Construction Management of STEEL CONSTRUCTION

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PROJECT MANAGEMENT•SCHEDULING•ESTIMATING

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Construction Management of **STEEL CONSTRUCTION**

Project Management Module

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.

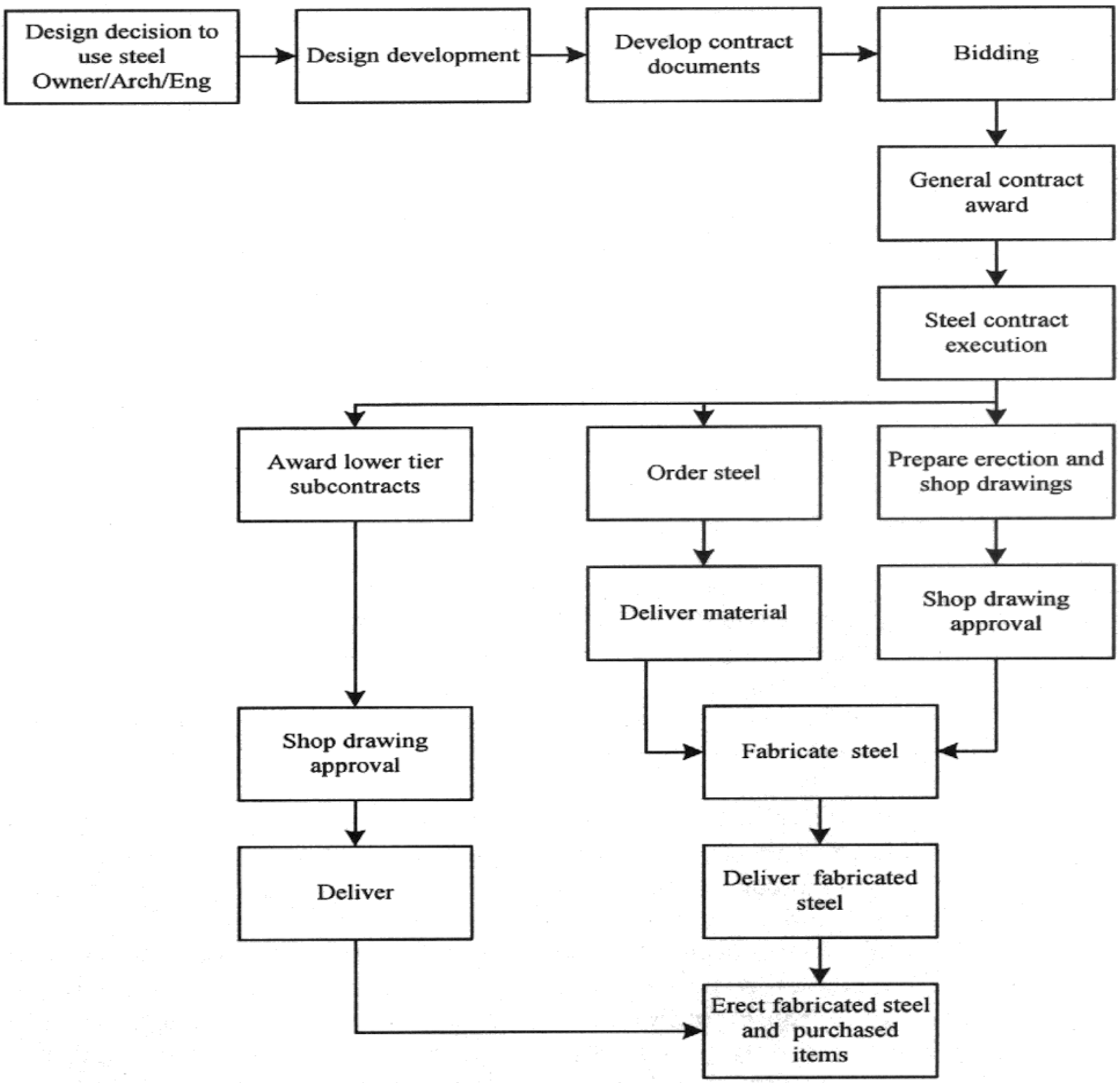

Figure 1-2 Stages of steel project management

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.

