity in the overall construction of the project, with acquisition of large amounts of raw material and accumulation of early costs. Fair provisions should be developed which protect the owner's security interest, but which also provide for timely cash flow for the steel contractor.

The AIA A201 General Conditions of the Contract for Construction that are frequently used by owners, restricts payment for materials and equipment not delivered and suitably stored on the site, or incorporated into the work. The fabricator may be placed in a position of having to make considerable capital outlays for raw material, with payment delayed until the steel is fabricated and delivered to the site. The owner is naturally concerned about payment for materials that may not arrive at the owner's job site, or when another party has a security interest. AIA A201 allows for payment for raw or fabricated materials stored off-site if approved in advance in writing by the owner, and if the contractor complies with the owner's conditions for establishing the owner's title to the material and proper provisions have been made for storage, transportation and insurance.

The schedule of values indicates how monies are allocated to the various work items for the project and is prepared by the general contractor from information on costs furnished by the subcontractors. Contract documents normally require the schedule of values to be submitted prior to the first application for payment and is used by the owner, architect, and engineer to evaluate the contractor's progress payment applications. The schedule of values for structural steel should contain sufficient detail for the approving architect and engineer to identify and approve payment for specific items such as individual materials acquired, shop drawings completed, elements fabricated or erected. The approving architect will look for elements that are easily identified as being completed and can be quantified. For example, fabrication and delivery of beams is an element that can easily be verified by the architect. Some consideration should be given as to how the schedule of values is structured, in order to obtain payment as quickly as possible for materials acquired or work completed.

Release of retainage is also a key issue with fabricators and erectors. Because the steel portion of the project is an early activity and represents a significant portion of the overall project cost, provisions for partial or early release of the steel contractor's retainage should be requested. For large projects, release of retainage by area or building sequence could be considered. Monies retained by the owner are monies already earned by the contractor, but withheld by the owner as leverage if the work is defective or incomplete. Retainage may be released at various points in the project, but is frequently held until late in the project. In the case of structural steel, defects would normally be discovered during the erection or inspection process, or shortly after, during attachment of other systems. When performance and payment bonds are required, the need for long retainage periods is decreased even further.

1.15 Changes and Modifications

Changes to the structural steel contract requirements due to owner desired changes, unforseen site or project conditions, misplaced anchor rods or foundation work, or inadequacies in the original steel design documents should be made either by the issuance of new documents, or by the reissuance of documents. Detailed procedures for construction change directives and change orders are typically outlined in the contract and usually allow the steel contractor to incorporate costs of material, equipment, labor, supervision, increased costs of bonds and insurance, plus a reasonable provision for profit and overhead. Change orders should clearly indicate the changes in scope, contract price, and any changes in time needed for the contract completion.

Change orders in steel construction contain many of the same problems inherent in other trades, such as disagreement over pricing, acceptable overhead and profit rates, and time extensions, or failure of the parties to recognize the impact of the change on other subcontractors or aspects of the project. Because steel is easily reinforced by adding material to the main member, steel may more readily accommodate changes than some other structural frame materials.

Areas of particular concern for change orders in structural steel are the need to reanalyze structural loads carried by members. Minor design changes, particularly of connections, may cause changes in the loading for which the element was originally designed.

Labor charges are also an important aspect of changes in steel. Because structural steel erection is largely impacted by union labor agreements, wage rates, and work rules, owners may not be aware of the impacts and labor charges for minor changes to work in place on the project.

Changes may be necessary to rework steel because the foundations or anchor rods are improperly located. Minor alteration of steel is anticipated by the erector and standard practice calls for the erector to perform some minor alterations such as reaming, welding or cutting. Extensive correction requiring rework of pieces are beyond the scope of the erector's work and would need to be reported to the fabricator. The fabricator, in turn will coordinate repairs with the general contractor or engineer of record. Field work (FW) drawings outlining any rework should be detailed, approved and utilized in the field. It is important that a clear process for documenting field changes is in place and should include documentation of the need for field changes, field work drawings, corrective action records, and "as built" drawings.

The need to control changes on projects in order to reduce impacts on project costs and schedule, is an important activity. Close coordination by the general contractor, the steel subcontractor, other subcontractors, the architect, structural engineer, and the owner can eliminate or reduce the need and impact of change orders. Nevertheless, change orders will occur and it is important that clear change order practices are defined in the contract. Timely notification to the owner of impacts of changes on time and cost are normally required by the contract..

1.16 Quality Assurance

Quality assurance for steel construction is achieved by several means. Quality begins with proper structural design by the structural engineer. The engineer should consider structural loads, building codes, performance parameters, service life and structural efficiency when developing the design. The structural engineer prepares the contract drawings and specifications which convey to the fabricator and erector, dimensional information, member size, material characteristics and standards, installation requirements, and administrative procedures. The contract drawings are assumed to provide complete structural steel design plans clearly showing the work to be performed and to contain the information required by Section 3 of the *Code of Standard Practice.* Failure to meet these requirements can have a direct adverse effect upon the quality of the project.

The specifications normally include elements such as the material strength requirements, dimensional tolerances, and compliance with certain reference standards such as the American Society of Testing and Materials (ASTM), American Welding Society (AWS) the Steel Joist Institute (SJI), the AISC Specifications for Design, and the AISC Code of Standard Practice. The specifications may also require that testing, inspection, and certifications be conducted and are evidenced for mill material, fabrication processes, and erection quality. Mills routinely conduct required tests to assure compliance with ASTM standards for material quality. These test reports are available to the owner when required by the contract documents. Additional testing may be required by the specifications or by the building official. Dimensional tolerances, surface preparation and paint thickness may be checked by the owner's representative, and weld testing and inspection may be required by the specifications.

Quality is also controlled by the shop drawing approval process. Because many parties review these documents, the opportunity to identify problems before they are fabricated are increased. Other important activities in assuring quality include the engineer's periodic review of the work in place, as well as, the internal quality control measures of the fabricator and erector.

AISC has taken a very active role in assuring quality by generating standards that guide the industry in the design, fabrication, and erection of steel construction. AISC publishes the Code of Standard Practice which extensively defines the standard practice for the fabricator and erector. AISC publishes the Manual of Steel Construction, along with numerous other publications which are used by industry. The Code of Standard Practice addresses many aspects of quality control. AISC has both fabricator and erector certification programs in place, which help to elevate the quality of the steel construction industry. AISC is a frequent sponsor of research and educational programs. See Appendix D for a listing of AISC activities.

The purpose of the AISC Quality Certification Program is to confirm to the construction industry that a certified firm has the personnel, organization, experience, procedures, knowledge, equipment, capability and commitment to fabricate and erect steel of the required quality for a given category of structural steel work. However, the AISC Certification Program is not intended to involve inspection and/or judgment of product quality on individual projects. Neither is it intended to guarantee the quality of specific fabricated steel products.

The program uses independent auditors to confirm that an individual fabrication plant has the capability to perform the desired level of work. The program does not look at specific projects; rather, the highly detailed checklist focuses on general management, engineering and drafting, procurement, operations, and quality control.

Fabricators can be certified in one of five categories coinciding with the market for fabrication; erectors are certified in two categories. In addition, fabricators can receive two optional endorsements, one for Sophisticated Paint Systems and one for Fracture Critical Members. Refer to Appendix D for more information on certification programs.

1.17 Project Closeout

At the completion of the structural steel portion of the project, the general contractor and steel contractor will close out the steel contract. Closeout activities include preparation of a punch list of items to be corrected, furnishing of contract documentation, agreement on any extras or back charges that the fabricator, steel erector or general contractor may be owed, and may include "as-built" or record drawings. The steel erector also needs to demobilize equipment, remove any unused materials, remove tools and equipment, and provide general cleanup of the work area.

Punch List. The punch list is prepared when the steel contractor has essentially completed the contract work. At this point, the steel components have been erected but there may be minor elements that need to be corrected or finished in order to bring the project in compliance with the contract documents. The punch list is prepared by the general contractor, steel contractor, structural engineer and architect, who will conduct a walk-through of the project. The punch list represents the work the steel contractor must finish before the work is considered finally complete.

Record Drawings. Many owners require that the general contractor prepare and furnish record drawings or "as-built" drawings of the project. Owners recognize that as the project progresses, the building will change from the original contract drawings. Changes may occur from owner directed changes, corrections to errors in the original drawings, errors in fabrication or erection, and unforseen site conditions. Many design drawings such as mechanical or heating, ventilation and air conditioning (HVAC) drawings are schematic only and the final layout and placement for ductwork is determined during the course of construction. Because of these factors, many owners require by contract that the general contractor furnish a record of how the building was actually built. These record drawings can be invaluable when the owner makes future changes to the building.

As part of the overall responsibility to furnish record drawings to the owner, the general contractor may require the steel contractor to furnish record drawings of the structural steel for the project. Record drawings can range from simple mark-ups of blueline prints, to precise computer-aided design (CAD) drawings of the steel. Some steel contractors will update their erection sheets and furnish them to the owner. Owners may require the contractor to furnish the drawings in electronic format. Since the cost can be substantial, depending on the quality level of record drawings, the contract should clearly state the requirements for record drawings.

Contract Documentation. Closing out the contract requires the transfer of various written documents to the owner and general contractor. The owner will require that the contractor furnish lien waivers for the project from all suppliers and contractors. Governmental owners will have requirements for wage verification statements for those projects requiring payment of prevailing wage. Testing and inspection reports, as well as various certifications may need to be furnished. Mill certificates, weld test data etc. may be required by the contract documents. Generally, documents which are required as part of the close out activities are outlined in the subcontract, the specifications, or in the general and supplementary conditions of the contract.

1.18 Summary

Proper construction management of steel construction can help lead to a cost effective, time efficient structural frame. Construction managers should work closely with their steel contractors to establish a strategy for construction that considers the schedule, site layout, safety, quality assurance, and the work of other subcontractors. Communication and coordination among the contractor, steel contractor, and the design engineer are important components of an overall management approach. Construction managers should understand the roles, responsibilities, and workscopes of each of the participants and how they interact throughout the delivery process. Module One has been developed to give students interested in construction management an understanding of the primary activities necessary to manage steel construction effectively.

Questions for Classroom Discussion

1. What steel components of a building are classified as structural steel by AISC? Are steel joists and metal deck considered part of structural steel?

2. Define the contractual relationships among the general contractor, steel subcontractor, suppliers, and lower tier subcontractors.

3. Define the scope of work of the steel contractor and one of the steel contractor's lower tier subcontractors.

4.. Discuss opportunities for early input by the steel contractor that the general contractor should take advantage of during project planning.

5. How is responsibility for design of connections addressed in steel contracts?

6. Define and differentiate self-supporting and non-self-supporting steel frames.

7. Who is responsible for structure stability during steel frame erection? After steel erection?

8. Discuss the impacts of steel construction on project site layout.

9. What special contractual issues are important in developing steel subcontracts?

10. How can a well managed shop drawing process be used as a coordination tool for project management?

11. Discuss the time and cost implications of safety in steel erection.

Notes

Construction Management of **STEEL CONSTRUCTION**

Scheduling Estimating Module

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INDEX

2 SCHEDULING AND ESTIMATING MODULE

SCHEDULING AND ESTIMATING

2.1 Overview

Construction of the structural frame for a building project is a significant and critical project phase, which represents a substantial portion of the project, in terms of time, money, equipment, and personnel. Structural steel, with proper planning, offers the potential for significant time and cost benefits over other structural systems. In order to take full advantage of these potential benefits, close coordination among the parties and proper planning is essential. An understanding of structural steel activities and their sequence, as well as their relationship to preceding and subsequent construction phases, is important in being able to take full advantage of the schedule reductions which can be generated by using steel. Module Two is intended to introduce students to scheduling and estimating issues which are important in planning for structural steel construction. Project management and contractual aspects of steel construction were presented in Module One of this manual; the reader should refer as needed to Module One for supporting information which is relevant to the scheduler and estimator.

The discussions in this section are based on a typical midsize (three to ten-story) building project similar to the case study discussed in section 1.2. (See case study project documents in Appendix A.) The case study project is based on a general contract form of project management. However, the issues presented in this educational module are also relevant to construction management and design-build project environments.

SCHEDULING

2.2 Introduction to Scheduling

The construction of structural steel is fast paced. On-site construction time is reduced relative to other systems by fabricating steel components prior to erection. Steel may also be erected in all seasons, which provides scheduling flexibility for the overall project. The reduction of on-site time along with scheduling flexibility can ultimately lead to significant savings in general conditions and financing costs.

The fabrication of steel components requires careful planning and close coordination among the various parties. Shop drawing approval, ordering of material, erection planing, fabrication, delivery, and erection activities need to be well orchestrated to ensure a streamlined, delay free process. The preparation of a proper schedule of structural steel activities and integration of this schedule into the overall project schedule are important activities in planning for structural steel construction.

The intent of this portion of the manual is to provide students with an understanding of scheduling structural steel construction by 1) defining the usual structural steel activities, 2) presenting information on sequencing and durations, and 3) discussing scheduling methods which are used in preparing the structural steel schedule. In addition, a discussion of methods for avoiding delays in structural steel is presented.

2.3 Project Delivery Participants and Coordination

A large number of professionals are involved in the construction of a structural steel frame. Industry participants and their roles were discussed in detail in Module One, Section 1-5. The need for proper communication and coordination among the participants is essential for the timely completion of the structural steel.

In order to make an effective and practical schedule for the execution of the overall project, the scheduler should understand how the roles and responsibilities of the participants impact the schedule. The steel contractor, together with the general contractor, will play primary roles in coordinating the various participants. The general contractor will facilitate communications between the designer, other subcontractors, and the steel contractor. The steel contractor will coordinate the suppliers and lower tier subcontractors for the steel contract.

2.4 Project Phases

All building construction projects consist of a series of broad construction phases. While there may be considerable overlap and concurrent activity between the phases, building construction projects may generally be characterized as consisting of the following:

1. Site work
2. Foundation
3. Structural frame (steel construction)
4. Enclosure
5. Electrical and mechanical installation
6. Finishes
7. Testing and operations

The structural steel phase has a significant impact on the overall project schedule; completion of the structural frame is generally considered a significant milestone in overall project completion. Completion of the frame allows the work of the architectural, mechanical, electrical, and finally the finishing trades, to proceed.

While the structural steel phase above is shown as a single phase that follows the foundation work, in actuality considerable pre-erection work consisting of shop drawings, material ordering, and fabrication is conducted simultaneously with the site work and foundation phases. A well integrated overall project schedule will have fabricated steel ready for erection by the time foundations are completed.

Careful coordination between the general contractor and the steel contractor is essential to ensure an efficient overall construction plan. The general contractor and steel contractor will need to decide on an erection sequence. Site layout for construction operations will need to be determined. The steel contractor will need to decide on equipment and methods to be used to erect the steel. Delivery and erection strategies for fabricated steel need to be considered. Early input and consultation with the steel contractor is essential and will allow the general contractor to prepare an effective overall project schedule.

2.5 Overview of Steel Construction Activities

The steel construction phase consists of a large number of detailed activities and sub-activities. However, the entire set of activities can be placed into two broad categories as shown below (AISC 1997, Koch 1997):

1. Fabrication related activities
2. Erection related activities

The two categories of activities are described in detail in the following section 2.6. Other details related to producing a schedule for steel construction are also provided.

Fabrication related activities consist of reviewing the project plans, preconstruction planning, ordering of material for the main steel members, preparing erection and shop drawings, obtaining approval of shop drawings, fabrication and delivery. These activities provide the preparatory work for on-site erection of the structural steel frame.

Erection activities consist of the on-site assembly of the frame, plus considerable pre-erection work. Erection planning and sequencing, equipment selection, safety planning, etc. are all important erection activities. Steel erection can often set the tone for the overall project, and a well coordinated erection plan and timely completion of the frame can greatly enhance the project's success.

Fabrication and erection activities are the responsibility of the steel contractor. This contractor may be a fabricator who subcontracts erection or could be the steel contractor who has the expertise to fabricate and also erect the work. For the case study project, both fabrication and erection were undertaken by the same company.

2.6 Fabrication Related Activities

Structural steel arrives at the job site as a fabricated, ready - to - assemble product. However, prior to delivering the steel to the project site, a considerable amount of activity is undertaken by the steel fabricator (steel contractor). The fabricator has the following primary responsibilities as identified below:

1. Order/purchase steel
2. Produce erection drawings
3. Produce fabrication shop drawings
4. Fabricate steel
5. Quality control
6. Deliver structural steel
7. Coordinate delivery of deck and steel joists
8. Coordinate delivery of miscellaneous steel

Order/purchase steel. Once the contract has been awarded, steel shapes are ordered for the project from the steel mill. Generally, the main beam and column shapes are ordered immediately after contract execution in order to have steel at the fabricator's plant as erection and shop drawings are approved by the design engineer. On expedited or smaller projects, steel may be ordered from a steel supply service center (warehouse) or come from the fabricator's own stock. Fabricators usually maintain an inventory of certain widely used shapes in stock (a sample listing obtained from one of the fabricator members of the Industry Technical Committee is provided in Appendix C). Depending on the project design, specifications, cost, and schedule, the steel fabricator will determine the most appropriate sources of material.

Mill orders often require from 4 to 10 weeks notice before delivery. With fast-track projects, where there may be frequent changes and additions, reordering from a mill can be expensive and impractical. In this case, the fabricator may use service centers or over-design members to accommodate changes. Service centers are usually more expensive sources of material compared to mills. Mills often require that steel members be purchased in 5-ton bundles with a minimum order of 20 tons. This can be a problem when only a small number of certain size members are needed, or if a member is a less common size. When preparing a schedule, the scheduler must consider the timing of steel delivery, based upon purchasing from different sources.

Produce Erection Drawings. The fabricator is responsible for preparing erection drawings (commonly called E Sheets), that show piece marks and where various steel members are to be installed on the job site. These drawings are produced before or simultaneously with the fabrication shop drawings. E-Sheets are also used during the shop drawing approval process in order to identify the exact location of a particular member. Proper identification of the pieces is important so that other detailers and designers know the location of members shown on the shop drawings. The production of E-Sheets for the case study project was spread over 10-12 weeks. See Appendix A for a sample erection drawing for the case study project.

Produce Fabrication Shop Drawings. Shop drawings with details, dimensions, and location of bolts and welds are necessary for fabrication. Shop drawings provide the instructions that the shop worker will follow to fabricate the steel. Shop drawings are sent to the architect and/or structural designer for approval. Shop drawing preparation and approval is an important stage. Defective or incomplete shop drawings create significant problems and time delays during fabrication and erection.

Issuance of contract drawings and specifications that do not conform to Section 3 of the AISC *Code of Standard Practice* is a primary cause of defective or incomplete shop drawings. For this reason, all entities involved in the process of reviewing the contract drawings and specifications on behalf of the steel contractor should exercise great care in dealing with these documents and should forward prompt RFI's up the project chain-of-command whenever ambiguities appear in these contract documents.

The scheduler needs to keep in mind the time required for production, submission, and receipt of approved shop drawings from the structural engineer. Production and approval of shop drawings should be included as independent activities in the schedule. Some contracts specify time limitations for shop drawings approval. Occasionally the need for resubmission of rejected shop drawings may affect the schedule of the entire project.

In cases where fabricators are required to perform design work of complex connections, it may be necessary for fabricators to have a Professional Engineer (PE) on staff or to contract work with an outside consultant. This entire operation can have an impact on shop drawing preparation for the project. The production of fabrication shop drawings for the case study project required approximately 10 to 12 weeks. This process overlaped with the shop drawing approval because shop drawings were submitted in several batches, with batches being sent for approval every other week. See Appendix A for two fabrication shop drawings (one for beams and one for columns) for the case study project.

Fabricate steel. Material ordered from the steel mill or service center, is delivered, unloaded, and stored at the fabricator's plant. Steel beams are ordered to length, while steel columns are generally ordered from the mill 2" longer than required in case the ends are not square. The mill cuts steel into lengths varying from the minimum length to plus 2". Because of this possible length variance, the steel pieces may have to be cut to their final lengths prior to fabrication. For an extra charge, warehouses can supply steel lengths cut to their exact size. After approved shop drawings are received by the fabricator, steel is brought into the shop and the fabrication process begins. This process typically consists of the following steps:

1. Cut to proper lengths
2. Create templates and /or mark steel
3. Punch and/or drill holes
4. Camber members (if required)
5. Prepare accessory steel pieces
6. Add shop-welded or bolted pieces to members and make special cuts
7. Clean members (can be done prior to cutting)
8. Tag steel members
9. Surfaces treatment (painting and galvanizing) steel members, if required.

Templates may be made or automated equipment may be used to transfer information on the shop drawings to steel pieces, so that the holes/slots can be made at the required location. Pieces are then welded or bolted together to form the required assemblies and create members with section properties which are different from than those of the standard shapes, e.g. clip angles and base plates. Specialty cuts, such as coping are performed. Some steel may also require straightening or cambering.

The time required by the various fabrication steps as noted above, depends on the fabricator's personnel skills, available shop facilities, location of the plant etc. Fabrication of a sequence may require several weeks to complete; therefore the fabricator will need to plan shop hours to accommodate the schedule of several simultaneous projects. It is important for the scheduler to give proper consideration to all of these factors when establishing the structural steel schedule.

Quality Control Inspections. In-house quality inspections are normally carried out at the assembly stage; piece lengths are measured, and the location of bolt holes, bolt diameters, added pieces, and weld quality and size are examined and checked for compliance with the shop drawings. Steel pieces which pass inspection are labeled and painted (if required) and stocked in the fabrication yard for shipment. For future identification, the steel is labeled with piece marks (a code specific to a piece of steel), plus a job number or code. If the project is large and divided into sequences, the sequence code is also indicated on the steel. The labeling technique will vary from one fabricator to another. Tags, paint, or crayon markings are common examples of labeling.

Deliver Structural Steel. One of the most important tasks of the fabricator is delivery of structural steel to the job site. Transportation options, such as truck and trailer, rail system, and water transport can be adopted depending upon the size and quantity of the steel members, location of job site, and the general economy. Shipping by trucks and trailers is the most common method of delivery. Many fabricators are equipped with their own trucking fleet. If this is not the case, or the amount of work exceeds the capacity of the fabricator's fleet, independent drivers are subcontracted to deliver the steel to the job site.

The maximum length and width of a fabricated member that may be transported in Michigan by trailer are 110 ft and 16 ft, respectively. These size restrictions can vary from state to state. The load carrying capacity of the common trailer ranges from 20 to 25 tons, taking approximately two hours to load a trailer.

Depending on the project's size and on-site storage conditions, the material is either shipped all at once or "as needed" based by sequence. The erection contractor and/or the fabricator break down large steel projects into sequences. A given sequence defines a section of the project and the pieces of steel included in that section. A typical sequence for a small to medium size project consists of 2 to 5 truckloads of steel; for large projects, from 6 to 12 truck loads. Close communication and cooperation between the fabricator and the erector is essential in coordinating the deliveries with the erection schedule. The fabricator will also need to consider deliveries for other projects that may be in the shop at the same time. Other important delivery considerations are site conditions, access for trucks, as well as storage space for material, if required.

Coordinate Delivery of Decks and Joists. The steel contractor arranges for shop drawings, delivery, and erection of metal decking and open web joists through lower tier subcontractors. The metal deck and open web joists are released for production when the shop drawings are approved. The steel subcontractor (or representative) coordinates delivery to the job site according to the erection schedule.

Coordinate Delivery of Miscellaneous Steel. The steel subcontractor may also subcontract miscellaneous steel fabrications such as railings, stairs, and floor gratings. Their delivery to the job site is coordinated by the steel subcontractor in conjunction with the general contractor and the overall project schedule.

2.7 Erection Related Activities

Steel erection is the process of field assembling structural pieces to create the frame, roof truss or other structural systems. Erection of steel members can commence after all the steel is fabricated or after certain portions are fabricated, depending upon the size of the project. Some steel subcontractors (fabricators) have in-house erection capabilities and others enter into a subcontract with an erector. In some instances, the erectors also serve as primary steel subcontractors. An erector has the following major responsibilities as listed below:

1. Design of temporary bracing system
2. Steel frame erection
3. Roof truss assembly and placement
4. Field corrections
5. Safety during the erection
6. Inspection and testing

Design of Temporary Bracing System. One of the erector's responsibilities is to design the temporary bracing system during construction. During the erection process, steel members are temporarily held in place with an adequate number of required bolts, to allow for leveling and plumbing (vertical and horizontal alignment) adjustments. Other sections of the structure expected to add lateral stability may not be installed until after the steel is in place. Because of these conditions, the structure may not be stable when subjected to high winds or other adverse weather conditions.

