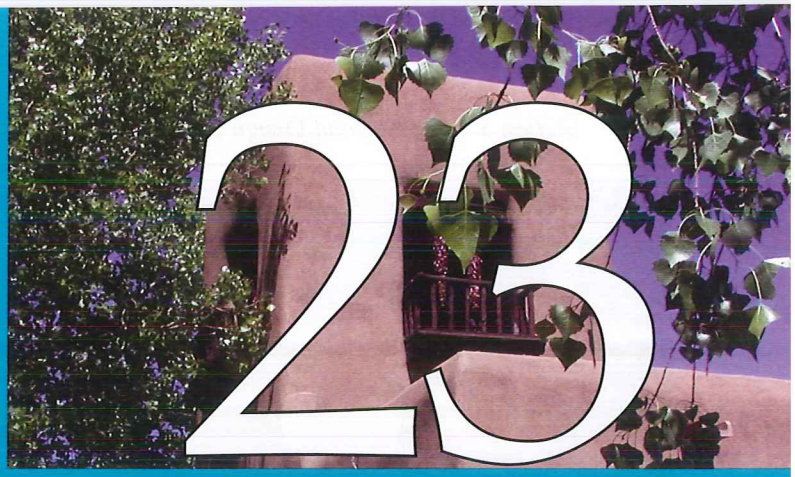
Structural Drafting



Learning Objectives

After studying this chapter, you will be able to:

- List the types of structures for which drawings are prepared.
- List and describe the common types of drawings made by structural drafters.
- Identify and explain the types of components used in structural wood construction.
- Describe the common structural shapes used in steel construction.
- List and describe the common types of concrete construction.

Technical Terms

Cast-in-place concrete
Curtain walls
Engineering design drawings
Engineering drawing
Filler beams
Placing drawing
Precast concrete
Prestressed concrete
Reinforced concrete
Shop drawings
Structural drafting
Structural steel
Wood post and beam construction

Structural drafting is the preparation of drawings for the design and construction of structures such as buildings, towers, bridges, and dams. See **Figure 23-1**. Structural drawings may be developed as plan view drawings, elevations, details, or pictorial drawings. Whatever the drawing form, the structure's supporting members and fastening connectors are at the heart of a structural drawing.

The structural drafter needs to be familiar not only with the proper presentation of structural drawings, but also with the most common structural components used in construction and the materials they are made from. The primary materials used in the construction of buildings and other structures include wood, structural steel, and reinforced concrete. Other materials, such as aluminum shapes and glass, are used in structures, but not generally for structural support members.

Figure 23-1. Structural drafters prepare drawings used in the construction of buildings. Precast concrete panel units were used to construct this building.

Structural Wood Construction

Wood is a traditional structural material widely used in residential construction and in other types of structural building. Several species are available for structural timber. Douglas fir, spruce, redwood, southern yellow pine, oak, and poplar are the most familiar.

The American Forest and Paper Association (AF&PA) provides information about the strength, weight, and other properties of wood species commonly used in construction. The AF&PA also provides information about the design specifications for different structural members as well as common connectors. Common structural members made from wood include trusses, beams, columns, and braces.

Wood structural members can be fastened together using nails, screws, lag bolts, machine bolts, steel plates, and special timber connectors. The fastening method chosen should be determined by factors such as the direction of the grain, the force being transmitted, and the strength resistance of the wood. See **Figure 23-2**.

Nails are not used in timber construction as often as screws and bolts because they lack the holding power. They may, however, be combined with hangers, straps, ties, or plates to increase holding power.

Bolts and lag screws are commonly used in timber construction. They provide good holding power and may be used with or without steel plates depending on the design system and strength required.

Split-ring metal connectors are frequently used between wood structural members to increase strength. One of the popular applications is in the construction of large roof trusses. Other similar connectors for timber structures include pressed steel shear plates, malleable iron shear plates, and toothed ring connectors.

Timber used for structural applications is usually kiln dried and surfaced on all sides. As a result of the drying and surfacing operations, the finished size of a timber member is less than the nominal or name size. For example, a 4″ × 6″ beam is actually 3 1/2″ × 5 1/2″. Framing members that are 5″ and thicker and 5″ and wider (measured by nominal size) will have an actual dimension 1/2″ less than the nominal size. Dry lumber has 19% or less moisture content.