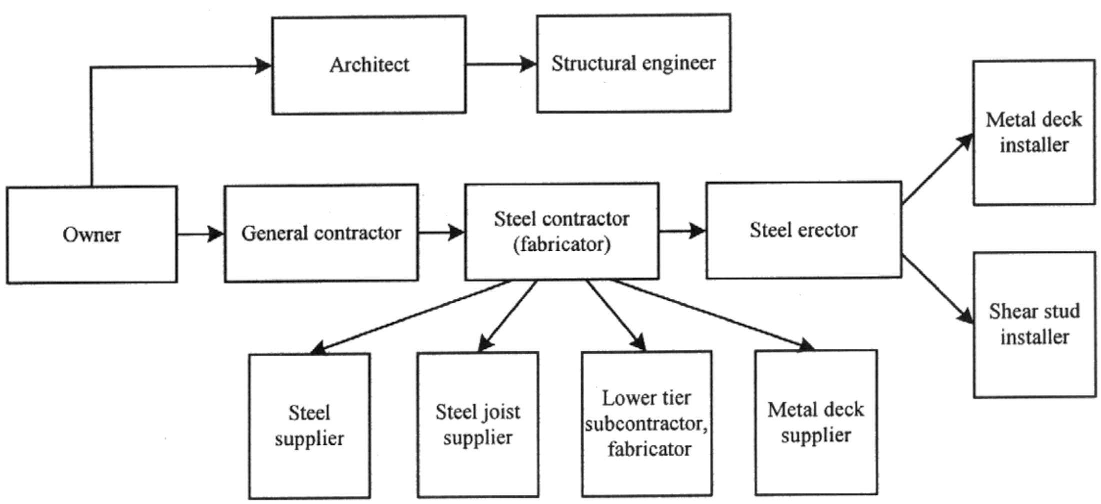

Figure 1-3 Lines of responsibility on a steel project.

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.