The steel erector is responsible for the design of the bracing system and may require the services of a structural engineer. AISC's publication on bracing systems, titled "Erection Bracing for Low-Rise Structural Steel Buildings," AISC (1997) also provides information on various types of bracing systems. The design of the bracing system is normally done by the erector, before the delivery of steel to the job site.

Steel Frame Erection. The construction of a steel frame is a repetitive process of placing columns, attaching beams, leveling and plumbing (vertical and horizontal alignment), and bolt tensioning. This practice produces the basic structural framework, while attachment of miscellaneous steel products completes the steel phase of the project. Steel frame erection consists of the following steps as listed below:

1. Attachment of the base columns and adjustments to appropriate elevation
2. Attachment of major horizontal structural components, i.e. beams and girders
3. Erection of temporary braces for unbraced frame sections
4. Plumbing (vertical and horizontal alignment) of the frame and completion of connections, i.e. fully tension connections and tighten anchor rods
5. Attachment of minor horizontal steel members, i.e. joists, purlins (roof support), and lintels (supports brick or block masonry)
6. Attachment of metal decking and other miscellaneous steel products

For a multi-story frame, the same process is repeated for the subsequent stories. Columns can be erected for more than two stories at a time. For the midsize case study project, steel erection was completed in 10-12 weeks, with a 230 ton crane.

Roof Truss Assembly and Placement. Roof trusses are used to support longer spans such as those found in sports facilities or convention centers. The method of placement depends upon the size of the truss, together with accessibility and capacity of the crane. The major components of a truss are produced in the fabricator's shop. However, if the truss is too large to transport as a single unit, it may be shipped in pieces to the site, where assembly will be completed by ironworkers in the field. After placement of the truss, lateral support systems consisting of beams or smaller truss assemblies are installed.

Field Corrections. Field correction of small errors (such as missing or non-matching bolt holes, incorrect location of an attached piece, etc,.) found in the fabricated steel components, are also the responsibility of the erector. Ironworkers in the field are equipped to perform minor cutting and welding alterations as required. However, If the problem is extensive, the component may need to be returned to the fabrication shop. Therefore, while scheduling the steel construction phase of a project, certain time allowances should be allotted for a moderate level of field corrections, as this impacts the productivity of the erection crew.

Inspection and Testing. A number of inspections and testing procedures are performed during and after erection. In addition to inspection and testing done by the erector, project specifications may require an independent testing agency to perform certain tests on the job site. These tests relate mainly to bolted and welded connections.

2.8 Work Breakdown Structure (WBS) for Scheduling

Production of a Work Breakdown Structure (WBS) is the starting point for the development of a detailed schedule for a project. The WBS is the breakdown of a project into its component parts to increasingly lower levels. This breakdown is continued until the project is fully defined in terms of activities. An activity is a single work step that has a recognizable beginning and end. Activities are time and resource consuming tasks (CQR 1992).

The WBS is a name for an end-item-oriented family tree type subdivision of a project. It graphically displays the work involved in a project. It provides a framework for organizing and ordering the activities that comprise a project, and is the basic cornerstone of effective project management.

The WBS for the structural steel phase of the case study project is illustrated in Figure 2-1. This WBS is based on the following six sub-phases within the structural steel construction phase. These sub-phases provide a logical method to divide the case study project into scheduling activities. Fabrication and erection related activities as described in earlier sections, can be easily represented as part of the six sub-phases listed below:

1. Material procurement
2. Shop drawing preparation
3. Shop drawing approval
4. Fabrication
5. Erection
6. Inspection and testing

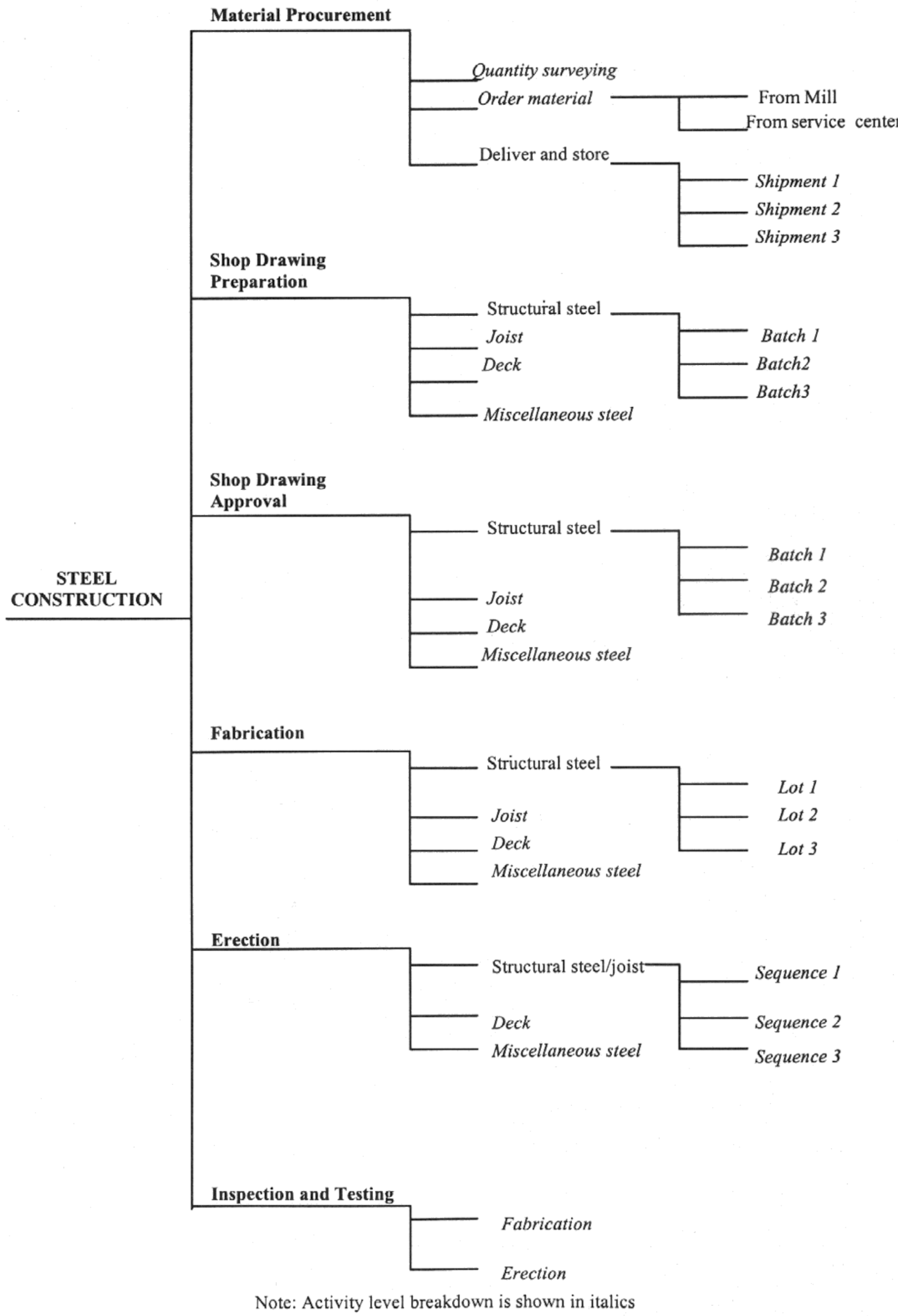


Figure 2.1 Work breakdown structure (WBS)

2.9 Activity Durations

Durations of the steel construction activities depend on a number of factors. These include: type of project and location, time of year, material availability, economic conditions, fabrication shop availability, crew skill, size of crew, number of crews used, etc. For the purpose of developing the schedule for the case study project, typical durations agreed upon by the Industry Technical Committee are used. These durations are summarized in Table 2.1. Based on the schedule developed for the case study project, the total project duration is 115 working days.

S. No	Activity Description	Duration (working days)	Comments
1	Quantity surveying	5	
2	Order material	5	
3	Delivery and storage of material	20	For each shipment
4	Shop drawing preparation structural steel	10	For each batch
5	Shop drawing preparation Joist	10	
6	Shop drawing preparation deck	10	
7	Shop drawing preparation miscellaneous steel	10	
8	Shop drawing approval structural steel	10	For each batch
9	Shop drawing approval joist	10	
10	Shop drawing approval deck	10	
11	Shop drawing approval miscellaneous steel	10	
12	Fabrication of structural steel	15	For each lot
13	Fabrication of joists	20	
14	Fabrication of deck	20	
15	Fabrication of miscellaneous steel	15	
16	Erection of structural steel/joist	20	For each sequence
17	Erection of deck	20	
18	Erection of miscellaneous steel	15	
19	Inspection and testing fabrication	15	
20	Inspection and testing erection	5	

Table 2-1 Activity durations for the case study project

2.10 Critical Path Method (CPM) Network Diagrams

During the development of the schedule for the case study project, the following assumptions were made:

1. The structural steel was delivered in three sequences (shipments)
2. The shop drawings for the fabrication of the structural steel were prepared and approved in three batches
3. The shop drawings for the joist, deck, and miscellaneous steel were prepared and approved in a single batch for each
4. The fabrication of the structural steel was carried out in three lots
5. The fabrication of the joist, deck, and miscellaneous steel was carried out in a single lot for each
6. Erection of structural steel and joists was carried out by the steel erector, and divided into three sequences (shipments)
7. Erection of deck and miscellaneous steel was carried out in a single phase

The alphanumeric codes shown in Table 2.2 were assigned to the activities to identify and sort them out efficiently and conveniently.

Codes	Description of Alpha portion	Comments
ST 001	Start of the project	001-series for all the activities in the start up phase
MP 100	Material procurement	100-series for all the activities in the material procurement phase
SP 200	Shop drawing preparation	200-series for all the activities in the shop drawing preparation phase
SA 300	Shop drawing approval	300-series for all the activities in the shop drawing approval phase
FB 400	Fabrication	400-series for all the activities in the fabrication phase
ER 500	Erection	500-series for all the activities in the erection phase
IT 600	Inspection and testing	600-series for all the activities in the inspection and testing phase
FI 700	Finish of the project	700-series for all the activities in the finish phase

Table 2.2 Alphanumeric codes assigned to activities

A CPM diagram provides a logic diagram that shows complex sequential relationships among various construction activities. For the case study project, the following layouts are provided:

1. Detailed CPM diagram (Figure 2.2), showing all activities according to execution framework
2. CPM diagram on the basis of the sub-phases (Figure 2.3), showing all activities by grouping them into various sub-phases
3. CPM diagram on the basis of responsibilities of the participants (Figure 2.4) presenting all activities by grouping them under execution responsibility

Primavera Project Planner ® (P3) version 2 (Primavera 1997) was used to develop various network diagrams. Based on the activity durations listed in Table 2.1 and the scheduling logic presented in Figure 2.2, the overall project duration for the case study project comes out to be 163 calendar days or 115 working days.

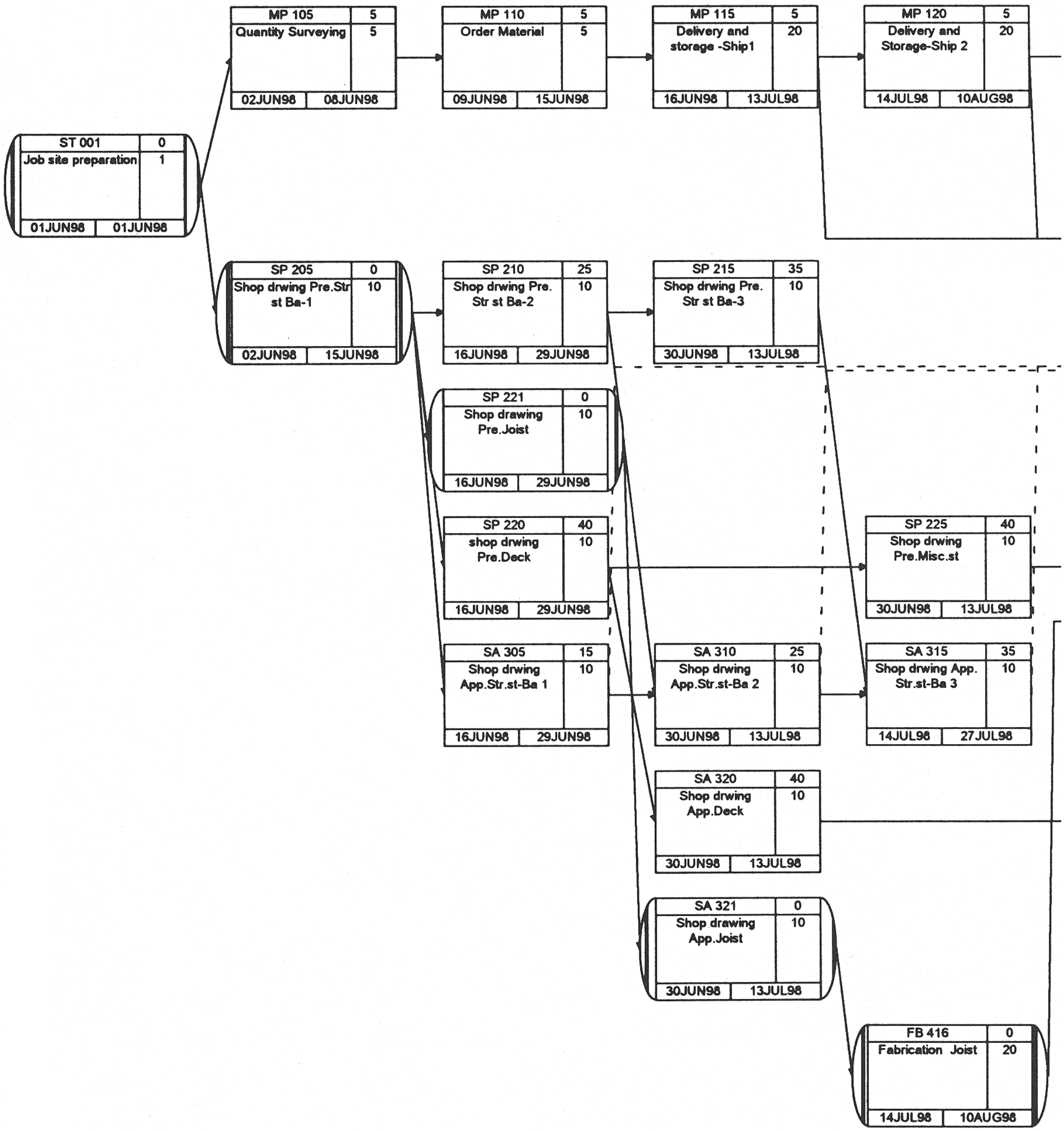
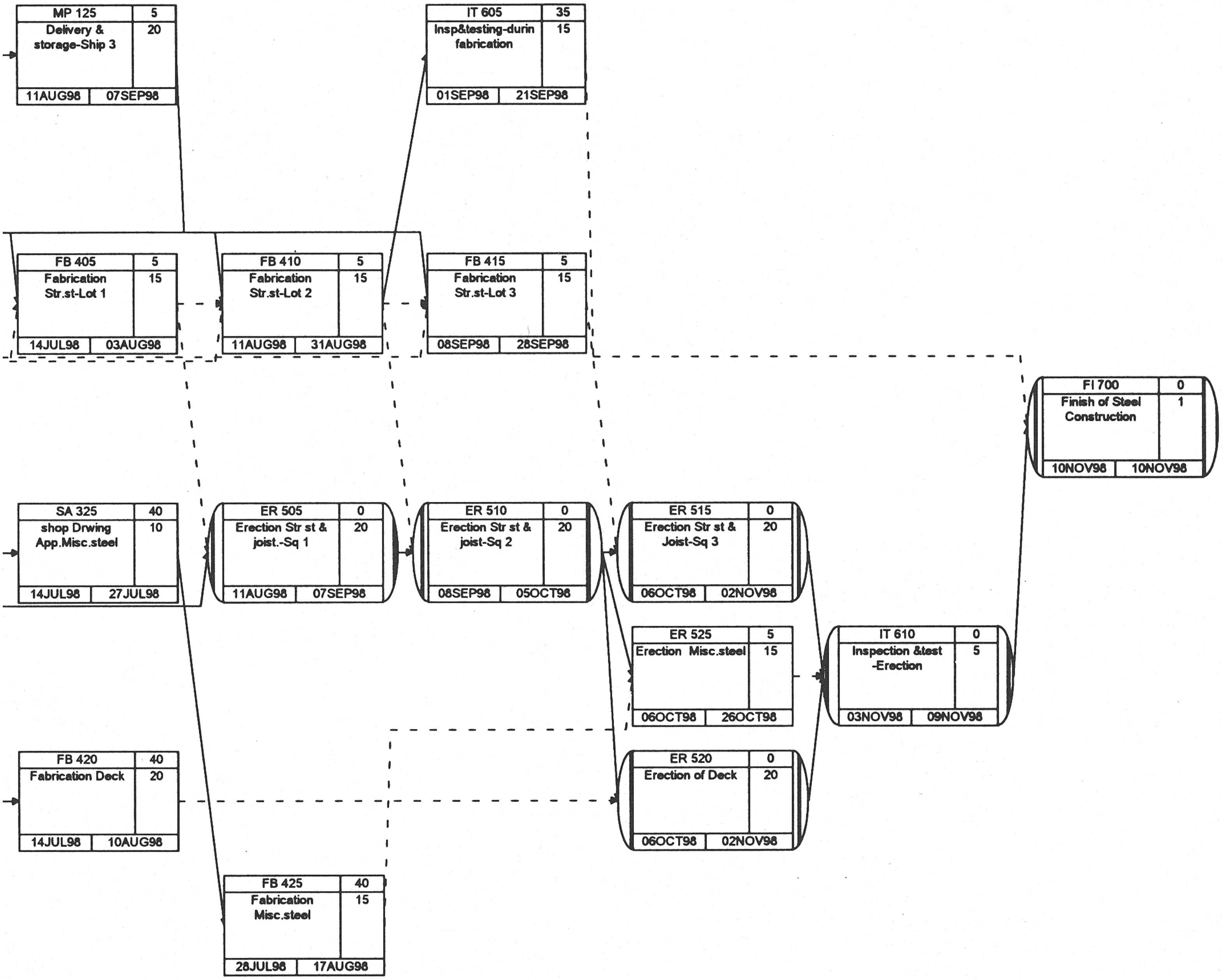


Figure 2.2 Detailed CPM diagram



MP 125
5
Delivery & storage-Ship 3
20
11AUG98
07SEP98
IT 605
35
Insp&testing-durin fabrication
15
01SEP98
21SEP98
FB 405
5
Fabrication Str.st-Lot 1
15
14JUL98
03AUG98
FB 410
5
Fabrication Str.st-Lot 2
15
11AUG98
31AUG98
FB 415
5
Fabrication Str.st-Lot 3
15
08SEP98
28SEP98
FI 700
0
Finish of Steel Construction
1
10NOV98
10NOV98
SA 325
40
shop Drwing App.Misc.steel
10
14JUL98
27JUL98
ER 505
0
Erection Str st & joist.-Sq 1
20
11AUG98
07SEP98
ER 510
0
Erection Str st & joist-Sq 2
20
08SEP98
05OCT98
ER 515
0
Erection Str st & Joist-Sq 3
20
06OCT98
02NOV98
ER 525
5
Erection Misc.steel
15
06OCT98
26OCT98
IT 610
0
Inspection &test -Erection
5
03NOV98
09NOV98
FB 420
40
Fabrication Deck
20
14JUL98
10AUG98
ER 520
0
Erection of Deck
20
06OCT98
02NOV98
FB 425
40
Fabrication Misc.steel
15
28JUL98
17AUG98

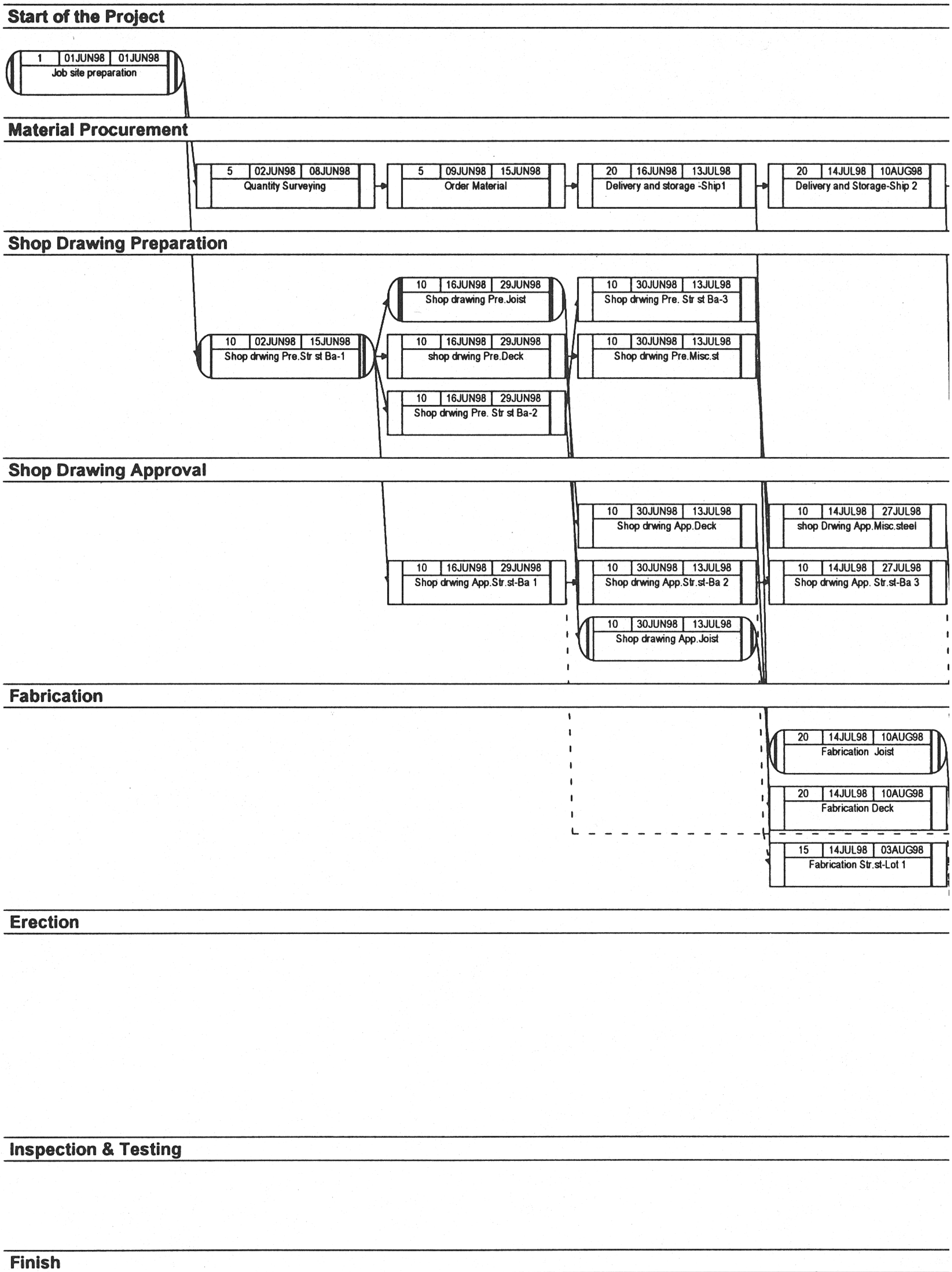
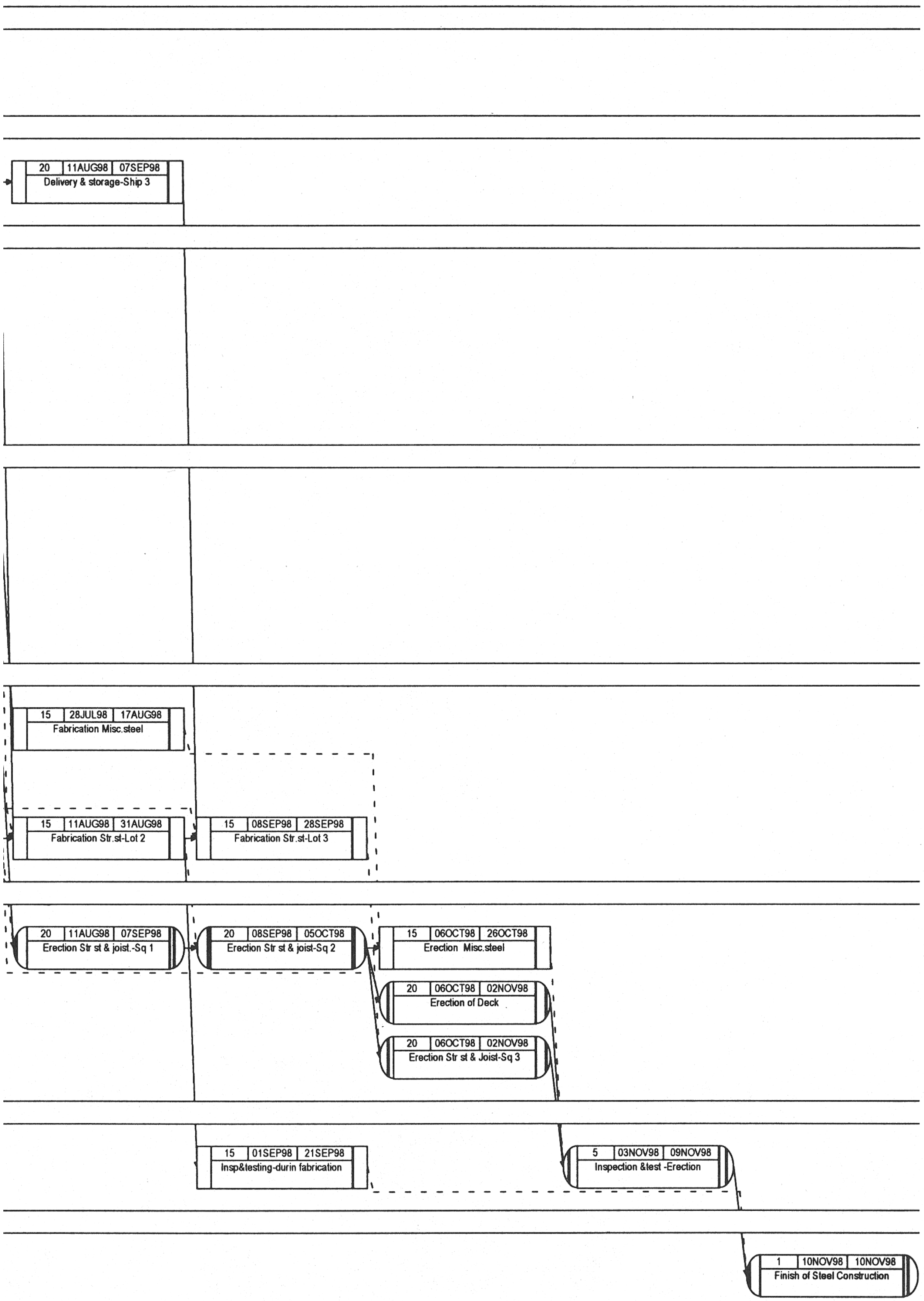