Wood Post and Beam Construction

Wood post and beam construction uses framing posts, beams, and planks that are larger and spaced farther apart than conventional framing members, **Figure 23-3**. Post and beam construction provides a greater freedom of design than conventional framing techniques. The system is basically simple, but presents problems related to larger structural sizes, framing connectors, and joining methods.

Most of the weight of a post and beam building is carried by the posts. The walls do not support much weight and are called ***curtain walls***.

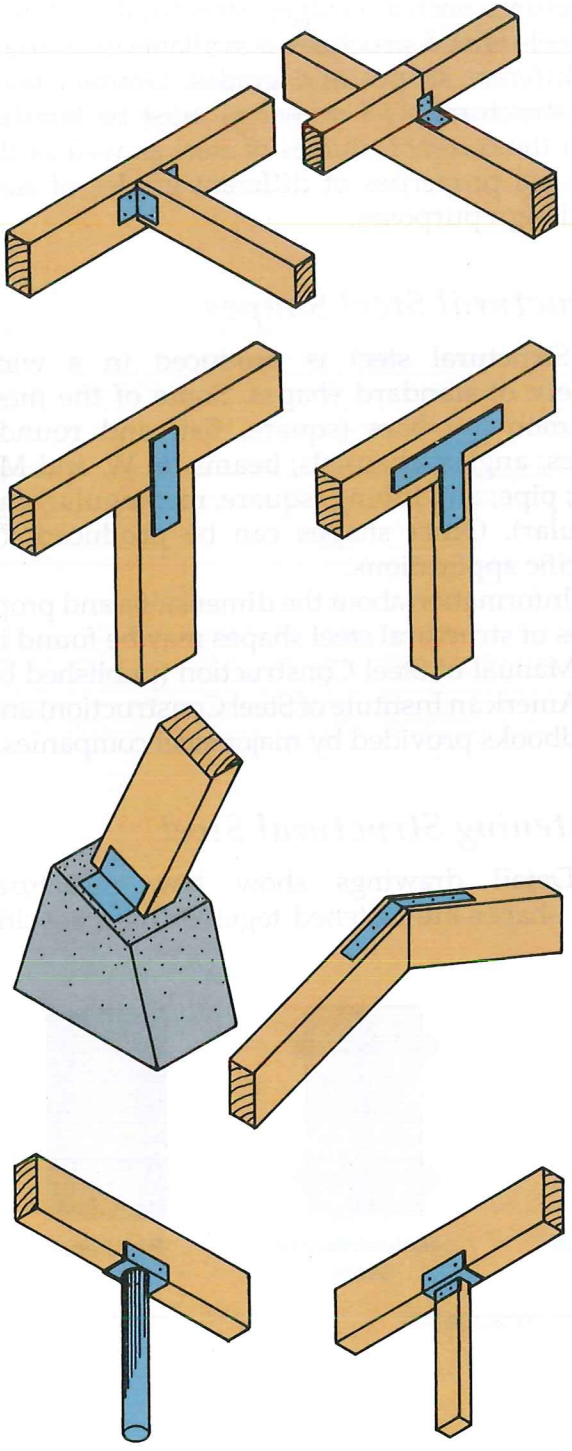


Figure 23-2. Metal fasteners are typically used to connect large wood beam sections. Shown are common ways to fasten sections together.