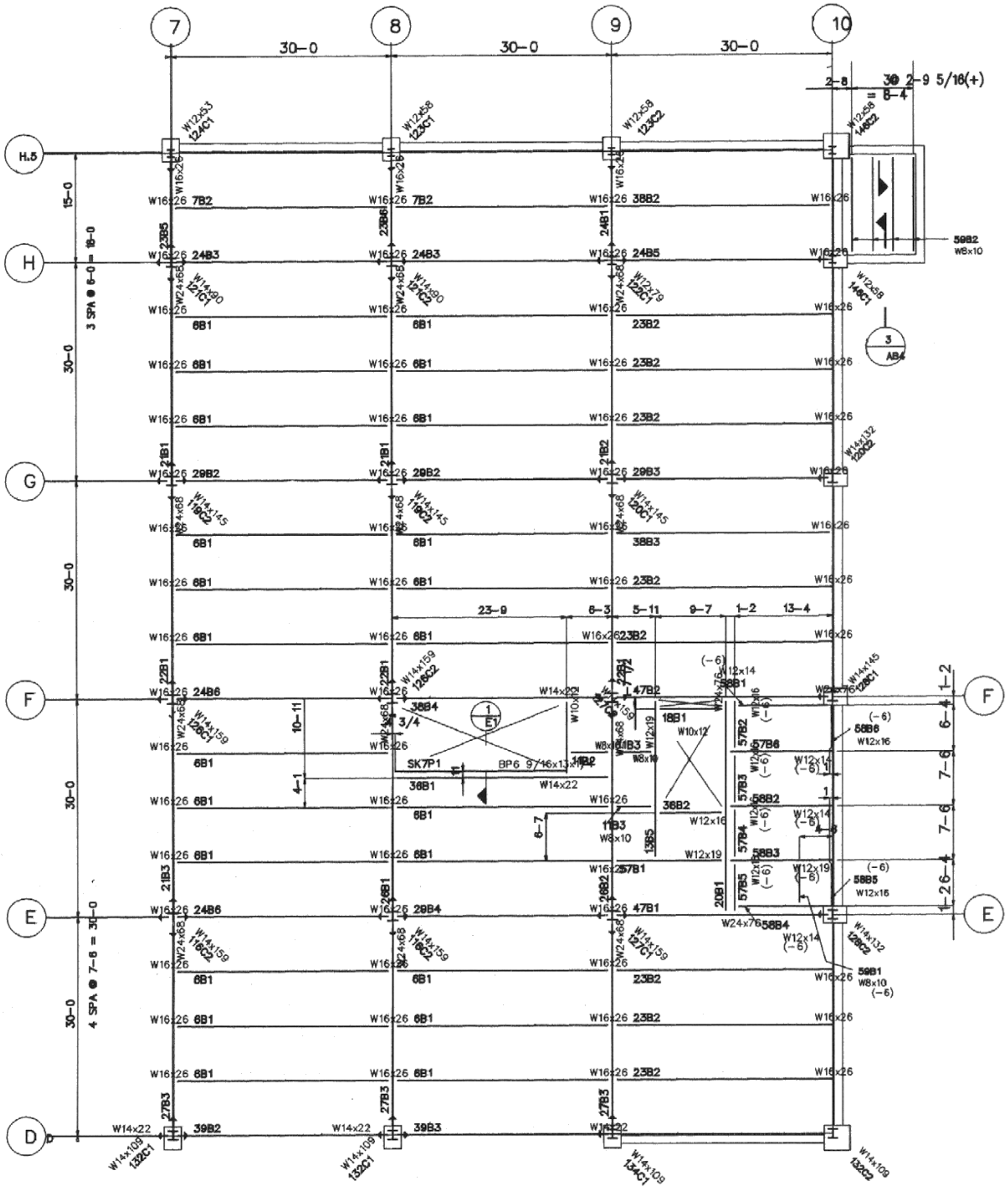

Figure 1-4 Representative structural framing plan

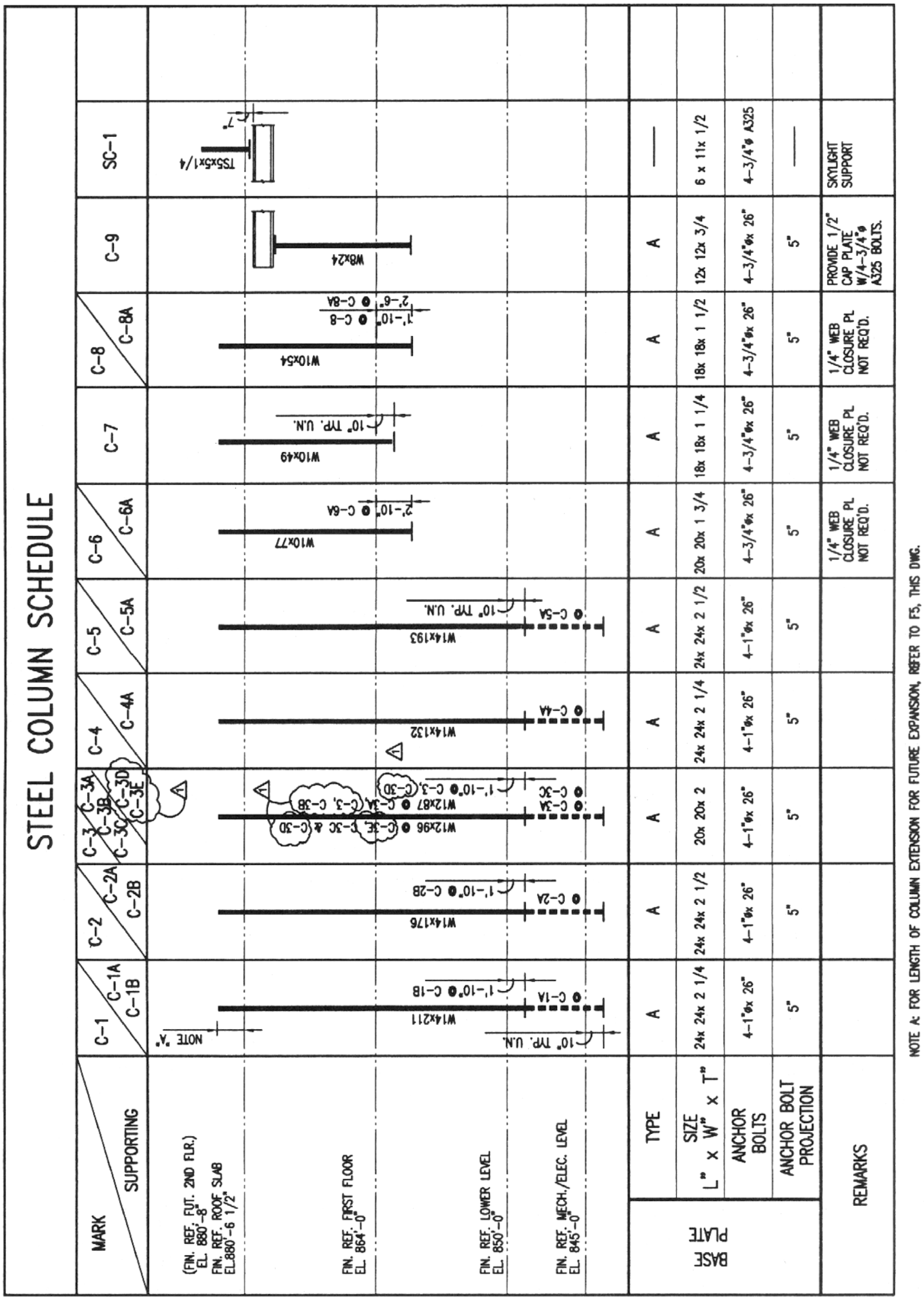

Figure 1-5 Representative column schedule

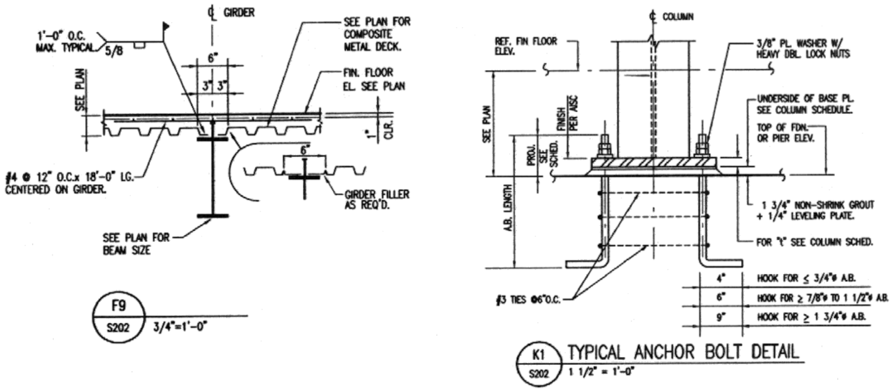

Figure 1-6 Typical details

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