Figure 2.3 CPM diagram on the basis of sub-phases



20 11AUG98 07SEP98
Delivery & storage-Ship 3
15 28JUL98 17AUG98
Fabrication Misc.steel
15 11AUG98 31AUG98
Fabrication Str.st-Lot 2
15 08SEP98 28SEP98
Fabrication Str.st-Lot 3
20 11AUG98 07SEP98
Erection Str st & joist.-Sq 1
20 08SEP98 05OCT98
Erection Str st & joist-Sq 2
15 06OCT98 26OCT98
Erection Misc.steel
20 06OCT98 02NOV98
Erection of Deck
20 06OCT98 02NOV98
Erection Str st & Joist-Sq 3
15 01SEP98 21SEP98
Insp&testing-durin fabrication
5 03NOV98 09NOV98
Inspection &test -Erection
1 10NOV98 10NOV98
Finish of Steel Construction

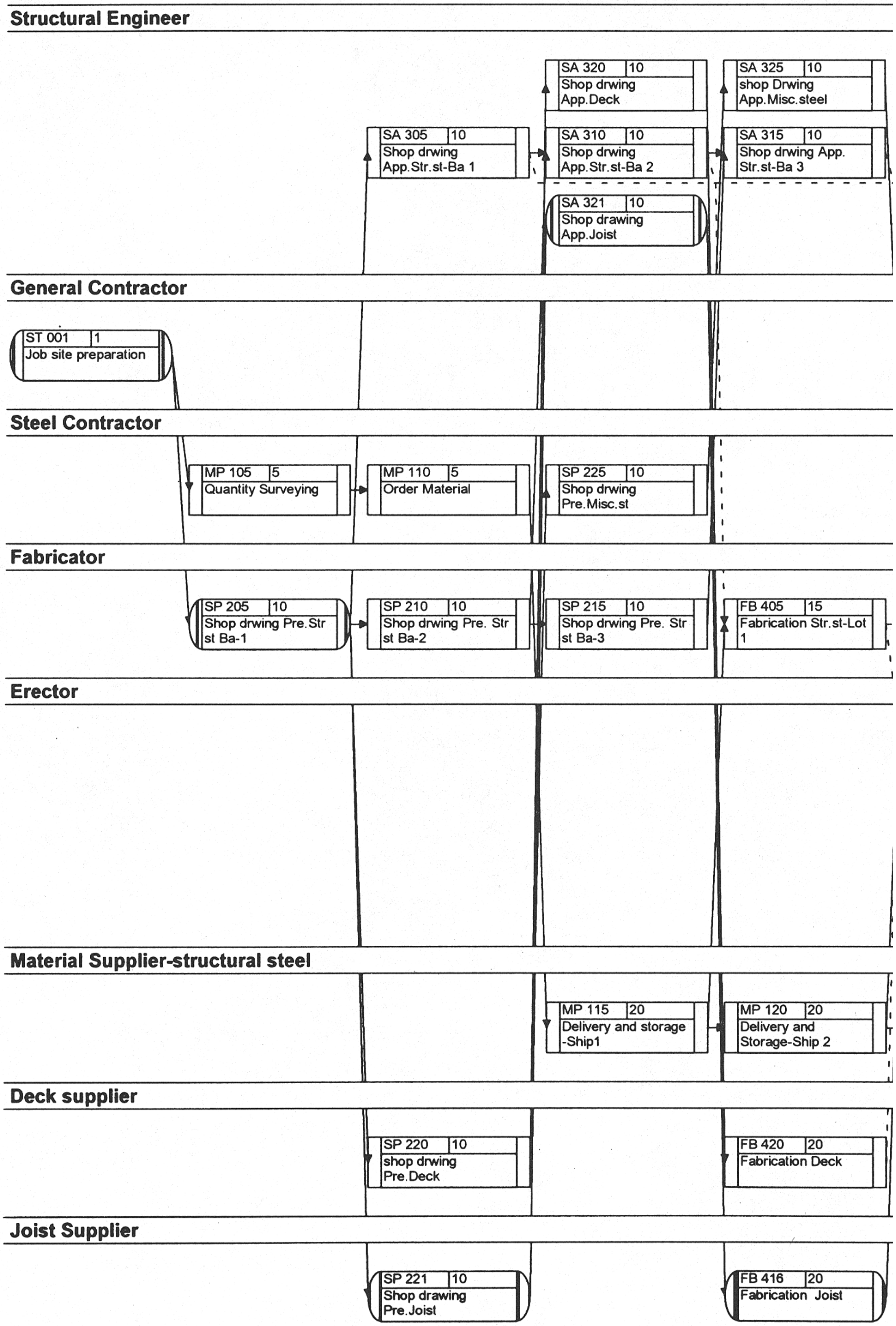
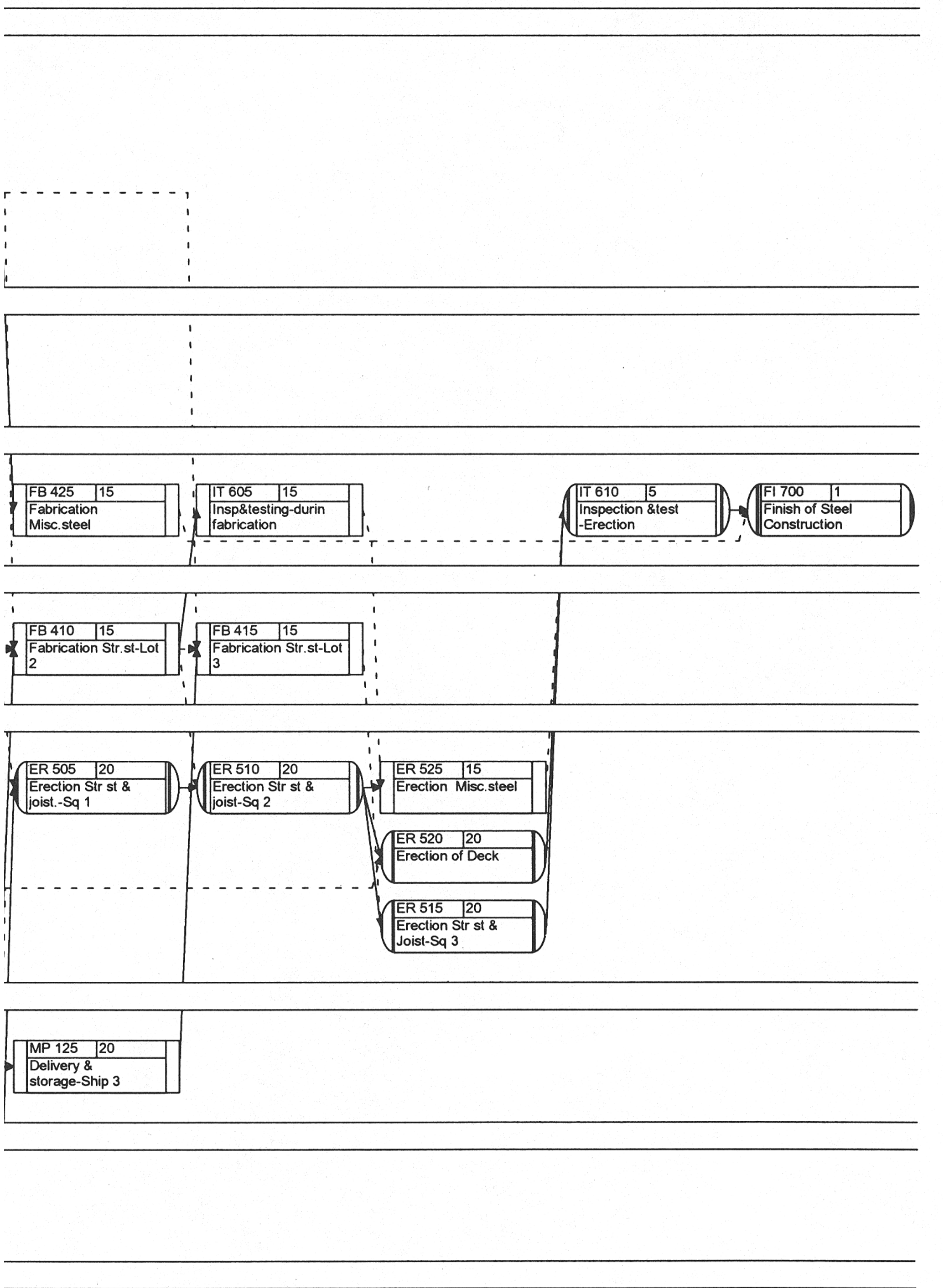


Figure 2.4 CPM diagram on the basis of the responsibility of the participants


FB 425 15
Fabrication Misc.steel
IT 605 15
Insp&testing-durin fabrication
IT 610 5
Inspection &test -Erection
FI 700 1
Finish of Steel Construction
FB 410 15
Fabrication Str.st-Lot 2
FB 415 15
Fabrication Str.st-Lot 3
ER 505 20
Erection Str st & joist.-Sq 1
ER 510 20
Erection Str st & joist-Sq 2
ER 525 15
Erection Misc.steel
ER 520 20
Erection of Deck
ER 515 20
Erection Str st & Joist-Sq 3
MP 125 20
Delivery & storage-Ship 3

2.11 Bar Charts

The primary advantage of the bar chart is its overall simplicity. It is easy to read and interpret, and therefore, can be an effective communication tool. The primary disadvantage is that it does not show the interrelationships among the project activities. For the case study project, the following layouts of the bar charts are provided. Primavera Project Planner ® (P 3) version 2 (Primavera 1997) was used to develop the various bar charts.

1. Summary bar chart (Figure 2.5), showing each sub-phase as a milestone activity
2. Bar chart on the basis of sub-phases (Figure 2.6); all activities by grouping them into various sub-phases
3. Bar chart on the basis of the responsibility of the participants (Figure 2.7), presenting all activities by grouping them under execution responsibility

To demonstrate the role of the schedule as a project management tool, each activity is assigned two sets of activity codes. One represents the sub-phase to which it belongs, and the other represents the party responsible for its execution. These activity codes can be used to sort out various activities in different scheduling layouts. Refer to Figures 2.3 and 2.6 for scheduling layouts based on sub-phases and Figures 2.4 and 2.7 for scheduling layouts based on responsibilities of the participants.

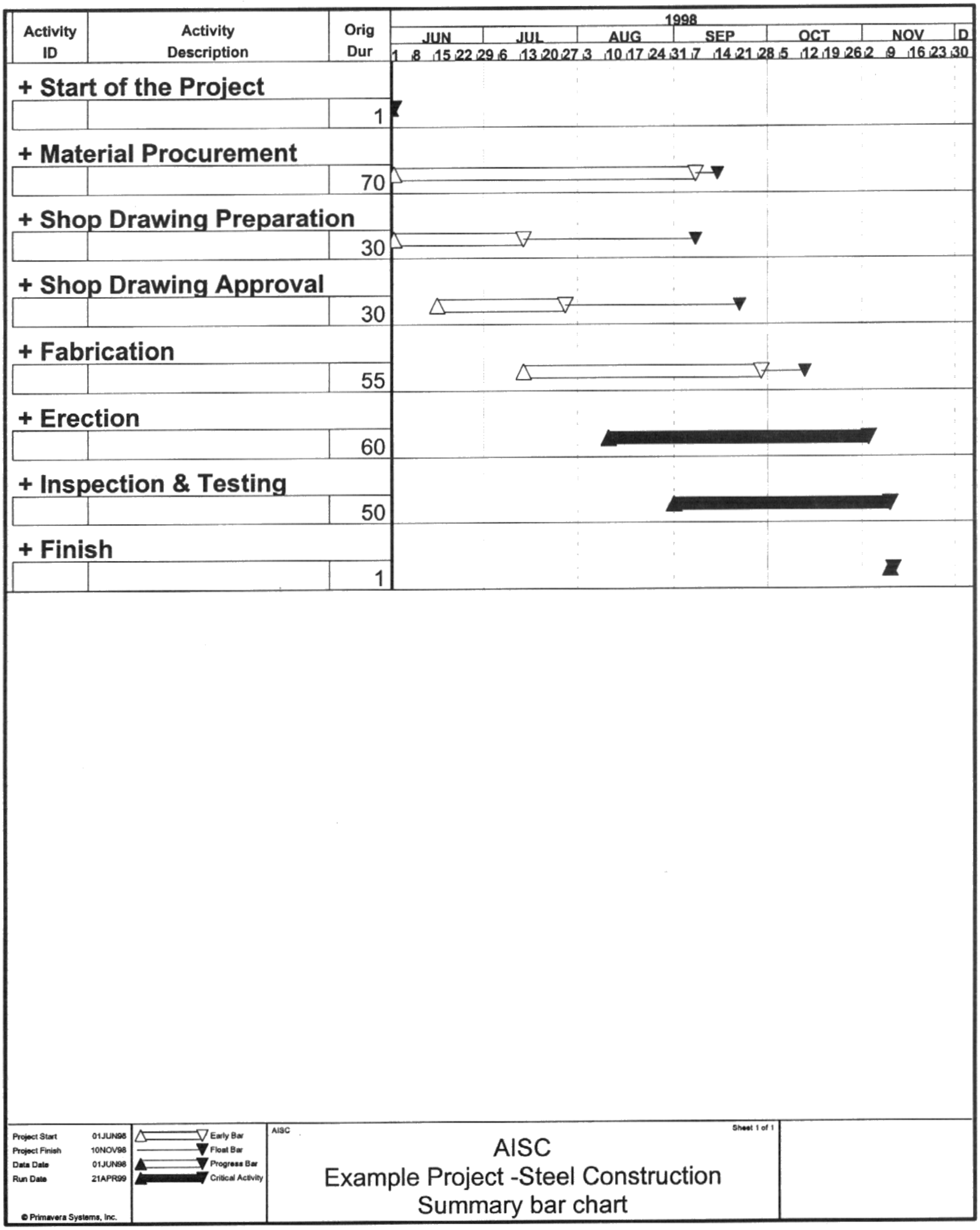


Figure 2.5 Summary bar chart

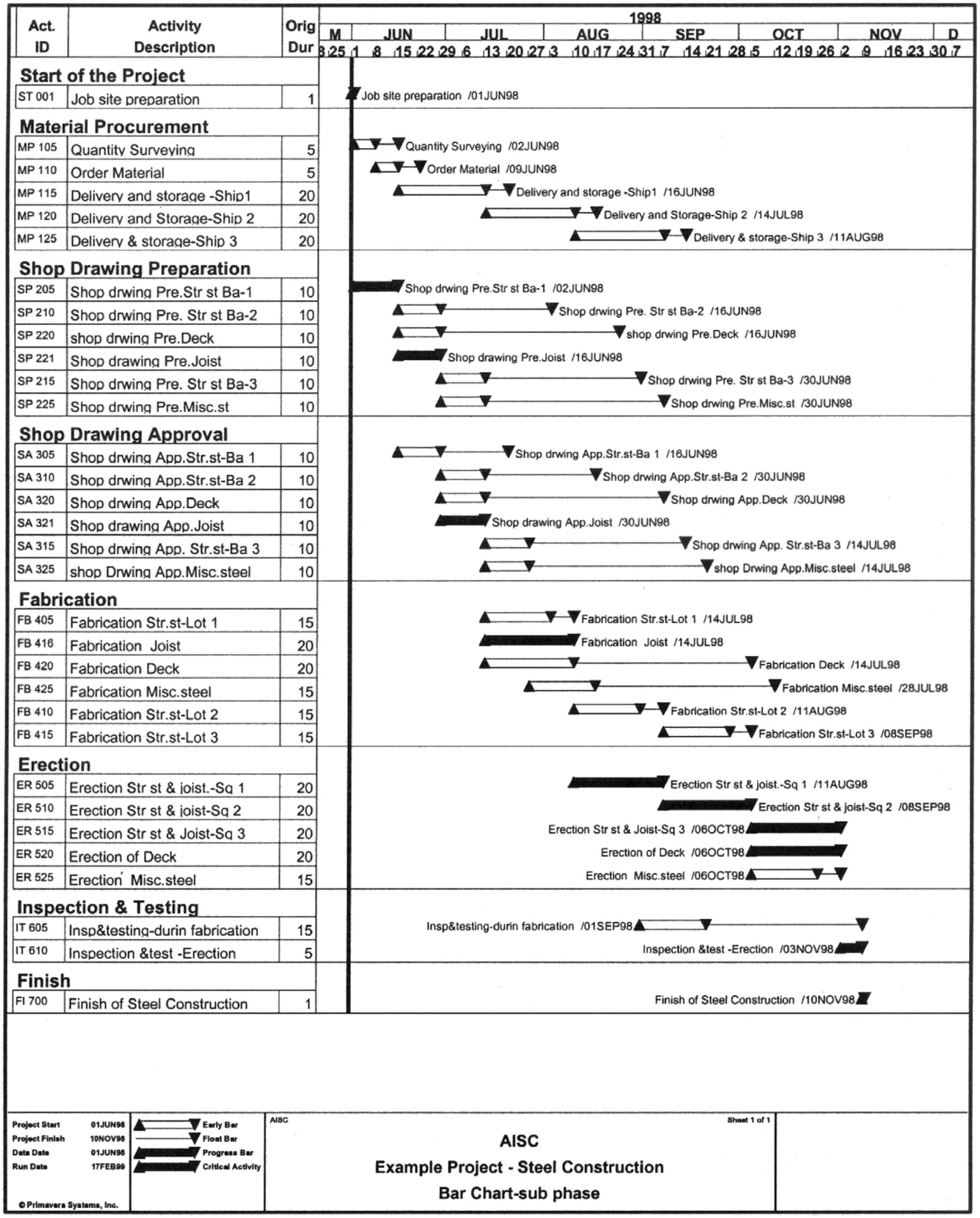


Figure 2.6 Bar chart on the basis of sub-phases

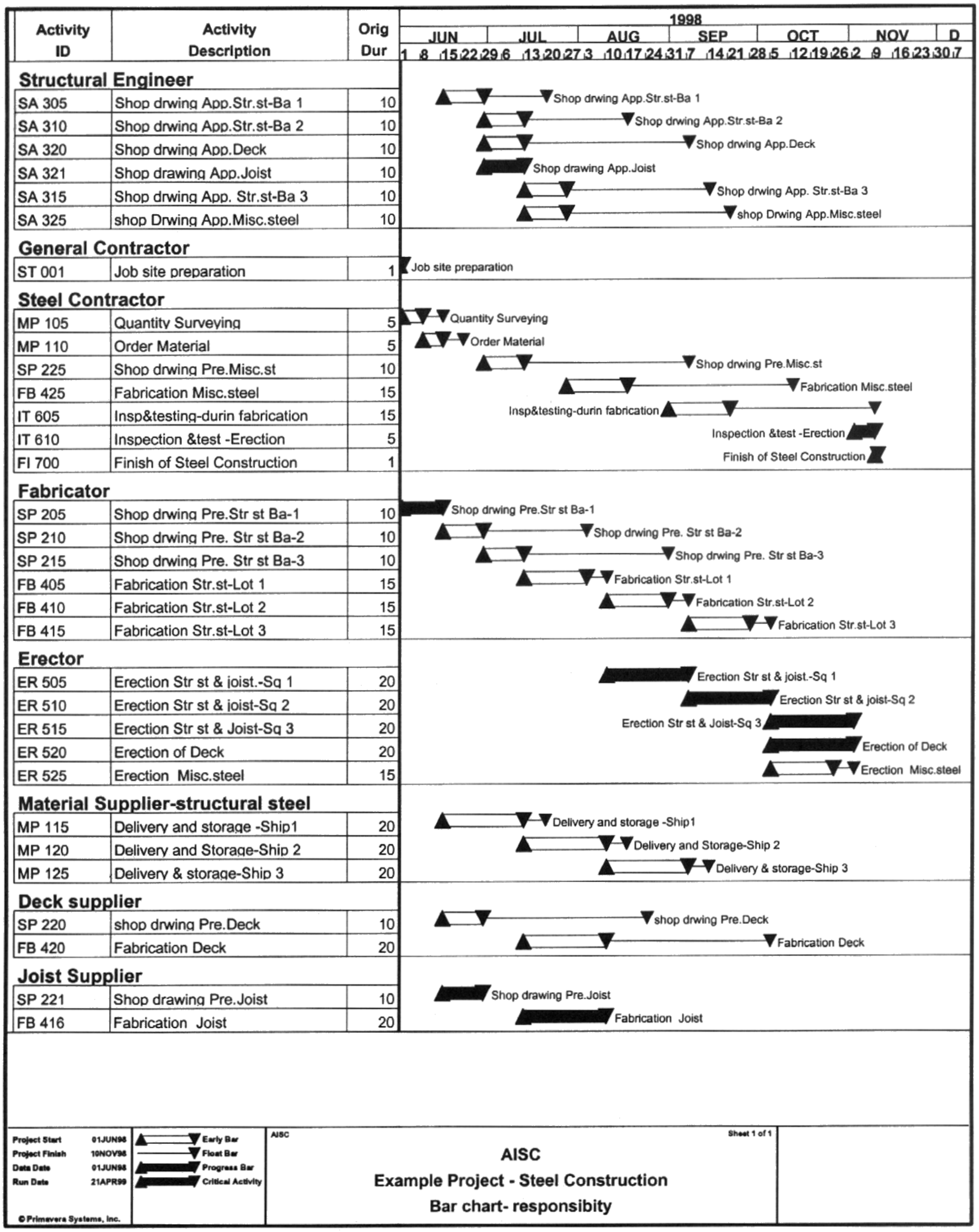


Figure 2.7 Bar chart on the basis of the responsibility of the participants

2.12 Steel Schedule Vs. Overall Project Schedule

One of the major benefits of steel construction is its reduced construction time compared to other competing materials, such as concrete or timber. This advantage can be achieved if the participants involved in the steel construction phase are well coordinated and follow a realistic time schedule. Previous sections broadly explained the different stages of steel construction, starting with material procurement to erection of the components. The purpose behind explaining the entire process was to provide information to the potential scheduler about 1) activities and their sequence which influence the steel construction schedule, 2) how to estimate the duration of the various activities in different situations, and 3) scheduling methods.

Steel construction is highly schedule driven with every activity in the steel construction phase dependent on other activities. Good communication and cooperation among various steel subcontractors and lower tier subcontractors is mandatory for completion of the project within planned time and cost. A realistic and complete schedule can provide the basis for communication and coordination. The schedule provides an excellent information and communication tool, with each participant knowing well in advance when their services are required at various stages of steel construction, and when each resource needs to be available on the site.

2.13 Items Impacting the Schedule

Major items that can affect the progress of the steel construction phase and consequently the overall completion time of the project are discussed in the following section.

Material Procurement. Material is commonly procured from the steel mill. Material purchased from a service center (warehouse) can cost 30 to 50% more. Lead time in the case of mill procurement is 4 to 6 five weeks for the first batch to be received and 6-10 weeks for final delivery. To save time, the ordering of material is initiated as quickly as possible after contracting and receipt of the "notice to proceed," without waiting for the preparation of shop drawings.

Shop Drawing Approval. Approval of shop drawings is another item that may greatly impact the completion of the project. Excellent coordination is needed during the shop drawing approval process. The AISC recommends two weeks for the approval of one batch of shop drawings (AISC 1997A). Some contracts specify a definite approval time for the architect/structural engineer. These time limitations must be adhered to while estimating the duration of activities. In fast track projects, shop drawings may sometimes be submitted directly to the structural steel engineer, or to both the engineer and the construction manager.(Refer to Figure 2.8)

Coordination Among the Various Sub Contractors. Coordination among various trade subcontractors and the steel contractor is important for timely completion of the project. Delays caused by one subcontractor can affect the time schedule of another subcontractor and subsequently adversely affect the overall progress of the project. In the conventional project delivery contract, the GC coordinates the trade contractors, while in CM projects, the construction manager coordinates the work. In any case, a realistic schedule will keep all participants informed of the progress of the work and of any changes made during the process.

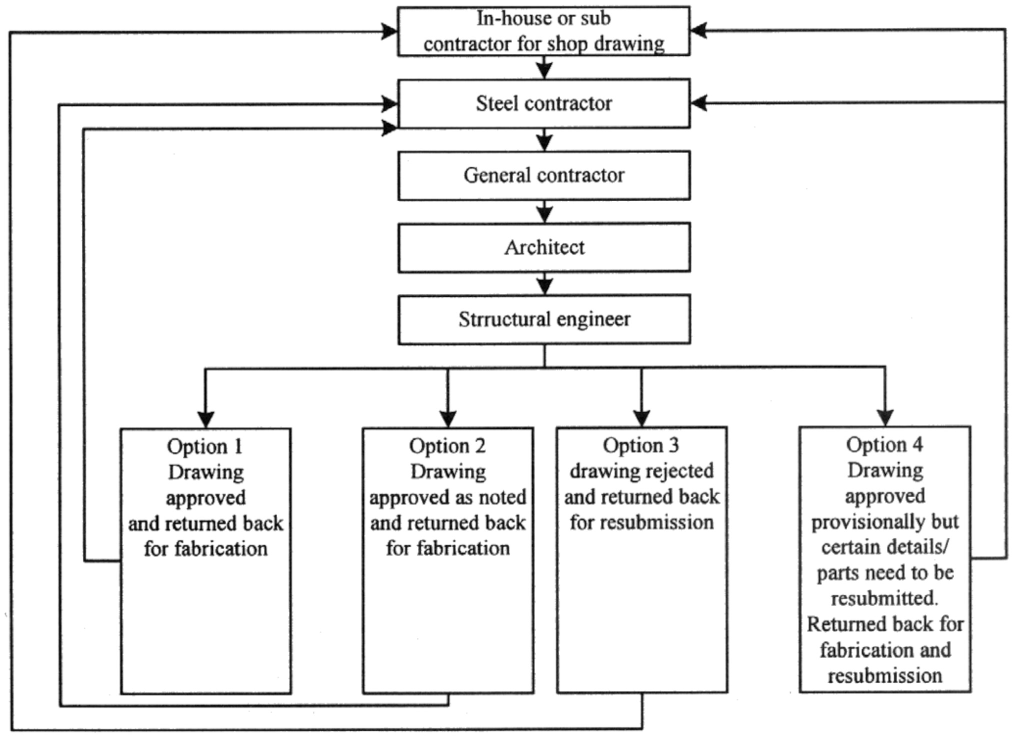


Figure 2.8 Shop drawing approval process

Impact of Erection Methods on Overall Project Schedule. The erection method depends on the shape of the building, such as horizontal or vertical structure. If the building is as high as three stories and spread over a comparatively large area, the erection can be performed simultaneously at more than one location. By executing the erection at more than one location, time can be saved and the schedule may be compressed. The consideration of vertical versus horizontal structure should be given considerable weight when scheduling the project. Two buildings requiring the same amount of structural steel but having different types of structure, one horizontal and the other vertical, will have substantially different erection schedules. Erection can be carried out in one of two ways:

1. Vertical slicing for a horizontal building: In this method the structure is divided into vertical segments. After the erection of one segment, the next section (slice) is started. Vertical slicing has a relatively slower erection sequence but utilizes manpower and equipment efficiently

2. Horizontal slicing for a vertical building: This method is adopted for tall buildings. In this method the building is divided into horizontal segments. It is a faster operation, but can be slowed because of equipment maneuverability

2.14 Areas Requiring Special Attention

The process of developing a detailed and accurate schedule is helpful for the steel contractor to foresee problems related to on-time and on-budget work completion. It can also provide insight into possible solutions to these problems. Resulting from discussions with the Industry Technical Committee, areas requiring special attention related to steel construction were identified as follows:

Delays/problems due to steel subcontractors and lower tier subcontractors:

Delays due to non-availability of materials
1. Material shortage
2. Production delay
3. Delivery delay
4. Uncommon size/types

Limitations of fabrication shop capacity
1. Delays in earlier projects
2. Over booked fabrication shop

Labor shortage and/or disputes
1. Erectors
2. Fabricators
3. Strikes

Shop drawing production
1. Over booked detailer
2. Delay in earlier projects

Lack of capability to accommodate special requirements
1. Special painting requirements
2. Rolling of materials
3. Special surface preparation
4. Galvanizing

Transportation problems
1. Over booked
2. Coordination

Problems caused by lower tier subcontractors
1. Delays by deck supplier
2. Delays by deck erector
3. Delays by joist supplier
4. Delays by other lower tier subcontractors and suppliers

Delays /Problems due to others:

Shop drawings and project scope changes
1. Before shop drawings are prepared
2. During shop drawings preparation
3. After shop drawings are prepared

Fabrication and scope changes
1. Before fabrication
2. During fabrication
3. After fabrication

Shop Drawings Approval
1. Incomplete design drawings
2. Communication delay
3. Over-committed designers

Foundations
1. Improperly located foundations
2. Timely completion

Anchor rods
1. Improperly located anchor rods
2. Realignment time and cost

Site conditions
1. Material storage
2. Erection space
3. Movement of crane
4. Soil stabilization and preparation
5. Removals of obstructions, e.g., power lines, stones, etc.

Special permits and requirements
1. Special delivery requirements
2. Special storage requirement
3. Special hoisting requirements

Design and construction of other trades
1. Issuance and completeness of design drawings
2. Shop drawings by other contractors
3. Information about size and location of openings
4. Timely completion of work by other contractors

Others
1. Change order finalization
2. Financing
3. Payments
4. Jurisdictional disputes or strikes

Helpful Solutions

1. Coordination drawings, early decisions by owners, and early coordination among design disciplines allow mechanical and electrical subcontractors to mark their details on E-sheets during pre-detailing coordination meetings.
2. Fabrication before approval of the shop drawings should be avoided or limited to common simply framed pieces.
3. Provide detailed schedule:
   GC to all subcontractors
   Steel subcontractor to lower tier subcontractors
4. Early agreement on erection sequences. (Do not change erection sequences). Involve steel subcontractor early in the project and use their input to select designer team and details. Use value engineering when possible.
5. Download of structural drawings to fabricator's computer from the structural engineer, cuts both shop drawing and fabrication time. The steel detailer can work faster and more efficiently by using the computerized steel detailing programs.
6. Computer numerically controlled (CNC) fabricating equipment can be used to speed fabrication and free the fabrication shop for the next job. Similarly, automatic and semi-automatic welding processes can be used to speed welding operations.

2.15 Summary

Scheduling of a midsize building project can serve as an effective training tool for students in construction management and construction related programs. Module Two provides detailed information on the process of steel construction leading to the development of CPM network diagrams and bar charts. Module Two also highlights the use of the schedule as a project management tool. It demonstrates the use of activity codes to categorize scheduling activities within various sub-phases by responsibilities. The impact of the steel schedule on the overall project schedule is also discussed Finally, this module outlines possible problem areas that a scheduler must be aware of to produce realistic schedules.

Questions for Classroom Discussion

1. Outline the major steel construction activities for a midsize building project.

2. How are activity codes for sub phases and responsibilities useful in preparing a construction schedule for steel construction?

3. How can the shop drawing approval process cause time delays if not managed properly?

4. What are some of the areas related to steel construction that may require special attention? How will you anticipate or solve some of these problems with the help of effective scheduling?

5. Discuss two major erection methods and their impact on the steel construction as well as the overall project schedule.

6. What major sub-phases can be defined for the steel construction phase of a midrise building project?

7. Discuss opportunities for early input by the steel contractor that the GC should take advantage of while scheduling the project.

8. Discuss the time compression potential of major fabrication related activities for steel construction of a building project.

Notes

STEEL ESTIMATING

2.16 Introduction

Estimating of structural steel can be a complex activity because of the variety of members, member sizes, applications, fabrication requirements, detailing, and connection types. Erection methods, equipment used, and project conditions also play significant roles in pricing of structural steel. Systematic estimating approaches can, however, serve to make the job of the estimator easier. An overview of steel estimating techniques, as well as a discussion of factors influencing the cost of steel construction are presented in this section. This material is intended to provide construction management students with an appreciation for the issues that impact costs and quantity surveying methods of structural steel.

2.17 Introduction to Estimation

Accurate estimation of steel requires specialized knowledge of fabrication and erection methods. The general contractor (GC) or construction manager (CM) would not normally have the expertise to conduct accurate detailed quantity takeoffs and estimates. The general contractor or CM usually works closely with the steel subcontractor to obtain pricing. Ultimately, final pricing of structural steel will be a function of the steel contractor's bid price and any negotiations that the two parties may undertake.

Many general contractors, construction managers, and design-builders have significant experience with the use and subcontracting of structural steel framing. As a consequence, they will have a project and bid data base which may be drawn upon to evaluate the steel contractor's price quotation. The contractor may compare the steel contractor's price quotation with average square foot costs for steel or with average costs per ton, based on past similar projects. Some published guides, such as the R.S. Means Building Construction Cost Data series contain tables which provide average tonnages for a variety of standard building types. Figure 2.9 indicates that for midrise office buildings with average beam spans and typical live loads, the structural steel should weigh approximately 10 lbs per square ft of building area.

Building Type	No. of Stories	Avg. Spans	LL #Per S.F.	Lbs Per S.F.
Steel Framed	1	20' x 20'		8
Manufacturing		30' x 30'	40	13
		40' x 40'		18
Office Bldgs	0-10			10
	10-20	Varies	80	18
	20-30			26
	Over 50			35

Figure 2.9 Structural steel weights per square ft. floor area for building types
(Adapted from 1998 Means Building Construction Cost Data, R.S. Means)

These approximate methods may yield initial estimates that are accurate to within 10-20% of the actual price for standard building types, with average conditions. However, if atypical or special conditions exist for the building type, the estimate will not be very accurate, unless the general contractor is sufficiently experienced in judging the impact on pricing of these unique conditions. Pricing of steel is highly dependent on the details of the design. The steel contractor can be very useful in helping to assess the impacts of special project details and conditions. The general contractor should develop a close working relationship with the steel contractor in order to take advantage of this expertise.

2.18 Preliminary Conceptual Estimating

During the initial design and planning phase of the project, the owner frequently requires the architect, structural engineer, construction manager, or design-build firm to furnish conceptual budgetary estimates. These estimates may be for the purpose of evaluating the cost of alternative systems (such as concrete or timber), or for preparing an overall budget for the project. Based on information provided by the owner, such as building type, overall quality level, size of floors, number of stories, height of stories and time and location of construction, the design or construction professional will be able to prepare conceptual estimates, using square foot and volumetric methods, cost data from past projects, or published data. When individual systems are to be conceptually estimated, the steel fabricator can be very helpful in assisting the design or construction professional in assembling conceptual costs. Fabricators are increasingly becoming involved early in the conceptual phases of the project, particularly as construction management and design-build project delivery methods gain popularity with owners. For standard building types such as office buildings or warehouse facilities, once the basic building characteristics discussed above and the structural bay size and design loads are established , the structural engineer or fabricator can readily determine the preliminary beam and column sizes, as well as lateral bracing and connection requirements for the project. This preliminary structural design, coupled with the fabricator's cost data, can allow for more accurate conceptual estimates.

Conceptual or preliminary estimating methods should always carry a contingency. Because the estimate is based only on partial information, all of the project conditions are not likely to be known at the time the conceptual estimate is prepared. It is important to document the scope of work and project conditions which were initially assumed, in preparing the conceptual estimate. Building designs frequently change during the development of the project, and it is important to monitor any changes in the conceptual design or in the performance criteria, and to adjust the conceptual estimate accordingly. A clear statement of assumptions can help alleviate disputes about project scope and budget at later project stages.

2.19 Bidding: The Subcontractor's Role

During the bidding period, the general contractor will divide the building project into subcontract workscopes. These workscopes should be carefully defined so that work intended to be included in each subcontractor's workscope is clear to all parties. The general contractor may decide to award a single subcontract for the steel portion of the project or to break the steel into multiple subcontracts. For example, it is fairly common for miscellaneous metals or metal fabrications to be furnished by a separate supplier or subcontractor and therefore not be included in the structural steel contractor's workscope.

When the subcontract workscope and contract documents are received by the steel contractor, the steel contractor should thoroughly review the project plans, specifications, contractual conditions, project site conditions, and correlate the information. The steel contractor may prepare a work breakdown structure illustrating all of the steel component types for the project. This work breakdown structure serves to illustrate the elements which will need to be addressed in the detailed estimate. The steel contractor will need to determine the items for which to seek lower tier subcontractors or suppliers. For example, the steel contractor (who is primarily a fabricator) will seek subcontractors for erection. Steel joists and metal decking will be purchased for the project from suppliers. The steel contractor will need to determine whether the steel will be supplied by a rolling mill, steel service center (warehouse) or from the steel contractor's own inventory. After deciding which portions will be subcontracted, the steel contractor will develop lower tier subcontract workscopes and seek price quotations from these contractors.

The steel contractor will conduct detailed estimates for the portion of the subcontract that the steel contractor retains, and will evaluate competitive offers from lower tier subcontract bidders. Evaluation of the lower tier subcontract bids will be based on price, quality, schedule, and working relationships. The steel contractor will assemble a final price for the total subcontract workscope combining the steel contractor's portions of the work with that of selected lower tier subcontractors.

Upon receipt of the steel contractor's subcontract proposal, the general contractor will evaluate competitive offers from the various steel contractors and decide which steel contractor to utilize. Figure 2.10 below illustrates a flow chart of the bid process.

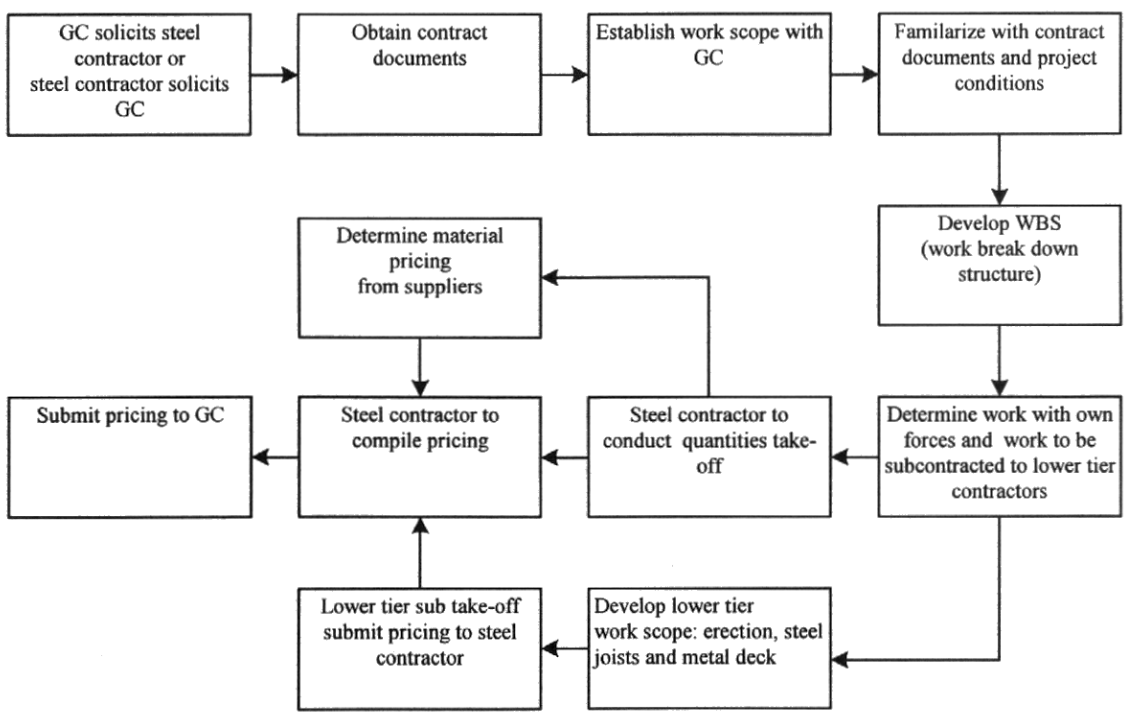


Figure 2.10 Flow chart of bid process

2.20 Quantity Takeoff Methods

Unlike the general contractor who will estimate steel using approximation methods, the steel contractor's estimator must undertake a very careful quantity takeoff of each separate element with its corresponding shape and size for the entire steel frame. Each element, shape, bolt, clip, etc. will need to be accounted for. Beams and columns will typically be recorded separately because the fabrication requirements for these components will vary. In addition, the connections, fabrication, material characteristics, weld requirements, and finishing requirements for each member will need to be identified and tallied. Because of the complexity of this task, most steel contractors have developed systematic methods for taking off steel.

The takeoff must begin with a careful review of the project plans, specifications, contractual requirements, and project conditions. The estimator should review all plans, including the structural, architectural and mechanical sheets. All documents should be correlated to obtain a complete understanding of the project, including administrative and procedural requirements. Because architects and engineers have individual styles of organizing information on the plans, the estimator must quickly adapt to the symbols, sheet arrangement, and level of detail on the set of plans being worked with. The thoroughness of the plans will vary frequently from project to project, making the estimator's job more difficult. The estimator may need to contact the structural engineer or architect to obtain clarifications on what was intended in the design.

After the plans have been carefully reviewed and the estimator understands the project, the estimator will begin the takeoff of the elements in the project workscope. A useful tool in structuring the takeoff is to develop a master checklist or a Work Breakdown Structure (WBS). Section 2.8 discussed the scheduler's activity based WBS; similarly the estimator may find it useful to create a WBS, but one that is take-off item based. The estimator's WBS lists the components which are included in the workscope and serves as a check list of elements to estimate. Figure 2.11 illustrates a sample WBS for estimating.

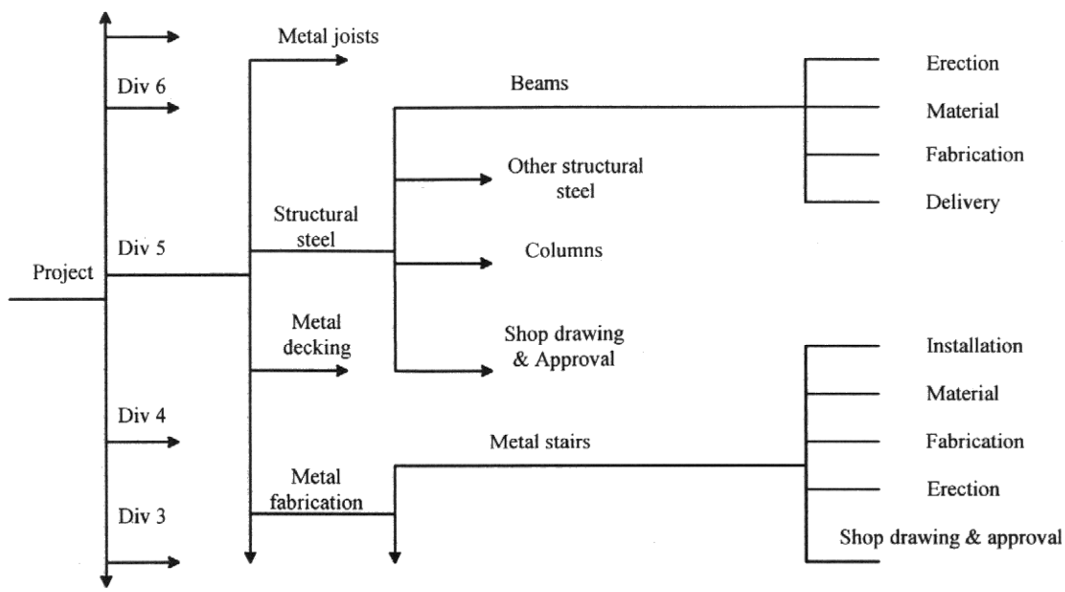


Figure 2.11 Estimator's work breakdown structure

Each structural steel contractor will have a systematic method for quantity takeoff of the steel elements. Frequently the estimator, project manager or other estimators will need to review the estimate; therefore, the steel contractor should have a well-established sequence of taking off and recording the elements. This is important so that all users will be able to decipher the estimate and correlate the estimate with the plans. For example, one method is to takeoff the elements using a standardized order such as all first floor north-south beams, starting with the western most row and then proceeding with the next north-south row until all first floor north-south beams have been recorded. The estimator would then proceed to east-west beams. By using a common system for sequencing the takeoff, elements will not be missed. Every element should receive an identifier for later reference. The estimator may use the structural steel beam and column line identifiers on the structural plans, or may establish other identifiers using the steel fabricator's standard practice.

The characteristics of each element should be recorded. For example, when taking off beams, the estimator should record each beam number identifier, span, shape and size, as well as the connections and any attached plates, angles, stiffeners, etc. Any special fabrication, cambering, bending , special painting, galvanizing or finishing requirements will also need to be noted. Some fabricators will use specialized steel estimating computer programs and spreadsheets to catalog the information. Figure 2.12 shows a sample takeoff sheet.

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Structural Shapes - Warehouse Angles - Warehouse Plates - Warehouse Tubes - Warehouse Other Shapes - Warehouse

Page#	Item#	Qty	Sh	Dimensions	Length	Grade	Type	F	Weight	UnitCost	Cost	Lbr/Pc	Labor mh	Sq/Ft
1	5960	1	C	12 x 20.7	32'-0	A36	A	U	662#	$0.00	$0	0.70	0.70~	94
1	5970	1	W	18 x 35	24'-0	A572-50	D	U	840#	$0.00	$0	1.81	1.81	118
1	5980	4	L	3 1/2 x 3 x 5/16	1'-3	A36	AA	U	33#	$0.00	$0	0.05	0.20~	5
1	5990	1	W	24 x 84	32'-0	A572-50	D	U	2688#	$0.00	$0	4.55	4.55	222
1	6000	4	L	3 1/2 x 3 x 5/16	1'-9	A36	AA	U	46#	$0.00	$0	0.06	0.24~	8
1	6010	1	CO	HOSPITAL ROOF FRAMING							$0		0.00	
1	6020	1	W	18 x 35	32'-0	A572-50	D	U	1120#	$0.00	$0	2.24	2.24	157
1	6030	4	L	3 1/2 x 3 x 5/16	1'-3	A36	AA	U	33#	$0.00	$0	0.05	0.20~	5
1	6040	16	W	18 x 35	32'-0	A572-50	D	U	17920#	$0.00	$0	2.04	32.59	2509
1	6050	64	L	3 1/2 x 3 x 5/16	1'-3	A36	AA	U	528#	$0.00	$0	0.05	3.20~	87
1	6060	6	W	18 x 35	32'-0	A572-50	D	U	6720#	$0.00	$0	1.84	11.05	941
1	6070	24	L	3 1/2 x 3 x 5/16	1'-3	A36	AA	U	198#	$0.00	$0	0.05	1.20~	33
1	6080	1	W	18 x 35	32'-0	A572-50	D	U	1120#	$0.00	$0	2.24	2.24	157
1	6090	4	L	3 1/2 x 3 x 5/16	1'-3	A36	AA	U	33#	$0.00	$0	0.05	0.20~	5
1	6100	2	W	18 x 40	32'-0	A572-50	D	U	2560#	$0.00	$0	2.53	5.06	316
1	6110	8	L	3 1/2 x 3 x 5/16	1'-3	A36	AA	U	66#	$0.00	$0	0.05	0.40~	11
1	6120	11	W	18 x 40	32'-0	A572-50	D	U	14080#	$0.00	$0	2.33	25.63	1737
1	6130	44	L	3 1/2 x 3 x 5/16	1'-3	A36	AA	U	363#	$0.00	$0	0.05	2.20~	60
1	6140	4	W	18 x 40	32'-0	A572-50	D	U	5120#	$0.00	$0	2.23	8.94	632
1	6150	16	L	3 1/2 x 3 x 5/16	1'-3	A36	AA	U	132#	$0.00	$0	0.05	0.80~	22
1	6160	7	W	18 x 35	32'-0	A572-50	D	U	7840#	$0.00	$0	2.14	14.96	1098
1	6170	28	L	3 1/2 x 3 x 5/16	1'-3	A36	AA	U	231#	$0.00	$0	0.05	1.40~	38
1	6180	1	W	18 x 35	32'-0	A572-50	D	U	1120#	$0.00	$0	1.94	1.94	157
1	6190	4	L	3 1/2 x 3 x 5/16	1'-3	A36	AA	U	33#	$0.00	$0	0.05	0.20~	5
1	6200	4	W	18 x 40	32'-0	A572-50	D	U	5120#	$0.00	$0	2.43	9.72	632
1	6210	16	L	3 1/2 x 3 x 5/16	1'-3	A36	AA	U	132#	$0.00	$0	0.05	0.80~	22
1	6220	8	W	14 x 30	14'-0	A572-50	D	U	3360#	$0.00	$0	1.81	14.48	505
1	6230	32	L	3 1/2 x 3 x 5/16	0'-9	A36	AA	U	158#	$0.00	$0	0.04	1.28~	26
1	6240	2	W	14 x 22	24'-0	A572-50	D	U	1056#	$0.00	$0	1.81	3.61	188
1	6250	8	L	3 1/2 x 3 x 5/16	0'-9	A36	AA	U	40#	$0.00	$0	0.04	0.32~	7
1	6260	1	W	16 x 36	24'-0	A572-50	D	U	864#	$0.00	$0	2.17	2.17	118

Figure 2.12 Sample takeoff sheet

Connections for the various members will have a significant impact on fabrication and material costs, therefore, each connection will need to be described and designed. Larger fabricators utilize specialized computer programs which allow the estimator to enter a connection type or class for the connection, when inputting the beam or column information. The computer will be used to determine fabrication requirements and labor hours.

In addition to the main members, the structural steel contractor will also need to takeoff steel items which are attached to the frame, such as spandrel frames and bracing, screed angles, bent plates, framing for floor or roof openings, etc. These elements can add considerable fabrication time as well as tonnage to the project.

The steel contractor may also have in the workscope miscellaneous loose structural steel items and metal fabrications. These miscellaneous items may include lintels, bearing plates, anchor bolts, rods and other pieces of steel which will be installed by other contractors, such as the mason. Some of these components will not be shown on the structural plans and may only appear on the architectural plans. Support for roof top units and other mechanical equipment may be detailed on the mechanical sheets and may be in the structural steel contractor's workscope. Therefore, the estimator must carefully review the architectural, structural and mechanical sheets. Fabrications such as metal stairs, ladders, handrails, guardrails, floor grating, ornamental metals, and expansion joint cover assemblies are also specified in CSI Division 5 Metals, and may need to be estimated for the project.

2.21 Costs Included in the Fabricator's Estimate

Once the steel contractor has taken off the quantities, the steel contractor must determine the pricing to fabricate and to deliver the individual items to the site. Costs which will need to be included are indicated below:

1. Costs including applicable sales taxes and mill certification of structural steel material from the mill, warehouse, or fabricator inventory
2. Freight for shipping steel material from the mill or warehouse to the fabricator's plant
3. Costs of preparing shop and erection drawings, including engineering if required, plus printing and distribution
4. Costs of fabrication of the structural elements, including connections and special processes such as bending or cambering, etc.
5. Finishing the members, including cleaning, shop painting, or galvanizing
6. Costs of independent testing, if required by the contract documents
7. Handling, storage, and loading costs at the fabricator plant
8. Field verification and surveying anchor rod locations
9. Shop testing and inspection, if required; (estimator must verify who pays for independent testing)
10. Shop expenses, including general overhead, supervision, plant and equipment, etc.
11. Freight for shipping fabricated elements to the project site
12. Product liability insurance
13. Bonds (if required)
14. Subcontracted items such as, steel joist and metal deck supply
15. Profit plus general sales and administrative overhead

Source: Adapted from Walker's Building Estimator's Reference Book, 24th Edition

Figure 2.13 below represents a sample estimate summary sheet from a midsize fabricator indicating the estimating summary categories used.

PROJECT:	**MILES TO SITE** 40		**ESTIMATE #** Q
	ESTIMATOR:	STR STL TONNAGE:	0 TONS
DESCRIPTION:		JOIST TONNAGE:	0 TONS
	F.O.B.-	MISC TONNAGE:	0 TONS
		TOTAL	**0 TONS**

ITEM	WEIGHT	QUANTITY	UNIT PRICE	PRICE
MILL A36 GRP I			$23.00	**$0**
MILL A36 GRP II			$25.00	**$0**
MILL A572 GRP I			$23.00	**$0**
MILL A572 GRP II			$25.00	**$0**
PLATE			$40.00	**$0**
BENT PLATE			$40.00	**$0**
ANGLE			$27.00	**$0**
CHANNEL			$27.00	**$0**
TUBE			$50.00	**$0**
PIPE			$45.00	**$0**
ANCHOR BOLTS			$0.00	**$0**
L.I.B. BOLTS			$0.85	**$0**
STD H S BOLTS			$0.65	**$0**
STUDS			$0.55	**$0**
PAINT MATERIAL	R=1 W=2		$20.00	**$0**
GALVANIZING			$0.27	**$0**
MISC				
MISC				
MISC				
TOTAL WEIGHT		**0 #**	**TOTAL MATERIAL COSTS**	**$0**
MATL $ PER CWT	**$0**		**PLUS 6% TAX**	**$0**

SHOP LABOR & TRUCKING COSTS				
STRUCTURAL		**0.00**	**HOURS / TON**	
MISC				
MISC				
MISC				
CARTAGE JOBSITE	**3**	X TRUCKING	$50.00	$0
CARTAGE OTHER		X TRUCKING	$50.00	$0
CLEANING HOURS	**0**			
TOTAL LABOR		**2 HRS x RATE**	**$50.00**	**$0**
SHOP PRICE / TON	**$0**		**TAX ON LABOR**	**$0**

BLAST CLEANING SP 6			
O.5 HRS/PIECE X	PIECES		
$9 /MAIN PIECE	**0** PIECES	BLAST MACH	**$0**
MISCELLANEOUS			**$0**
MISC			
TOTAL CLEANING COSTS			**$0**

ENGINEERING			
SUB DETAILER	+ IN HOUSE	10%	**$0**
IN HOUSE HOURS	**0** HRS	$50.00	**$0**
PRINTING			**$0**
DESIGN HOURS	**0** HRS	$75.00	**$0**
ESTIMATING HOURS	**0** HRS	$58.00	**$0**
TOTAL ENGINEERING COST			**$0**
	ENGINEERING COST $ / TON		**$0**

	TOTAL F O B COST	**$0**
Rev. 1/28/99	**STRUCTURAL STEEL FOB / TON**	**$0**

ERECTION	I.W. HOURS	
STR STL	**0**	**$0**
MISC IRON		
DECK ERECTION		
SHEAR STUDS F&I		
HORIZ STUDS F&I		
INSPECTION		
SUB MARK UP		
A B SURVEY		
MISC		
MISC		
TOTAL ERECTION COSTS		**$0**
0 BOLTS / TON	**ERECT $/TON**	**$0**

SUBLET TAXED ITEMS	
JOISTS	
DECK	
GRATING	
MISC	
MISC	
MISC	
MISC	
MISC	
MISC	
TOTAL TAXED ITEMS	**$0**
PLUS 6% TAX	**$0**

SUBLET NON-TAXED ITEMS	
MISC IRON - F & I	
DECK - F & I	
STAIRS - F & I	
ROLLING LABOR	
MILLING BASE PL	
MISC	
MISC	
MISC	
TOTAL NON-TAXED ITEMS	**$0**

TOTAL SUBLET ITEMS	**$0**
2.5% S & A	**$0**

SUMMARY	
ESTIMATE SUB TOTAL	**$0**
PROFIT	**$0**
PRODUCT LIABILITY	**$2.5**
F.O.B. TAX	**$0**
TOTAL ESTIMATE	**$0**
P & P BOND -	**$0**
TOTAL ESTIMATE W/ BOND	**$0**
WEIGHT (#) PER SQUARE FOOT	**0.00**
PRICE PER SQUARE FOOT	**$0.00**
PROFIT $/ SHOP HOUR	**$0**
TOTAL ESTIMATE COST /TON	**$0**

Figure 2.13 Sample estimate summary sheet

PROJECT: 0 TONS 0 IRONWORKER HOURS INSURANCE CODE A

0

NO	HOISTING OPERATIONS	QUANT	STD.	CREW HOURS	SIZE	TOTAL HOURS
1	SET-UP & DISMANTLE CRANE		0.75	0	4	0
2	UNLOAD TRUCKS - STRUCTURAL		0.75	0	4	0
3	UNLOAD TRUCKS - JOISTS		0.75	0	4	0
4	UNLOAD TRUCKS - DECK		0.75	0	4	0
5	UNLOAD & HOIST SHEAR STUDS (PALLETS)		7.50	0	4	0
6	COLUMNS		9.00	0	4	0
7	BEAMS		7.50	0	4	0
8	BRACING		0.75	0	4	0
9			0.75	0	4	0
10			0.75	0	4	0
11			0.75	0	4	0
12			0.75	0	4	0
13			0.75	0	4	0
14			0.75	0	4	0
15			0.75	0	4	0
16	ROOF FRAMES		7.50	0	4	0
17	TRUSSES		3.00	0	4	0
18	JOISTS		15.00	0	4	0
19	FASCIA FRAMES		7.50	0	4	0
20	X ANGLE BRACING		6.00	0	4	0
21	BUNDLES OF LOOSE MATL		75.00	0	4	0
22	**SECONDARY SUMMARY**	0	0.75	0	4	0
23	UNLOAD & HOIST STAIR /FLOOR		0.75	0	4	0
24	ROOF DECK SQ'S		90.00	0	4	0
25	FLOOR DECK SQ'S		45.00	0	4	0
	TOTAL HOISTING HOURS			0		0

	COMPLETION OPERATION	QUANT	STD.	HOURS	SIZE	HOURS
1	H S B - 3/4" STANDARD		9.00	0	1	0
2	H S B - 3/4" DIA. L.I.B.		18.75	0	1	0
3	BOLT JOIST ENDS		6.00	0	1	0
4	FW JOIST ENDS		7.50	0	1	0
5	FW BTM CHORD EXTENSIONS		6.00	0	1	0
6	FW HORIZ BRDG POINTS		18.00	0	2	0
7	SETS OF X BRDG - FW OR BOLT		6.75	0	2	0
8	FW & ALIGN FACIA FRAMES		0.36	0	3	0
9	FW & BOLT K B @ FACIA FRAME		7.50	0	3	0
10	FW BEAM MOMENT CONN ENDS		0.38	0	2	0
11	FW BEAM CONN ANGLE TO WALL PL		0.75	0	1	0
12	FW COLUMN SPLICE		0.38	0	2	0
13	EXPANSION BOLTS		6.00	0	1	0
14			0.75	0	1	0
15			0.75	0	1	0
16			0.75	0	1	0
17			0.75	0	1	0
18			0.75	0	1	0
19			0.75	0	1	0
20			0.75	0	1	0
21			0.75	0	1	0
22			0.75	0	1	0
23	**SECONDARY SUMMARY**	0	0.75	0	1	0
24	STAIR / FLOOR, INCL HR		0.38	0	1	0
25	SAFETY CABLE - LF		36.00	0	1	0
26	PLUMB CABLES - EACH		2.63	0	2	0
	TOTAL COMPLETION HOURS					0

IRONWORKER HOURS	**0** HOURS
15% SUPERVISION	**0** HOURS
10% WEATHER TIME	**0** HOURS
TOTAL IRONWORKER HOURS	**0 HOURS**

LABOR HOURS INCLUDING WEATHER TIME	
CRANE OPERATOR HOURS	**0** HOURS
CRANE OILER HOURS	**0** HOURS
COMP OPERATOR HOURS	**0** HOURS
WELDING MACH OPERATOR	**0** HOURS
TOTAL ERECTION MAN HOURS	**0 HOURS**

LABOR COSTS INCLUDING WEATHER AND TRAVEL		
IRONWORKER HOURS	$30.35 PER HR	**$0**
CRANE OPERATOR	$31.35 PER HR	**$0**
CRANE OILER	$23.50 PER HR	**$0**
COMPRESSOR OPER.	$22.50 PER HR	**$0**
WELD MACH OPER.	$22.60 PER HR	**$0**
TOTAL LABOR COSTS		**$0**

EQUIPMENT COSTS INCLUDING WEATHER		
SAFETY CABLE	0 LF x$0.75	**$0**
TOUCH-UP PAINT	0 TONS x$70	**$0**
CRANE	$0.00 PER HR	**$0**
ASSIST CRANES INC OPER. & OILER		
CARTAGE IN & OUT		
MATS	RENTAL & CARTAGE	
MISC		
MISC		
MISC		
TOTAL EQUIPMENT COSTS		**$0**

TOTAL ERECTION COSTS	**$0**
PRICE PER TON	**$0**

Figure 2.13 Sample estimate summary sheet cont'd

The seven-story project case study (documents included in Appendix A) utilized 1,330 tons of structural steel and averaged approximately 10.35 lbs of structural steel per square ft of building area (256,900 square feet). The structural frame used 26,000 bolts. Table 2.3 shows the project cost breakdown for the structure.

	Cost	% of Total
Structural Material (raw)	823,579	36%
Fabrication Labor	389,132	17%
Detailing Labor	78,389	3%
Erection Labor	415,889	18%
Deck Material	323,125	14%
Deck Erection Labor	82,368	4%
Stair Fabrication and Erection	145,200	6%
Total	$2,257,682	100%

Table 2.3 Structural steel cost breakdown for case study project

2.22 Special Estimating Issues for Fabrication

The cost of furnishing fabricated steel to the job includes the costs of the raw material, detailing, approvals, fabrication, finishing, delivery, as well as the costs of administrative procedures, profit, and overhead. The costs associated with fabrication will not only be impacted by the amount of material, but also by the type of material and shapes called for in the design, as well as the complexity of the connections and other fabrication. The steel fabricator's estimator must be skilled at quantifying and characterizing each piece of steel for the project. Some of the issues which will impact the fabricator's pricing are discussed below.

Mill Steel vs Warehouse Steel. The estimator must determine the source of the raw steel material to be fabricated for the project. Steel supplied from the mill will generate savings for raw steel, compared to ordering from a steel service center (warehouse). The estimator will need to contact the mill or warehouse to determine the latest pricing for steel. Costs of taxes and delivery to the fabricator's plant should also be included. Raw steel accounted for approximately 36% of the total cost of structural steel for the case study. Most of the steel material for the case study project was purchased directly from the mill.

Material Type and Strength. The estimator must determine the type of steel specified and a producer of the shapes indicated on the plans. At the time this manual was prepared (1999), the majority of steel shapes for smaller buildings were typically A36 steel. The use of recently introduced higher strength A992 grade 50 steel is highly recommended as it can provide increases in strength and therefore a reduction in member size. Also A992 grade 50 steel is available in all wide flange shapes and normally at no cost increase. Only large size sections might require an increase in cost; however, that is normally offset by savings due to the member's increased strength.

Weight/Cost Economies. Most midsize to large fabricators can handle relatively large steel shapes and sections. While the cost of steel is related to the weight of the member, it is also related to the amount of fabrication and erection required for the structure. When taken together, it is sometimes possible that frame costs can be lowered by increasing beam spans and reducing the number of columns. The increase in beam weight, size, and the cost necessary to accommodate the longer span, may be more than offset by a reduction in column costs, fabrication, and fewer number of pieces to be erected. Also, overall savings may sometimes be obtained by using heavier members and eliminating stiffeners and other strengthening plates. Refer to the AISC Design Guides.

Shop Drawings and Approvals. Shop drawings for steel can become quite detailed. For complex frame designs with specialized fabrication requirements, the process of producing the drawings can be very labor intensive. For the case study project, the production of these drawings accounted for approximately 3% of the total structural steel cost, which is about average for a midsize office building. Shop drawings are either produced in-house with the fabricator's own detailers or contracted to an independent steel detailing firm. In either case, the estimator will need to make a judgment regarding the costs of shop drawings based on experience or pricing from the detailer. The purpose of the steel shop drawings has been previously discussed in Project Management Module One and in the scheduling portion of this manual (Module Two).

Fabrication and Connections.
Fabrication of the steel members includes handling the member in the shop, laying out and setting up the piece, cutting to length, making cuts such as beam copes, drilling, punching, welding, bolting, etc. Each element of the structure will generally receive some fabrication. The estimator must evaluate the time and material required for each element of fabrication. Most fabricators will have developed guidelines for determining labor hours for various standard types of connections and fabrications. The estimator will characterize the type of fabrication necessary for the piece and utilize the fabricator's labor standard for that particular type of connection. Unique or specialized details which are not typical, may require the estimator to consult directly with the shop personnel or engineering staff to determine the methods and costs for fabricating a particular connection. Fabrication labor represents a significant cost and accounted for 17% of the structural steel costs for the case study project.

Fabricator's Equipment and Shop Operation. The fabricator must assess the economy of fabricating the pieces in-house or to subcontract portions to other shops. Shop setup and capacity, other simultaneous projects, and shop expertise dictate whether the element will be fabricated in-house. Large shops may find that they underutilize their shop equipment by fabricating small and time-consuming components, such as bending plates and fabrication of specialized items such as metal stairs and pipe railings. They may prefer to subcontract this work to smaller shops, thus preserving shop capacity for larger work. The fabricator should maintain close working relationships with smaller specialty shops which may be able to provide this specialty work.

Painting and Finishing. The estimator must determine from the specifications, the type of surface coating required for the project. Painting and finishing requires that the surface be cleaned, usually by shot blasting or wire brush, prior to painting. Finishes may range from shop priming with rust inhibiting primers, to galvanizing, or in some instances, finished painting for specialized architecturally exposed steel projects. The shop setup will determine whether the fabricator finishes the piece in-house or sends the piece to a separate entity, such as a galvanizing company. The cost of the finishing material, as well as the shop labor to prepare and apply the coatings will impact this portion of the steel price. With special finish coatings, increased care and time may be required in handling and touch-up in order to maintain a high quality finish.

Bolts. The fabricator furnishes all of the bolts to be installed by the fabricator in the shop, and those bolts installed in the field by the erector; 26,000 bolts were used in the case study project. Bolts are purchased from a supplier and must be furnished in the quantities, sizes, types, and strengths necessary for the connection. High strength A490 bolts may be used for heavier connections and standard A325 bolts used for typical and lighter connections as specified by the Research Council on Structural Connections (RCSC). A307 bolts will be used for some minor connections. Bolts may need to be fully tensioned for some slip critical connections, thus adding more erection labor. The fabricator's estimator will need to determine the number of bolts of various types and sizes. By determining the type of connections and their number, the estimator can typically determine the number of bolts either by using a steel estimating computer program, or by experience based on the number and the size of the pieces being connected, as well as approximate counting. The AISC Code of Standard Practice requires that the fabricator furnish an additional 2 percent of each bolt size (diameter and length) to the erector. Table 2.4 below is reprinted from the AISC Manual of Steel Construction and indicates material available for bolts.

BOLTS, AND THREADED PARTS
ASTM Specifications

TABLE I-C. MATERIAL FOR ANCHOR BOLTS AND TIE RODS

	ASTM Specification	Strength, Ksi			Maximum Diameter In.	Type of Material[b]	Headed or Unheaded
		Proof Load	Yield (Min.)	Tensile (Min.)			
Bolts and Studs	A307	—	—	60	4	C	H
	A325[a]	85 74	92 81	120 105	½ to 1, incl. 1⅛ to 1½ incl.	C, QT	H
	A354 Gr. BD	120 105	130 115	150 140	¼ to 2½ incl. over 2½ to 4 incl.	A, QT	H, U
	A354 Gr. BC	105 95	109 99	125 115	¼ to 2½ incl. over 2½ to 4 incl.	A, QT	H, U
	A449	85 74 55	92 81 58	120 105 90	¼ to 1 incl. 1⅛ to 1½ incl. 1¾ to 3 incl.	C, QT	H, U
	A490	120	—	150	½ to 1½ incl.	A, QT	H
	A687	—	105	150[c]	⅝ to 3 incl.	A, QT, NT	U
Threaded Round Stock	A36	—	36	58	8	C	U
	A572 Gr. 50	—	50	65	2	HSLA	U
	A572 Gr. 42	—	42	60	6	HSLA	U
	A588	— — —	50 46 42	70 67 63	To 4 incl. over 4 to 5 incl. over 5 to 8 incl.	HSLA, ACR	U

[a]Available with weathering (atmospheric corrosion resistance) characteristics comparable to ASTM A242 and A588 steel.

[b]C = carbon
QT = quenched and tempered
A = alloy
NT = notch tough (Charpy V-notch 15 ft-lb. @ −20°F)
HSLA = high-strength low alloy
ACR = atmospheric corrosion-resistant

[c]Maximum (ultimate tensile strength)

Notes:
ASTM specified material for anchor bolts, tie rods and similar applications can be obtained from either specifications for threaded bolts and studs normally used as connectors or for structural material available in round stock that may then be threaded. The material supplier should be consulted for availability of size and length.
Suitable nuts by grade may be obtained from ASTM Specification A563.
Anchor bolt material that is quenched and tempered should not be welded or heated to facilitate erection.
Threaded rod with properties meeting A325, A490 or A449 Specifications may be obtained by the use of an appropriate steel (such as AISI C1040 or C4140), quenched and tempered after fabrication.

AMERICAN INSTITUTE OF STEEL CONSTRUCTION

Table 2.4 Bolts and threaded parts
(AISC Manual of Steel Construction)

Shop Welding. Many of the fabricated components will be welded or bolted in the shop with connections prepared for bolting in the field. All welds should be made according to the provisions of the American Welding Society (AWS), Structural Welding Code and AISC specifications. Certain standard types of welded joints are prequalified by the AWS and are exempted from special testing and qualification. Amounts of weld for a particular connection are a function of the loads, type of weld joint such as fillet or full penetration, and the dimensions of the weld such as weld length and effective throat. Welds may be continuous or intermittent. Some welds require multiple passes of the welder to build up sufficient weld material. Figure 2.14 shows the standard welded joints symbols used to describe weld joints.

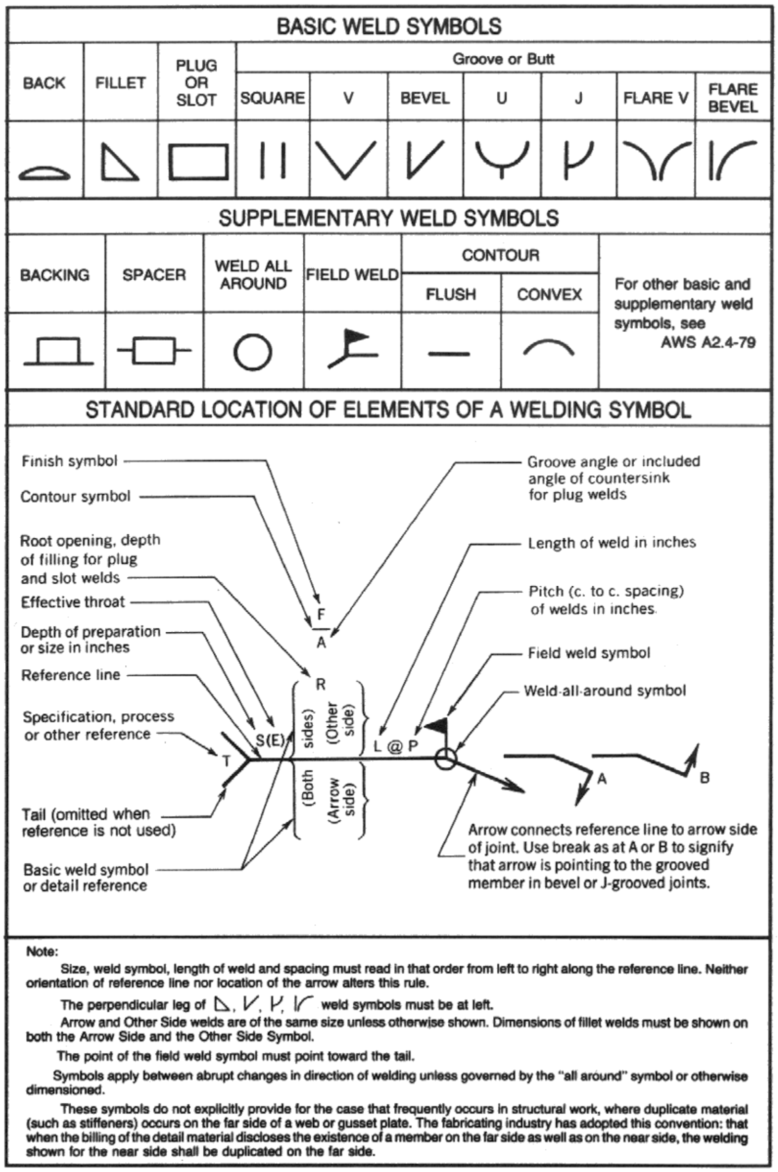

Figure 2.14 Welded joint symbols
(AISC Manual of Steel Construction)

Welding methods used in the shop vary among fabricators, but may include shielded metal arc, submerged arc, gas metal arc, and flux core arc welding. Generally, the welding method is left up to the fabricator, providing it meets the requirements of the design and complies with the AWS Structural Welding Code. Selection of the welding method is usually a function of the shop equipment and preference. Large shops may utilize automated welding operations. Shop welding is usually more economical than field welding because of the availability of welding equipment and jigs within the shop.

Estimators generally work with the fabricator's predetermined labor hours for typical welded connections. Estimating of specialized welded connections may require the estimator to consult with the shop or engineering personnel to determine labor hours.

Mill or Shop Inspection Costs. Typically, mill tests are performed to establish that the material is in compliance with ASTM specifications. If required by the contract documents or by the fabricator, the mill will provide test reports. These test reports are normally accepted by the fabricator as evidence of compliance with the American Society for Testing and Materials (ASTM) standards.

Occasionally the contract documents will require special testing or certification beyond that normally provided under standard industry practice. Costs for special testing of shop paint thickness, weld quality, or surface preparation, etc. should be identified and included by the fabricator in the estimate. The specifications may also require welding inspectors to be AWS/CWI certified by the American Welding Society.

Loading, Storage, Delivery, Transportation. Costs of loading, handling, storage, and delivery of fabricated steel items to the site need to be determined. Refer to section 2.6 for information on these activities. The estimator must determine the mode of transportation as well as travel distance, number of loads, and sequence of delivery when estimating these costs.

Metal Decking. Metal decking will normally be purchased by the fabricator from a metal deck supplier. Metal deck for the project will vary with the application. Deck span, rib or corrugation configuration, length and depth, material type and strength, finishes, etc. will all impact deck costs. The fabricator will usually work closely with the deck supplier to determine the quantity of the different deck types. The fabricator will receive a price quotation from the deck supplier, which is included in the fabricator's overall price. Metal deck material accounted for 14% of the case study steel contract.

Steel Joists. Steel joists can offer significant savings for long spans, such as in roofs. Typically the joists are purchased from a steel joist supplier who fabricates the joist for the project. Joists carry a letter and number designation signifying compliance with the Steel Joist Institute's (SJI) standards for load carrying capacity and span. The fabricator will obtain price quotations from the steel joist supplier for the project and incorporate this pricing into the overall pricing.

Architecturally Exposed Structural Steel. Architecturally exposed structural steel presents some unique fabricating, finishing, handling, and quality control measures for the fabricator. Connections and finishes are frequently detailed for their artistic expression as well as for strength. The fabricator may be required to fabricate nonstandard details, increase the amount of grinding, as well as alter standard surface preparation methods. Special coatings may be expensive or difficult to apply.

Careful handling and touch-up may be required. Sometimes architectural or engineering specifiers may have unrealistic expectations for tolerances and finish quality that can be achieved in the fabricator's shop. The estimator must recognize the special requirements necessary for architecturally exposed structural steel and include appropriate costs in making the estimate.

2.23 Costs Included in the Erector's Estimate

The erector must analyze the project to determine the cost for assembling the steel frame. The erector may be a subcontractor to the fabricator-steel contractor, or the steel contractor may conduct both fabrication and erection operations. The steel erector not only determines the number of pieces and their sizes, but will need to examine closely how they are to be installed. The building size, height, footprint, project type, site conditions, and construction sequence will heavily influence the equipment, methods, and duration necessary for the installation. Certain connections such as moment resisting connections, or field welded connections will increase the labor hours for installation. The erector may include the following costs when estimating for erection of the steel:

1. Verification of anchor rod layouts and elevations (if required)
2. Equipment, cranes and hoists, (including mobilization, setup, and removal)
3. Unloading steel at site
4. Lifting and assembling the steel
5. Temporary shores, and bracing for both self-supporting and non-self-supporting structures
6. Costs of maintaining safety
7. Making all field bolted and welded connections
8. Leveling , plumbing and final tightening of bolts
9. Metal decking supplied to fabricator installed by metal deck subcontractor
10. Shear studs furnished and installed by subcontractor
11. Demobilization
12. Overhead and profit

Source: Adapted from Walker's Building Estimator's Reference Book, 24th Edition

Similar to the fabricator, the erector's estimator must carefully review the project plans and specifications to determine the number and character of pieces to be installed. This includes number of bolts, amount of field welding, special installation requirements, testing, and inspection requirements. Some fabricators will make their quantity takeoff for pieces and bolts available to the erector, which may serve as a check for the erector's estimator; however, this practice will vary from fabricator to fabricator. In addition, the erector must work closely with the general contractor or construction manager to determine the project conditions, site layout, construction schedule, and construction sequence. The type of equipment for lifting and hoisting must be determined based on the loads and site configuration. Crew productivity must be determined based on the project conditions.

Most of the erection cost will be time dependent. Labor productivity, erection duration, and equipment rental or ownership costs are highly impacted by factors which do not show up on the plans. Although there are some general industry rules of thumb for estimating productivity of the erection crew, estimating of erection is largely empirical and based on the erector's many years of experience. Generally, an erection crew may be able to erect from 10 -20 tons or 50 pieces of steel per day on a simple one crane typical building with no special conditions to slow productivity.

Crew size is generally controlled by the project characteristics and union work rules, The crew would normally include a foreman, 4-6 ironworkers, a crane operator, and a crane oiler. The crew may also include a welding foreman, welders, and weld machine operators. Labor rates, including fringe benefits, are typically established by the local union agreement or by market conditions in nonunion areas.

Safety is an important component of steel erection. Methods for maintaining fall protection, safety netting, temporary railings, temporary shoring, as well as equipment operation, personal protective devices and clothing, etc. must be established and followed. Pricing for maintaining safety must be included. Refer to Section 1.12 for a discussion of safety issues.

Costs for surveying of anchor rod locations and plumbing the structure must be determined. Anchor rod locations should be checked by the erector prior to delivery of steel in order for the foundation contractor to correct elevations and center-to-center locations prior to arrival of steel. If required by the contract, the erector may be responsible for correcting misplaced anchor rods if steel is placed on them.

The cost for erection of structural steel and metal deck represented 18% and 4% respectively of the total steel construction cost for the case study project.

2.24 Special Estimating Issues Concerning Erection

Building shape and size, site conditions, and construction sequence all have a very large impact on the cost of steel erection. Building shape and size will dictate the number and type of cranes and hoisting equipment to be used for the project. Tall structures may require the use of stationary tower cranes. Horizontal structures require the use of crawler cranes or truck mounted mobile cranes. In some instances, the general contractor may provide a climbing crane. The lifting devices may be owned by the erector or may be rented for the project. In any case, the equipment required for the project must be determined, and costs for mobilization, rental, maintenance, financing, fuel, operation and labor must be calculated from the anticipated duration of use.

The duration of steel erection will be impacted by the above factors, as well as the characteristics and complexity of the installation and connection methods used. Some of the special issues that the erector's estimator must consider are discussed below.

Connections. Field connections are typically bolted for non-moment resisting frames and may be heavily bolted or welded for moment resisting frames. Field welding generally adds to the labor cost of erection, but costs are project specific. Bolting will usually be a more economical form of erection. However, the form of connection is usually a function of the structural design and is not normally a choice that the erector controls. The estimator must keep in mind the attachment methods and the types of connections in determining the labor estimate. When welding is the specified method of attachment, the erector must weld in accordance with AWS welding standards, and must furnish and install weld material in accordance with the erection drawings.

Metal Decking. Many steel erectors subcontract with a metal deck erector for installation of metal deck. Metal deck is usually installed by welding to the structural steel; metal deck erectors may be more efficient at installing this portion of the structure, thus freeing up the steel erector's crew for installation of the main steel elements. Decks must be installed on lower floors prior to framing subsequent floors in accordance with OSHA Sub Part R, or alternate fall protection must be installed by the erector. The erector should work closely with the deck erector to coordinate the schedule and establish this lower tier subcontract pricing. Metal deck installation was installed by a separate deck erector for the case study project and accounted for 4% of the total steel construction costs.

Shear Studs. Shear studs used for composite floor deck systems are typically installed by a separate shear stud subcontractor, who also furnishes and installs them. The erector estimator will generally seek price quotations for this portion of the work and will include this cost in the overall subcontract price.

2.25 Economy of Steel Construction and Methods for Reducing Costs

There are many potential economies to using a structural steel frame. Economy begins with an efficient design and layout by the structural engineer, and can be maintained or increased during fabrication and erection by careful coordination and communication by all parties. Site layout and construction sequencing will influence equipment requirements and costs, as well as the speed of erection. Early ordering of mill steel and a well orchestrated shop drawing and approval process can yield significant savings of time and its associated costs.

In a general contract form of project delivery, the steel contractor may be limited in changing the structural engineer's structural design. However, the fabricator can influence costs through connection detailing and may be able to suggest more efficient methods for achieving the desired results. In construction management and design-build project delivery methods, the steel contractor may be in a position to provide early input into the design which may lead to more economical designs.

AISC has published a variety of documents that present design methods for steel and ways to design efficient structures. These publications, together with discussions with fabricators and erectors have been used to prepare the following list of cost-saving measures. Construction managers and design-builders can suggest the following ideas in the early design stages of the project or during concept evaluation:

1. When possible, the use of repetitive members of the same length and size will allow for easier shop drawing development and approval, and shorter shop setup, fabrication, and erection times. There may be times when increasing the weight of some members to maintain repetitivity may be justified in order to save fabrication time.
2. The use of larger column spacings and beam spans will reduce the number of connections to be fabricated and erected, as well as foundation costs.
3. The use of high strength A992 Grade 50 members will reduce member size and handling costs. This material generally is available at no increase in cost over A36 steel.
4. Continuous beams or cantilevering over the top of columns to support adjacent beam ends will reduce beam sizes and weight.
5. Simplification of connections can save significant amounts of fabrication. For example, the use of complex moment resisting frames rather than braced frames, will add significant fabrication and erection labor costs to the structure.
6. The use of Load and Resistance Factored Design (LRFD) methods in lieu of Allowable Stress Design (ASD) methods can yield savings of 3-5% for some structures, depending on the loads and layouts.
7. Simplifying the connections of attached items such as curtain walls can save labor costs.
8. Expensive finishing methods such as galvanizing or special painting requirements should be avoided when possible. The specification of special coatings will add significant cost to the project. Preparation of the surface, painting, handling, and paint touch-up, are all increased by the use of special coatings. Where architecturally exposed steel is to be used on the project, these coatings may not be avoidable. However, fabricators should be

consulted during preparation of specifications to determine the appropriate coatings and their ability to apply them. When steel is to be completely enclosed, painting may not even be necessary.

9. Early ordering of steel from the mill instead of using steel from a steel service center.
10. Steel shapes which have cost premiums should be avoided when possible. Some structural shapes, such as bent plates and tees require fabrication to achieve the shape. The use of angles instead of bent plates may save project costs.
11. Avoid connections which require extensive field welding when possible. When the design is such that field welding is necessary, connections should be designed to avoid awkward or overhead welding angles.
12. Site layout and configuration, as well as construction sequencing, are important elements in establishing the type of equipment and the time required to erect the structure. Close coordination by the erector, fabricator, and contractor in project planning for construction can increase the efficiency of the erection crew and consequently reduce erection costs.
13. The quality of the contract documents has a significant impact on the ability of the estimator to determine precisely what is required for the project. Incomplete or poorly detailed plans require the steel contractor's estimator to guess at the designer's intentions. To be protected from risk of future modifications or (bulletins), the estimator will naturally increase the price.

2.26 Published Sources of Estimating Data and Estimating References

Pricing of structural steel, like most materials, will vary with supply and demand and general market conditions; therefore, the estimator should maintain frequent contact with mills and steel service centers to obtain current pricing. Students who may not have access to actual price information could utilize the most current pricing from RS Means Building Construction Cost Data or, Walker's Building Estimator's Reference Book to obtain approximate ranges of prices for standard items. Industry sources such as Engineering News Record, published by The McGraw-Hill Companies publish quarterly or annual cost reports which may also be helpful in assessing how prices are changing.

2.27 Summary

Costs for steel construction are highly dependent upon specific steel details and project conditions. Because the structural frame can represent a significant portion of overall project costs, durations, and sequencing, knowledge of steel estimation methods is important for students interested in managing construction projects In this portion of Module Two, a discussion of the steel estimator's overall approach to estimating steel was presented. Specific items included in the fabricator's and erector's estimates were emphasized. Factors that may influence the fabricator's and erector's pricing were also addressed. Finally, methods for reducing and controlling costs were introduced.

Questions for Classroom Discussion

1. How does the steel contractor's level of estimating detail differ from that of the general contractor? Why is it difficult for general contractors to prepare accurate detailed estimates?

2. How do project site conditions impact the cost of steel erection?

3. Give examples of detail types, materials or specification requirements that impact the fabricator's estimate.

4. How does the source of steel for fabrication impact cost and time of the project?

5. What are the proportionate values (costs) of raw material, fabrication and erection for a mid-rise steel framed project?

6. How can a construction manager or design builder work with the steel contractor to establish useful conceptual budgets?

7.. What value engineering suggestions would you recommend for steel design and construction?

Notes

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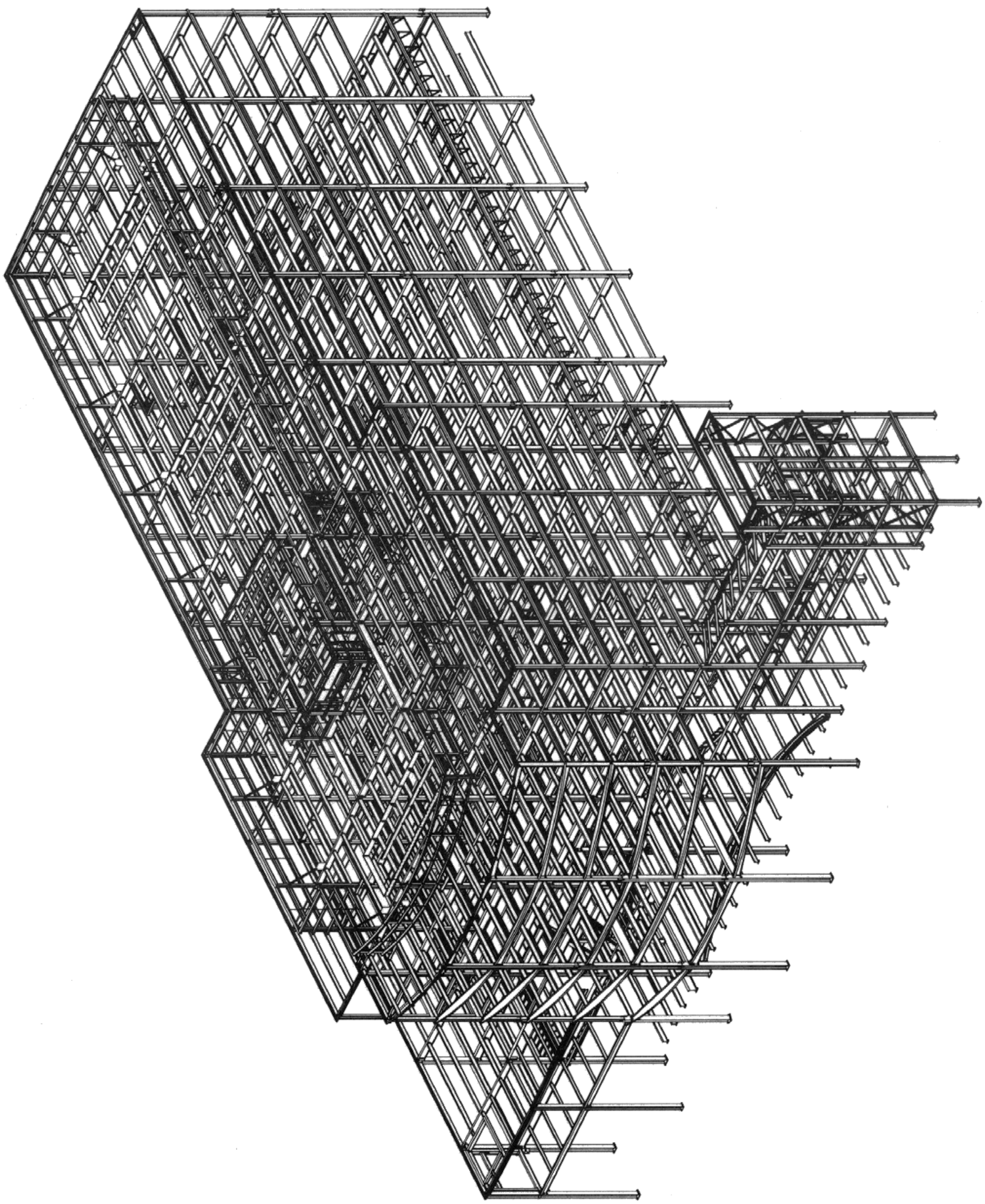
APPENDIX A - CASE STUDY PROJECT DETAILS

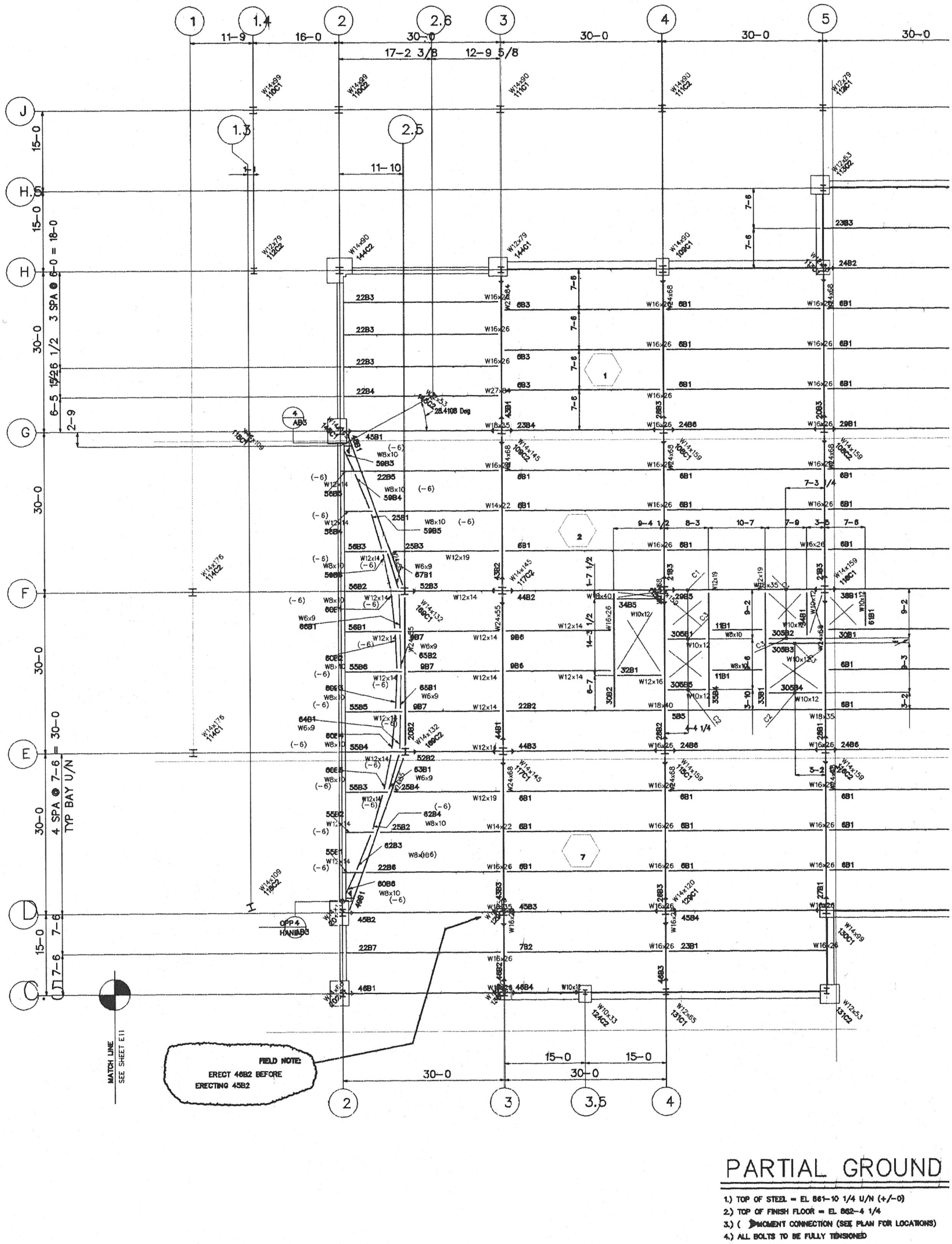
Case study photos

Case study photos

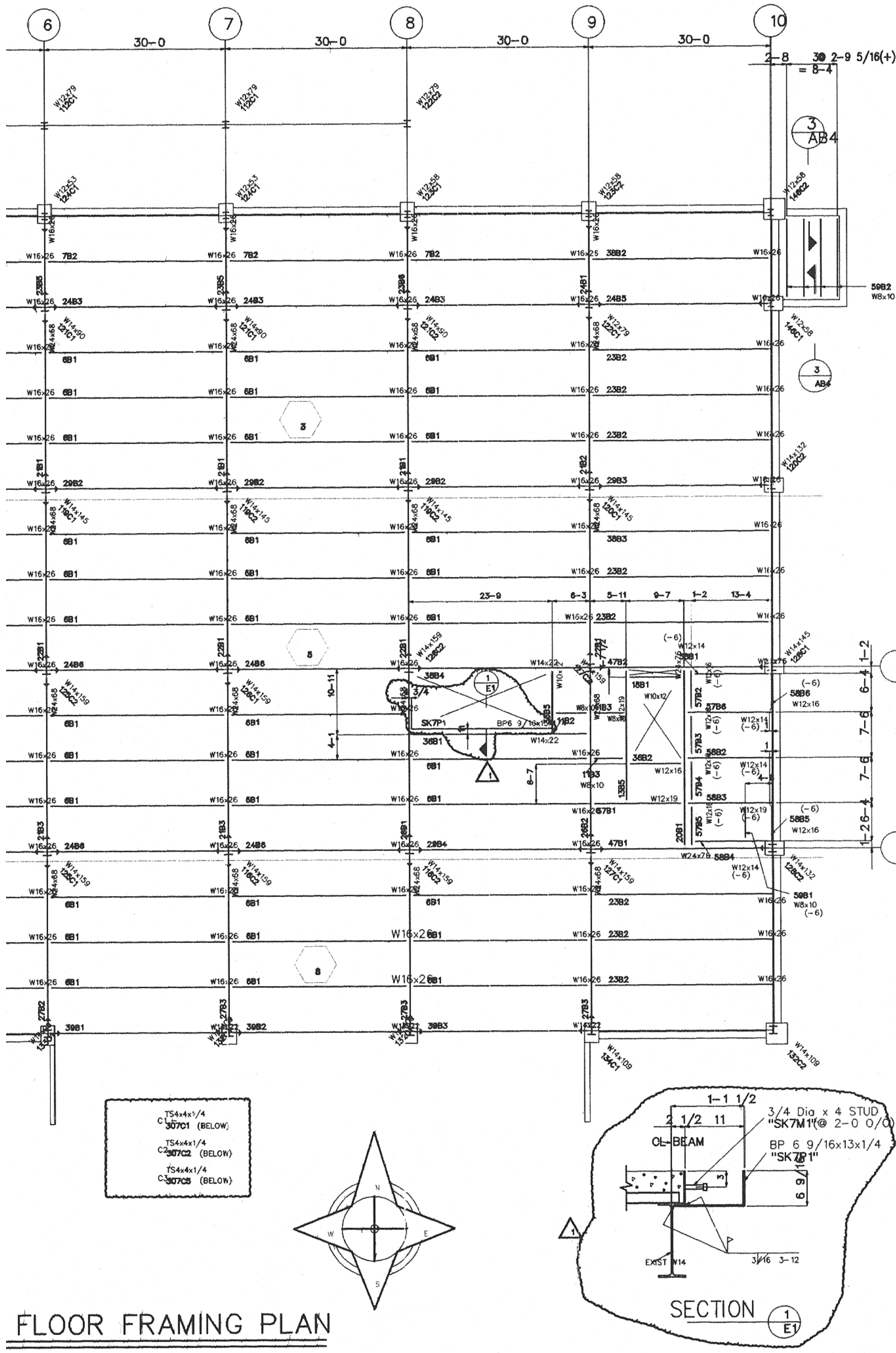
Case study photos



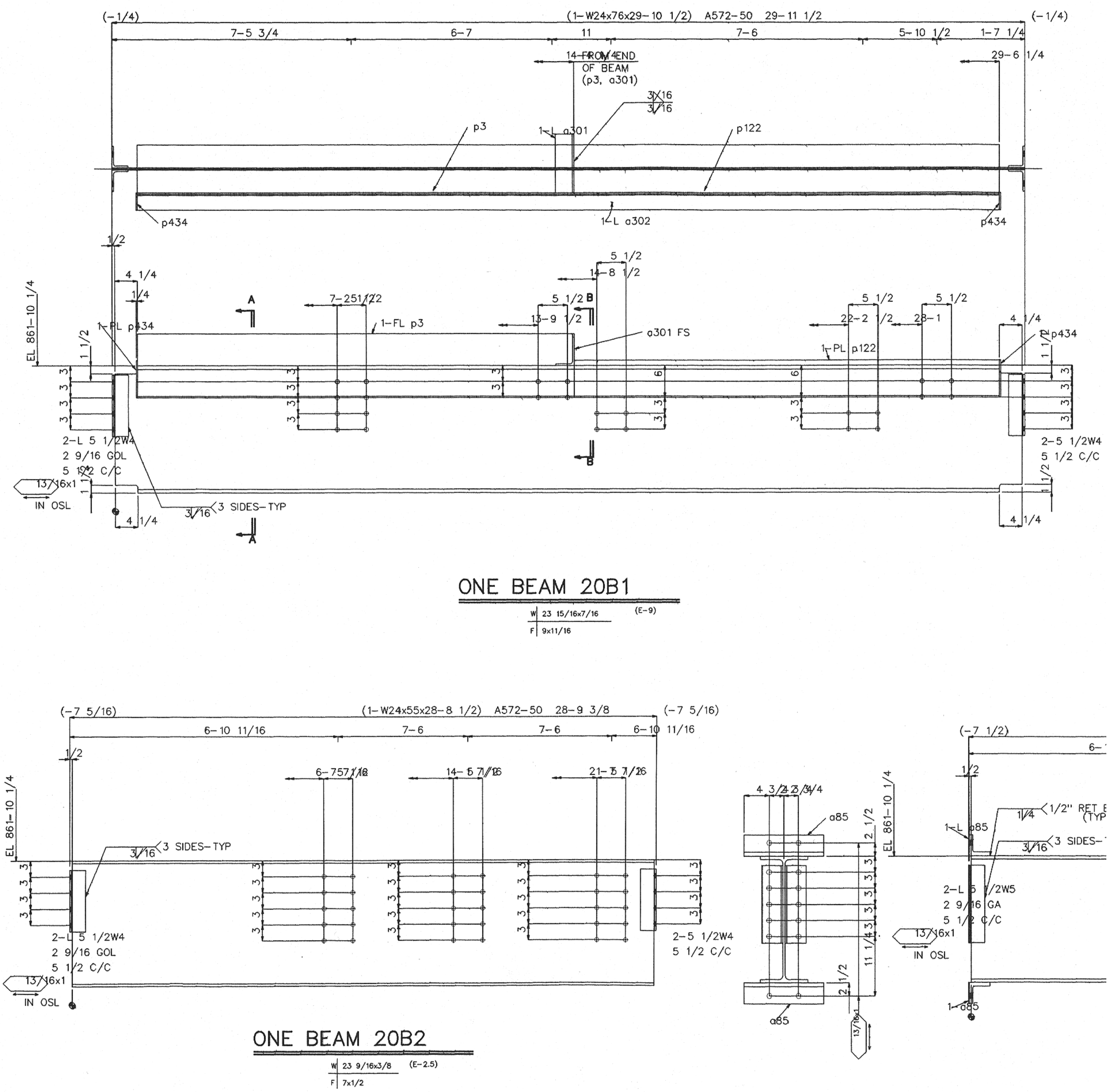
Case study isometric



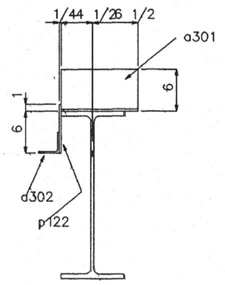
Erection drawing (E-sheet)



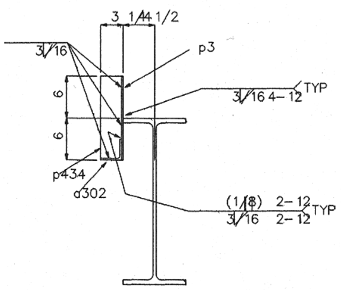
6
7
8
9
10
30-0
30-0
30-0
30-0
F
E
TS4x4x1/4 307C1 (BELOW)
TS4x4x1/4 307C2 (BELOW)
TS4x4x1/4 307C5 (BELOW)
N
S
E
W
1-1 1/2
3/4 Dia x 4 STUD "SK7M1" @ 2-0 O/C
CL BEAM
BP 6 9/16x13x1/4 "SK7P1"
EXIST W14
SECTION
FLOOR FRAMING PLAN



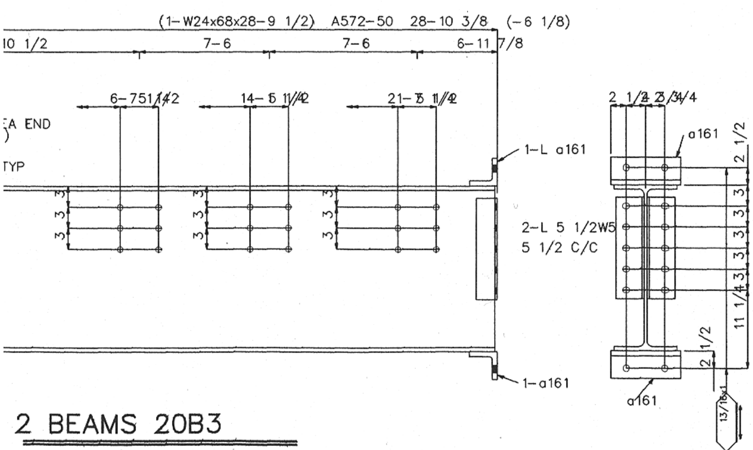
Shop drawing



Section B-B
20B1



Section A-A
20B1



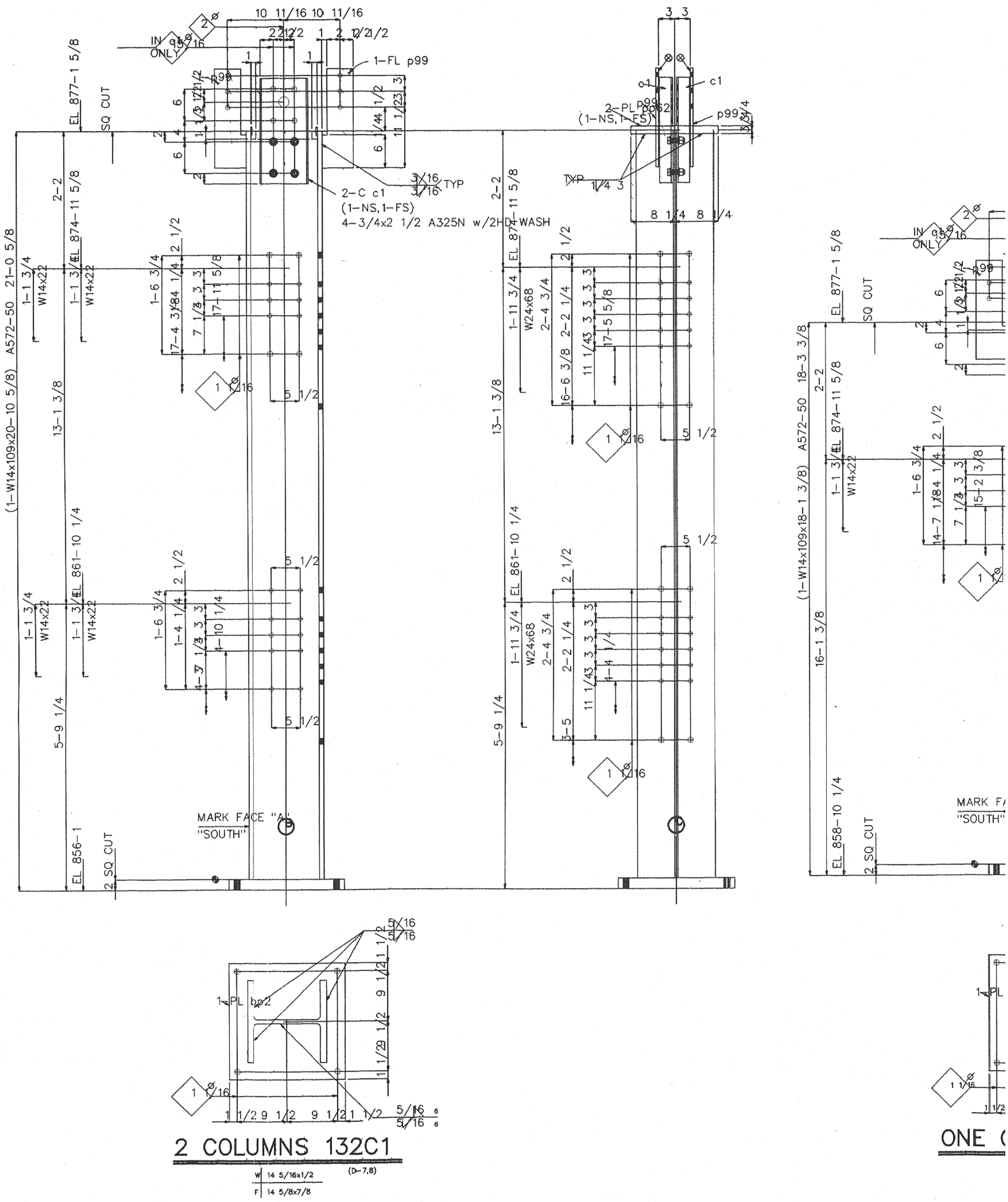
2 BEAMS 20B3

W	23 3/4x7/16 (G-5)
F	8 15/16x9/16

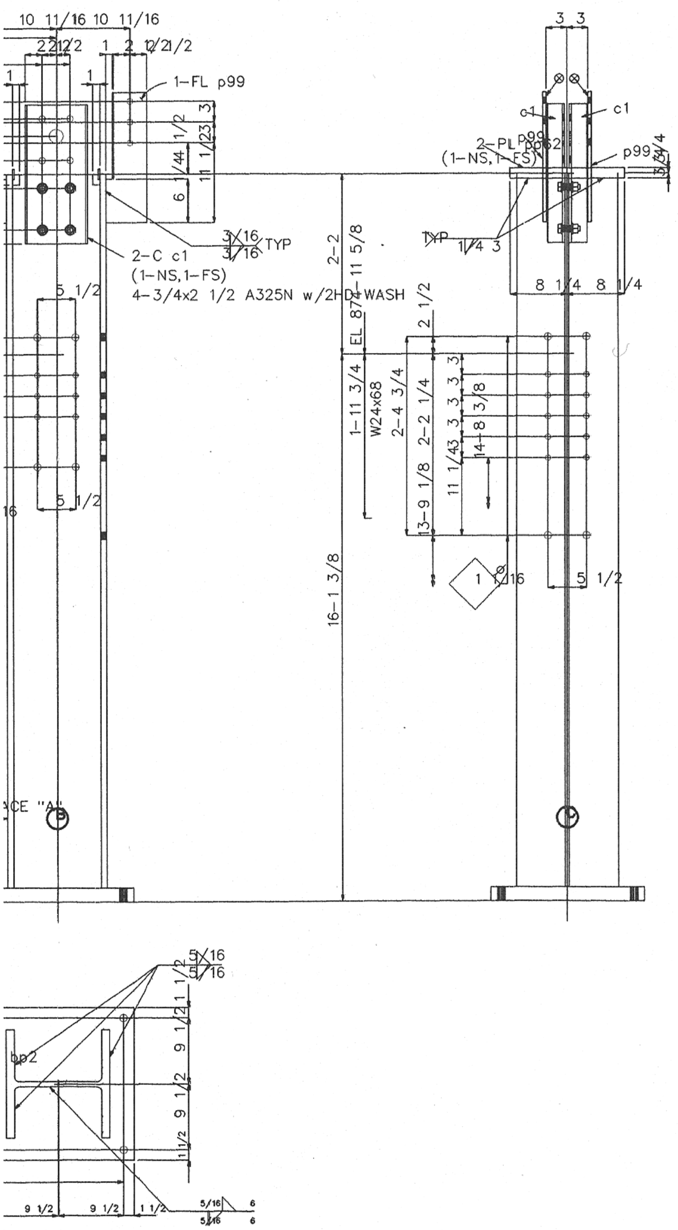
SHOP BILL OF MATERIAL

Total weight : 8432

SEQ NO	SEQ QUAN	MARK	QUAN	ITEM	LENGTH		WEIGHT	GRADE	REMARKS	PR
5	1	20B1	ONE	BEAM			2686			22-14
		20B1	1	W24x76	29	10 1/2	2270	A572-50		
		p3	1	FL1/4x12	14	0	143	A36		
		p122	1	PL1/4x7	15	2	90	A36		
		a301	1	L6x3 1/2x5/16	0	11	9	A36		
		a302	1	L3x3x1/4	29	2	143	A36		
		5 1/2W4	4	L4x3x5/16	0	11 1/2	28	A36		
		p434	2	PL1/4x3 1/4	0	7	3	A36		
				FIELD BOLTS						
			16	TC 3/4 Dia A325N	0	2 1/4			2HD WASH	
2	1	20B2	ONE	BEAM			1607			22-24
		20B2	1	W24x55	28	8 1/2	1579	A572-50		
		5 1/2W4	4	L4x3x5/16	0	11 1/2	28	A36		
				FIELD BOLTS						
			16	TC 3/4 Dia A325N	0	2 3/4			2HD WASH	
1	2	20B3	2	BEAM			4139		(1)-23/5,(1)-41/4	
		20B3	2	W24x68	28	9 1/2	3916	A572-50		
		5 1/2W5	8	L4x3x5/16	1	2 1/2	70	A36		
		a85	4	L4x4x3/4	1	3	92	A36		
		a161	4	L4x4x3/4	0	10	62	A36		
				FIELD BOLTS						
			8	TC 3/4 Dia A325N	0	3 1/2			2HD WASH	
			20	TC 3/4 Dia A325N	0	3			2HD WASH	
			8	TC 3/4 Dia A325N	0	2 3/4			2HD WASH	
			20	TC 3/4 Dia A325N	0	2 1/2			2HD WASH	



Shop drawing



COLUMN 132C2

W 14 5/16x1/2 (D-10)
F 14 5/8x7/8

SHOP BILL OF MATERIAL 7856 Total weight :

SEQ NO	SEQ QUAN	MARK	QUAN	ITEM	LENGTH		WEIGHT	GRADE	REMARKS	PR
8	2	132C1	2	COLUMN			5522			30-25
		132C1	2	W14x109	20	10 5/8	4803	A572-50	S2E	
		p99	4	FL1/2x6	1	6 3/4	57	A36		
		bp2	2	PL2x22	1	10	549	A36	. 10-8	
		c1	4	C9x15	1	8	100	A36	. 10-22	
		pp62	4	FL1/4x1 1/2	1	4 1/2	7	A36		
			8	TC 3/4 Dia A325N	0	2 1/2	6		2HD WASH	
				FIELD BOLTS						
			20	TC 3/4 Dia A325N	0	2 1/2			2HD WASH	
8	1	132C2	ONE	COLUMN			2334			30-26
		132C2	1	W14x109	18	1 3/8	1974	A572-50	S2E	
		p99	2	FL1/2x6	1	6 3/4	28	A36		
		bp2	1	PL2x22	1	10	275	A36	. 10-8	
		c1	2	C9x15	1	8	50	A36	. 10-22	
		pp62	2	FL1/4x1 1/2	1	4 1/2	4	A36		
			4	TC 3/4 Dia A325N	0	2 1/2	3		2HD WASH	
				FIELD BOLTS						
			10	TC 3/4 Dia A325N	0	2 1/2			2HD WASH	

APPENDIX B

SAMPLE SPECIFICATION

SECTION 05120
STRUCTURAL STEEL

PART 1 - GENERAL

SCOPE
Included are the following topics:

PART 1 - GENERAL

Scope
Related Work Specified Elsewhere
References
Submittals
Quality Assurance
Delivery, Storage and Handling

PART 2 - PRODUCTS

Materials
Fabrication
Shop Painting
Source Quality Control

PART 3 - EXECUTION

Erection
Field Quality Control

This section includes fabrication and erection of structural steel work, as shown on drawings, including schedules, notes and details showing size and location of members, typical connections and types of steel required.

RELATED WORK SPECIFIED ELSEWHERE
Section 03300 -- CAST-IN-PLACE CONCRETE for anchor rod installation in concrete.

Section 05500 – METAL FABRICATION for miscellaneous metal fabrications.

REFERENCES
Applicable provisions of Division 1 shall govern work of this Section.

Structural steel is that work defined in American Institute of Steel Construction (AISC) Code of Standard Practice and as otherwise shown on Drawings.

SUBMITTALS

General: Submit the following in accordance with the General and Supplementary Conditions.

Product data or manufacturer's specifications and printed installation instructions for following products. Include laboratory test reports and other data to show compliance with specifications (including specified standards).

> Structural steel (each type), including copies of mill reports covering chemical and physical properties.
>
> High-strength bolts (each type), including nuts and washers.
> Include Direct Tension Indicators if used.
> Structural steel primer paint.
> Shrinkage-resistant grout.

Test reports conducted on shop- and field-bolted and welded connections. Include data on type(s) of tests conducted and test results.

Copies of each survey showing elevations and locations of base plates and anchor rods to receive structural steel and final elevations and locations for major members. Indicate discrepancies between actual installation and Contract Documents.

Shop drawings, including complete details and schedules for fabrication and assembly of structural steel members, procedures and diagrams.

> Include details of cuts, connections, camber, holes and other pertinent data. Indicate welds by standard AWS symbols. Show size, length and type of each weld.
>
> Provide setting drawings, templates and directions for installation of anchor rods and other anchorages to be installed as work of other sections.

QUALITY ASSURANCE

Codes and Standards: Comply with provisions of following, except as otherwise indicated:

American Institute of Steel Construction (AISC) Code of Standard Practice for Steel Buildings and Bridges.

AISC Load and Resistance Factor Design Specification for Structural Steel Buildings, including Commentary.

Load and Resistance Factor Design Specification for Structural Joints using ASTM A325 or A490 Bolts approved by the Research Council on Structural Connections.

American Welding Society (AWS) D1.1 Structural Welding Code -- Steel.

ASTM A6 General Requirements for Delivery of Rolled Steel Plates, Shapes, Sheet Piling and Bars for Structural Use.

Society for Protective Coatings (SSPC): Steel Structures Painting Manual, Volume 2, Systems and Specifications. Specifications shown on design drawings.

Fabricator Qualification: The structural steel fabricator shall be AISC certified-Complex Steel Building Structures.

Qualifications for Welding Work: Use prequalified weld procedures or welding procedures and welding operators in accordance with AWS "Qualification" requirements.

Provide certification that welders employed in work have satisfactorily passed AWS qualification tests.

If recertification of welders is required, retesting will be Contractor's responsibility.

DELIVERY, STORAGE AND HANDLING
Deliver materials to site at such intervals to ensure uninterrupted work progress.

Deliver anchor rods and anchorage devices, which are to be embedded in cast-in-place concrete or masonry, in ample time to avoid delay of work.

Store materials to permit easy access for inspection and identification. Keep steel members off ground by using pallets, platforms, or other supports. Protect steel members and packaged materials from corrosion and deterioration. If bolts and nuts become dry or rusty, clean and relubricate before use.

Do not store materials in a manner that might cause distortion or damage to members or supporting structures. Repair or replace damaged materials or structures as directed.

PART 2 -- PRODUCTS

MATERIALS
Metal Surfaces, General: For fabrication of work that will be exposed to view, use only materials that are smooth and free of surface blemishes including pitting, rust and scale and roughness. Remove such blemishes by grinding, or by welding and grinding, prior to cleaning, treating and applying surface finishes.

Structural Steel Shapes: ASTM A992.

Plates, Angels and Bars: ASTM A36

Cold-Formed Steel Tubing: ASTM A500, Grade B

Headed Type Shear Connectors: ASTM A108, Grade 1015 or 1020 cold finished carbon steel, with dimensions complying with AISC Specifications.

Steel Castings: ASTM A27, Grade 65-35, medium-strength carbon steel.

Anchor Rods: F1554 Grade 36, nonheaded type unless otherwise indicated.

Unfinished Threaded Fasteners: ASTM A307, Grade A, regular low-carbon steel bolts and nuts. Provide hexagonal heads and nuts for all connections.

High-Strength Threaded Fasteners: Heavy hexagon structural bolts, heavy hexagon nuts and hardened washers as follows:

Quenched and tempered medium-carbon steel bolts, nuts and washers, complying with ASTM A325.

Where indicated as galvanized, provide units that are zinc coated, either mechanically deposited complying with ASTM B695, Class 50, or hot-dip galvanized complying with ASTM A153.

Tension Control Bolts (as required): ASTM F-1852

Electrodes for Welding: Comply with AWS Code.

Steel Primer Paint Fast-curing lead- and chromate-free, universal modified alkyd primer with good resistance to normal atmospheric corrosion, complying with performance requirements of FS TT-P-664.

Nonmetallic Shrinkage-Resistant Grout: Premixed, nonmetallic, noncorrosive, nonstaining product containing selected silica sands. Portland cement, shrinkage compensating agents, plasticizing and water-reducing agents, complying with CE-CRD-C621.

Available Products: Subject to compliance with requirements, products that may be incorporated in the work include, but are not limited to, the following:

100 Non-Shrink Grout (Non-Metallic), Conspec, Inc.
Supreme Grout, Cormix, Inc.
Sure Grip Grout, Dayton Superior
Euco N.S., Euclid Chemical Company
Crystex, L&M Construction Chemicals, Inc.
Masterflow 713, Master Builders
Sealtight 588 Grout, W.R. Meadows
Propak, Protex Industries, Inc.
Set Non-Shrink, Set Products, Inc.
Five Star Grout, U.S. Grout Corporation

FABRICATION

Shop Fabrication and Assembly: Fabricate and assemble structural assemblies in shop to greatest extent possible. Fabricate items of structural steel in accordance with AISC Specifications and as indicated on final shop drawings. Provide camber in structural members where indicated.

Properly mark and match-mark materials for field assembly. Fabricate for delivery sequence that will expedite erection and minimize field handling of materials.

Where finishing is required, complete assembly, including welding of units, before start of finishing operations. Provide finish surfaces of members exposed in final structure free of markings, burrs and other defects.

Connections: Weld or bolt shop connections, as indicated.

Bolt field connections, except where welded connections or other connections are indicated.

Provide high-strength threaded fasteners for all bolted connections, except where unfinished bolts are indicated.

High-Strength Bolted Construction: Install high-strength threaded fasteners in accordance with RCSC Specification for Structural Joints Using ASTM A325 or A490 Bolts. Use snug-tight bolts, except where noted and as recommended in the RCSC Specification for Structural Joints Using ASTM A325 or A490 Bolts.

Welded Construction: Comply with the AWS D1.1 Code as referenced in the AISC Specification for the Design and Fabrication of Steel Buildings.

Assemble and weld built-up sections by methods that will produce true alignment of axes without warp.

Build up welded doorframes attached to structural steel framing. Weld exposed joints continuously and grind smooth. Plug-weld steel bar stops to frames, except where shown removable. Secure removable stops to frames with countersunk, cross-recessed head machine screws, uniformly spaced not more than 10" o.c., unless otherwise indicated.

Holes for Other Work: Provide holes required for securing other work to structural steel framing and for passage of other work through steel framing members, as shown on final shop drawings.

Cut, drill, or punch holes perpendicular to metal surfaces. Do not flame-cut holes or enlarge holes by burning.

Expansion Joints: Provide expansion joints in steel shelf angles when part of structural steel frame, locate at vertical cladding expansion joints as indicated on Drawings.

SHOP PAINTING
General: Shop-paint structural steel, except those members or portions of members to be embedded in concrete or mortar. Paint embedded steel that is partially exposed on exposed portions and initial 2" of embedded areas only.

Do not paint surfaces to be welded or high-strength bolted with friction-type connections.

Apply 2 coats of paint to surfaces that are inaccessible after assembly or erection. Change color of second coat to distinguish it from first.

Color of Second Coat: Grey.

Surface Preparation: After inspection and before shipping, clean steelwork to be painted. Remove loose rust, loose mill scale and spatter, slag, or flux deposits. Clean steel in accordance with Society for Protective Coatings (SSPC) as follows:

SP-3 “Power-Tool Cleaning.”

Painting: Immediately after surface preparation, apply structural steel primer paint.

GALVANIZING

Hot-Dip Galvanized Finish: Apply zinc coating by the hot-dip process to structural steel indicated for galvanizing according to ASTM A123.

Galvanize structural steel in locations as indicated.

SOURCE QUALITY CONTROL

General: Materials and fabrication procedures are subject to inspection and tests in mill, shop and field, conducted by a qualified inspection agency. Such inspections and tests will not relieve Contractor of responsibility for providing materials and fabrication procedures in compliance with specified requirements.

Promptly remove and replace materials or fabricated components that do not comply.

Design of Members and Connections: Details shown are typical, similar details apply to similar conditions, unless otherwise indicated.

Promptly notify Architect whenever design of members and connections for any portion of structure are not clearly indicated.

PART 3 -- EXECUTION

ERECTION

Surveys: Check elevations of concrete and masonry bearing surfaces, and locations of anchor rods and similar devices, before erection work proceeds and report discrepancies to the owner's authorized representative. Do not proceed with erection until corrections have been made or until compensating adjustments to structural steel work have been agreed upon with the owner's authorized representative.

Temporary Shoring and Bracing: Provide temporary shoring and bracing members with connections of sufficient strength to bear imposed loads. Remove temporary members and connections when permanent members are in place and final connections are made. Provide temporary guy lines to achieve proper alignment of structures as erection proceeds.

Temporary Planking: Provide temporary planking and working platforms as necessary to effectively complete work.

Setting Bases and Bearing Plates: Clean concrete and masonry bearing surfaces of bond-reducing materials and roughen to improve bond to surfaces. Clean bottom surface of base and bearing plates.

Set loose and attached base plates and bearing plates for structural members on wedges or other adjusting devices.

Tighten anchor rods after supported members have been positioned and plumbed. Do not remove wedges or shims, but if protruding, cut off flush with edge of base or bearing plate prior to packing with grout.

Pack grout solidly between bearing surfaces and bases or plates to ensure that no voids remain. Finish exposed surfaces, protect installed materials and allow to cure.

For proprietary grout materials, comply with manufacturer's printed instructions.

Field Assembly: Set structural frames accurately to lines and elevations indicated. Align and adjust various members forming part of complete frame or structure before permanently fastening. Clean bearing surfaces and other surfaces that will be in permanent contact before assembly. Perform necessary adjustments to compensate for discrepancies in elevations and alignment.

Level and plumb individual members of structure within specified AISC tolerances.

Establish required leveling and plumbing measurements at mean operating temperature of structure. Make allowances for difference between temperature at time of erection and mean temperature at which structure will be when completed and in service.

Erection Bolts: On exposed welded construction, remove erection bolts, fill holes with plug welds and grind smooth at exposed surfaces.

Comply with AISC Specifications for bearing, adequacy of temporary connections, alignment and removal of paint on surfaces adjacent to field welds.

Do not enlarge unfair holes in members by burning or by using drift pins, except in secondary bracing members. Ream holes that must be enlarged to admit bolts.

Gas Cutting: Do not use gas-cutting torches in field for correcting fabrication errors in primary structural framing without the engineer's permission. Finish gas-cut sections equal to a sheared appearance when permitted.

Touch-Up Painting: Immediately after erection, clean field welds, bolted connections and abraded areas of shop paint. Apply paint to exposed areas using same material as used for shop painting. Comply with SSPC-PA 1 requirements for touch-up of field painted surfaces.

Apply by brush or spray to provide minimum dry film thickness of 2.0 mils.

FIELD QUALITY CONTROL

General: The Owner will engage the services of a testing agency to inspect high-strength bolted connections and welded connections and to perform tests and to submit test reports.

Testing agency shall conduct and interpret tests, state in each report whether test specimens comply with requirements and specifically state any deviations therefrom.

Provide access for testing agency to places where structural steel work is being fabricated or produced so that required inspection and testing can be accomplished.

The testing agency will review supplier's mill test reports for steel used in the project. The testing agency will report items that do not comply with ASTM material and test report requirements.

Shop and Field Welding, Inspection and Testing: The testing agency shall obtain copies of all welder certificates of welders assigned to the job all welders shall meet AWS requirements. Reports shall include welder's certifications, type and location of defects found during inspections and the measures required and performed to correct such defects, statements of final approval of all welding of connections and other fabrication data and information pertinent to the safe and proper welding of connections.

Ascertain that proper weld metal, electrodes, procedures and sequences are being used.

Ascertain that fit-up, joint preparation, size, contour, extent of reinforcement and length and location of welds comply with requirements of AWS D1.1.

Ascertain that fabricator's and erector's procedures correct for distortion and shrinkage caused by welding operations.

Shop Fabrication: Verify that fabricator's quality control program provides for the above mentioned items and the following minimum requirements for welding. Inspect and test during fabrication in accordance with AWS Structural Welding Code and as follows:

Perform visual inspections on 20% of all welds.

Perform Nondestructive Test of Welds as follows:

Fillet Welds: Test 10 percent of welds in accordance with magnetic particle testing.

Full Penetration Welds: Test 100 percent of welds in accordance with ultrasonic techniques.

Embedded Plates and Assemblies with Welded Deformed Bar and/or Stud Anchors: 50 percent of anchors shall be rapped with an 8 lb. hammer. Any that do not ring and 5 percent of all others shall be bent 15 degrees with a hammer test.

Field Welding: Inspect and Test for Conformance to AWS Requirements and as follows:

All welds shall be inspected visually.

Fillet Welds: Test 25 percent of all welds in accordance with magnetic particle testing.

Partial Penetration Welds: Test 100 percent of welds in accordance with ultrasonic testing techniques.

Welds that fail shall be rewelded and retested until they pass. The cost of retesting shall be borne by the Contractor.

Additional Testing in the Event of Rejected Welds: If more than 10 percent of any type of tested welds are rejected, an additional 20 percent of all such welds shall be tested in same manner. If more than 10 percent of these additional welds are defective and rejected then an additional 20 percent of such welds shall be tested. If more than 10 percent of this group are found rejectable then all welds shall be tested. The cost of this additional testing shall be borne by the Contractor.

Testing agency welding inspector shall have authority to reject weldments on the basis of a visual inspection.

Testing agency welding inspector's reports shall contain, as a minimum, a description of each weld tested, the identifying mark of the welder responsible for the weld, a critique of defects noted by visual inspection or testing and a statement regarding the acceptability of the weld as judged by current AWS standards. Distribute reports as early as possible but no later than one week after the tests have been performed. Notify the Architect by phone if the results require immediate comment.

Bolting: Inspect in accordance with RCSC Specification for Structural Joints and as follows:

Visually inspect all bolts.

For Bolts Indicated to be "Slip Critical" (Friction Connections):

Check for proper tension by using methods defined in the RCSC Specification for Structural Joints Using ASTM A325 or A490 Bolts.

Correct bolted connections that fail by replacing or retightening, and performing other corrective measures required by connection geometry and fit up. The cost of retests on connections that fail shall be borne by the Contractor.

For Bolts Not Indicated to be "Slip Critical": Inspect 5 percent of bolts by using wrench to verify that the plies of the connection are in firm contact, or "snug-tight".

END OF SECTION

APPENDIX C

Sample Inventory for a Fabricator

CHANNEL A36 40' OR 60'

C 12 X 20.7
C 10 X 15.3
C 8 X 11.5
C 6 X 8.2

BEAM 50 Ksi 60'

W 16 X 31
W 16 X 26
W 14 X 22
W 12 X 26
W 12 X 19
W 12 X 16
W 12 X 14
W 10 X 22
W 10 X 15
W 10 X 12
W 8 X 31
W 8 X 24
W 8 X 18
W 8 X 15
W 8 X 13
W 8 X 10

RODS A 36 x 20'

1 IN. DIA.
7/8 IN. DIA.
3/4 IN. DIA.
5/8 IN. DIA.
1/2 IN. DIA.

PIPE x 21'

1 1/4 DIA. STANDARD
1 1/2 DIA. STANDARD

PLATES A36 x 20'

PL 1 1/2 X 72
PL 1 X 72
PL 3/4 X 72
PL 5/8 X 72
PL 1/2 X 72
PL 3/8 X 72
PL 5/16 X 72

BARS A36 x 20'

FB 3/4 X 12
FB 3/4 X 10
FB 1/2 X 12
FB 1/2 X 10
FB 1/2 X 8
FB 1/2 X 6
FB 1/2 X 4
FB 1/2 X 3
FB 1/2 X 2
FB 3/8 X 12
FB 3/8 X 10
FB 3/8 X 8
FB 3/8 X 6
FB 3/8 X 4 1/2
FB 3/8 X 4
FB 3/8 X 2 1/2
FB 3/8 X 2
FB 3/8 X 1 1/2
FB 1/4 X 12
FB 1/4 X 10
FB 1/4 X 8
FB 1/4 X 6
FB 1/4 X 4
FB 1/4 X 3
FB 1/4 X 2 1/2
FB 1/4 X 2
FB 1/4 X 1 1/2

ANGLE A36 x 40'

L 6 X 4 X 3/8
L 6 X 3 1/2 X 5/16
L 5 X 3 1/2 X 3/8
L 5 X 3 1/2 X 5/16
L 5 X 3 X 1/4
L 4 X 4 X 3/8
L 4 X 4 X 5/16
L 4 X 4 X 1/4
L 4 X 3 X 3/8
L 4 X 3 X 5/16
L 4 X 3 X 1/4
L 3 1/2 X 3 1/2 X 1/4
L 3 X 3 X 3/8
L 3 X 3 X 5/16
L 3 X 3 1/4
L 2 1/2 X 2 1/2 X 1/4
L 2 X 2 X 1/4
L 1 1/2 X 1 1/2 X 1/4

APPENDIX D

AISC SERVICES

The American Institute of Steel Construction, Inc. is a nonprofit corporation established in 1921 to serve the fabricated structural steel industry in the United States. Its purpose is to promote the use of structural steel through research activities, market development, education, codes and specifications, technical assistance, quality certification, and standardization.

For more than 75 years, AISC has conducted its numerous activities with a scrupulous sense of public responsibility. For this reason, and because of the high caliber of its staff, the Institute enjoys a positive relationship with architects, engineers, code officials, construction managers and educators who recognize its professional status in the fields of specification writing, structural research, design development, and performance standards.

EDUCATIONAL

AISC, together with AISC Marketing, Inc., sponsors a series of continuing education seminars on a regular basis. For example, in 1996, the AISC Seminar Series focused on “Innovations in Structural Steel Systems” while the 1997 seminar featured information on “Designing of Steel for Service,” which included roof ponding, floor elevation and level, control of floor vibrations and control of lateral drift. The seminars are usually held in more than 60 cities around the country during a nine month period. For a complete list of seminar dates and locations, visit AISC’s web page at http://www.asic.org.

In addition to the Seminar Series, AISC sponsors a number of short courses and a series of lectures from the winner of the Annual T.R. Higgins Award. In the past, the short courses have covered topics such as bracing and hollow structural sections.

On the university side, one of AISC’s most noteworthy activities is sponsorship, together with ASCE, of the Student Steel Bridge Competition. The program challenges civil engineering students from across the country to design, fabricate and erect a 1:10 scale model of a bridge across a river valley in a mountainous region. While any type of steel bridge can be designed, there are height limits and the entries are judged on erection time, bridge weight, aesthetics, stiffness, and cost. During the past few years, solutions to the problem statement have become more and more advanced. Teams from more than 185 schools are expected to compete in the regional competitions, with the winners from each regional competition gaining eligibility to compete in the national competition.

AISC also fosters academic-industry relations through its Partners in Education (PIE) Committee. Among the chief goals of the committee are to encourage civil engineering programs to offer sufficient structural engineering content and steel design courses to ensure that future engineers understand the requirements necessary to provide safe and economic structures. The program also aims to encourage interaction between practicing engineers and both professors and engineering students. In addition, a goal is to expose architectural students to various facets of steel design and construction.

Among many other universities-related programs, AISC provides free copies of Modern Steel Construction magazine to students in accredited architectural and engineering programs.

NORTH AMERICAN STEEL CONSTRUCTION CONFERENCE

With today's economic climate and the fast pace of advancing technologies and resources, questions mount seemingly faster than they can be answered. The North American Steel Construction Conference provides an annual opportunity to delve into the rapidly changing and advancing world of steel design and construction, and surface with practical information to help your practice today. It also offers an opportunity to meet and network with other industry professionals.

The NASCC is designed to appeal to a wide range of attendees, including engineers, architects, educators, detailers, fabricators, construction managers, and erectors.

ENGINEERING & RESEARCH

The Engineering & Research Department, in coordination with numerous committees and selected outside consultants, provides the primary staff leadership and support for the technical activities of the Institute, including: Specifications & Codes; Publications; Software; Research; Quality Certification; and the North American Steel Construction Conference. (The latter two programs are highlighted separately.)

SPECIFICATIONS & CODES

The AISC Specification for Structural Steel Buildings has been promulgated for over 75 years with nine editions of Allowable Stress Design (ASD) and the more recent of two releases of Load and Resistance Factor Design (LRFD). These have been well recognized design standards, not only in the USA, but also worldwide. An expert and balanced committee has responsibility for maintaining the reliability (safety) of the specification in conformance with consensus operating procedures. Separate AISC Specifications on Seismic Provisions, Single Angle Members, Nuclear Facilities, and Tubular (HSS) Design (first introduced in 1997) supplement this parent document. In addition, AISC is responsible for producing the industry's Code of Standard Practice.

Active staff liaison with other independent and industry organizations, affiliated standards (such as AWS), code groups and professional societies, and research developments help to identify current needs and new information.

PUBLICATIONS

Dissemination of technical steel information in usable form is a constant task. A regular by-product of each main AISC Specification has been an accompanying "**Manual of Steel Construction"**. The Manual has and continues to be the best known engineering product of AISC. In addition, there now exists a series of **Design Guides** to expand coverage on special topics. More recently AISC published **"Designing with Structural Steel-A Guide for Architects,"** a comprehensive desk reference for architects which addresses the common steel systems, materials, and details. Ideas, and references used by architects daily, are incorporated. The quarterly publication, **Engineering Journal**, has been a popular reference for timely application articles on steel design and research. Contact AISC for a list of publications.

A periodical published by AISC is **Modern Steel Construction**. A monthly magazine reporting on innovative building and bridge projects, MSC presents in-depth information on the newest, most advanced applications of structural steel in a wide range of structure types. Two highly useful sections are Steel Interchange, a question-and-answer column, and Bridge Crossings, which offers practical design advice to bridge designers and owners on such subjects as:

- Tips on Designing Weathering Steel
- Designing and Specifying Better Bearing Details
- Design and Use of Integral Pier Caps
- Economical Bridge Connections

MSC also included product information, a calendar listing and structural shape availability. For information on U.S. subscriptions to Modern Steel Construction call 312-670-2400. For information on foreign subscriptions to Modern Steel Construction call 312-670-5444.

SOFTWARE

Software has taken on an increasingly important role. The steel shape database, connection design (CONXPRT), and beam web opening (WEBOPEN) computer programs are available. Updates, expansion, and new initiatives are under serious review by a dedicated committee. For more information on AISC Software, call (312) 670-5444.

An AISC Home Page is on-line (http://www.aisc.org). Efforts are continuing on standardizing a data exchange format among design and detailing software.

RESEARCH

AISC remains at the center of much of the structural steel research, either in an advisory and/or partial funding role. Close cooperation with government agencies, steel mills, the private sector, universities, and local fabricators help to focus projects and to quickly disseminate important research results. Extensive work is currently underway for seismic considerations, particularly changes in special steel moment frames, and further progress on design, welding, and materials is anticipated.

QUALITY

The purpose of the AISC Quality Certification Program is to confirm to the construction industry that a certified firm has the personnel, organization, experience, procedures, knowledge, equipment, capability and commitment to fabricate and erect steel of the required quality for a given category of structural steel work.

The AISC Certification Program is not intended to involve inspection and/or judgment of product quality on individual projects. Neither is it intended to guarantee the quality of specific fabricated steel products or erection.

The program uses independent auditors to confirm that an individual fabrication plant has the capability to perform the desired level of work. The program does not look at specific projects; rather, the highly detailed checklist focuses on general management, engineering and drafting, procurement, operations and quality control. And, of course, the auditors examine actual work performance.

Fabricators can be certified in one of five categories, coinciding with the market for fabrication. In addition, fabricators can receive two optional endorsements, one for Sophisticated Paint Systems and one for Fracture Critical Members. Erection can be certified in two catergories.

CERTIFICATION PROGRAM

Certification Categories

Conventional Steel Buildings
Includes small public service and institutional buildings (schools, etc.), shopping centers, light manufacturing plants, miscellaneous and ornamental iron work, warehouses, low-rise beam/column/light truss structures.

Simple Steel Bridge Structures
Includes highway sign structures, parts for bridges (such as cross frames), unspliced rolled beam bridges.

Complex Steel Buildings
Includes large public service and institutional buildings, heavy manufacturing plants, powerhouses, metal producing/rolling buildings, crane girders, bunkers and bins, stadiums, auditoriums, high-rise buildings, petro/chemical processing. Fabricators certified for Complex Steel Buildings also are automatically certified for Conventional Steel Buildings.

Major Steel Bridges
All bridge structures other than unspliced rolled beam bridges. Fabricators certified for Complex Steel Bridges also are automatically certified for Simple Steel Bridge Structures.

Metal Building Systems (Mb)
Pre-engineered metal building systems including cold-formed members and panels.

Sophisticated Paint System Endorsement
Systems that require an extra degree of training, control, preparation, and inspection beyond that normally used in common single-coat systems such as oxides, alkyds, solvent-based epoxies and solvent-based zincs.

Fracture Critical Members Endorsement (F)
Familiarity with procedures required to produce fracture critical members in accordance with a fracture control plan as defined by AASHTO or AREA.

Certified Steel Erector
Erection contractors qualified to erect buildings of various types of low- and mid-rise structures and simple non-continuous bridges.

Certified Advanced Steel Erector
Erection contractors qualified to erect heavy structures, continuous girder bridges, railway bridges, power plants, locks and dams and high-rise structures.

While the pre-qualification aspect of the program is important, it is not its sole raison d’ etre. Rather, the program also has long-term benefits for a fabricator through the periodic review and maintenance of quality systems and procedures. It helps communicate the latest quality issues to fabricators through the input of auditors trained in structural steel fabrication.

An up-to-date listing of all Quality Certified Fabricators and erectors can be found on AISC's homepage at http://www.aisc.org or in the December issue of Modern Steel Construction magazine. For more information on the program, call (312) 670-5435, e-mail qualcert@aiscmail.com or fax (312) 670-5403.

ENGINEERING JOURNAL

A quarterly technical journal devoted exclusively to the design of steel structures. Unlike some technical publications, EJ avoids the esoteric and aims instead to provide information that is usable in the everyday office. EJ provides structural engineers, architects, fabricators and educators the latest information on such subjects as base plate design, high-strength bolts for bridges, bracing design, serviceability limits and composite design. **For information on subscriptions to Engineering Journal, call 312-670-5444.**

AISC SOFTWARE:

AISC Database
A shapes program that can be incorporated into in-house programs

CONXPRT
A connections design program

WEBOPEN
For designing steel beam-web penetrations

AISC for AutoCAD
A shape drawing program that runs inside of DOS-based AutoCAD

SIMON Systems
A PC-based girder design program

New in 1997 is System VANCK
A V-load analysis program for curved open-framed I-girder bridges.

For more information on AISC Software, call 312-670-5444 or E-mail gonzalez@aiscmail.com
Or point your favorite web browser at AISC's homepage. For a complete and free listing of AISC publications, call 800-644-24400, or view the entire publications list on AISC homepage at http//www.aisc.org.