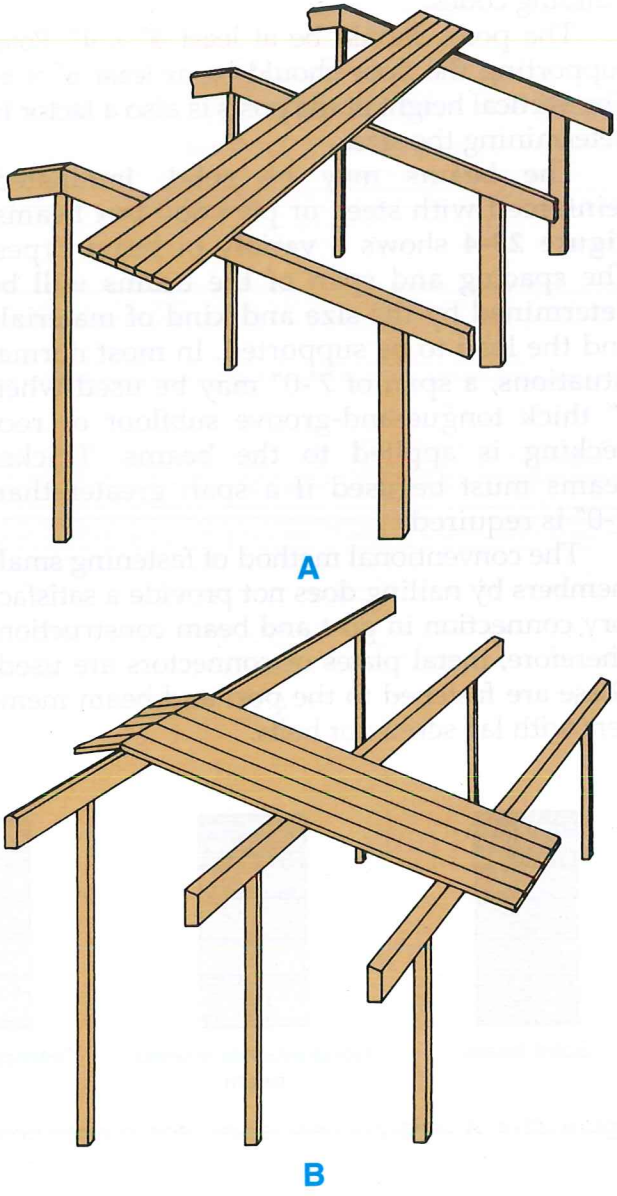


Figure 23-3. Post and beam construction may be either longitudinal or transverse. In either case, the primary framing members are spaced farther apart than in conventional framing. A—Longitudinal construction. B—Transverse construction.

Curtain walls provide for wide expanses of glass without the need for headers. Wide overhangs are also possible by extending the large beams to the desired length. Spacing of the posts is determined by the design of the building and the load to be supported.

The foundation for a post and beam structure may be a continuous wall or a series of piers on which each post is located. The size of the wall footings or piers is determined by the weight to be supported, soil bearing capacity, and local building codes.

The posts should be at least 4″ × 4″. Posts supporting the floor should be at least 6″ × 6″. The vertical height of the posts is also a factor in determining the size.

The beams may be solid, laminated, reinforced with steel, or plywood box beams. **Figure 23-4** shows a variety of beam types. The spacing and span of the beams will be determined by the size and kind of materials and the load to be supported. In most normal situations, a span of 7′-0″ may be used when 2″ thick tongue-and-groove subfloor or roof decking is applied to the beams. Thicker beams must be used if a span greater than 7′-0″ is required.

The conventional method of fastening small members by nailing does not provide a satisfactory connection in post and beam construction. Therefore, metal plates or connectors are used. These are fastened to the post and beam members with lag screws or bolts.

Structural Steel Construction

Structural steel is commonly used in the construction of commercial buildings and larger structures, such as bridges. Structural steel used in steel-framed structures is available in a variety of different shapes and grades. Drafters making structural steel drawings must be familiar with the common shapes of steel as well as the physical properties of different grades of steel for design purposes.

Structural Steel Shapes

Structural steel is produced in a wide variety of standard shapes. Some of the most common are bars (square, flat, and round); plates; angles; channels; beams (S, W, and M); tees; pipe; and tubing (square, rectangular, and circular). Other shapes can be produced for specific applications.

Information about the dimensions and properties of structural steel shapes may be found in the Manual of Steel Construction (published by the American Institute of Steel Construction) and handbooks provided by major steel companies.

Fastening Structural Steel

Detail drawings show how structural steel shapes are fastened together for a specific

Figure 23-4. A variety of beams are used in wood post and beam construction.

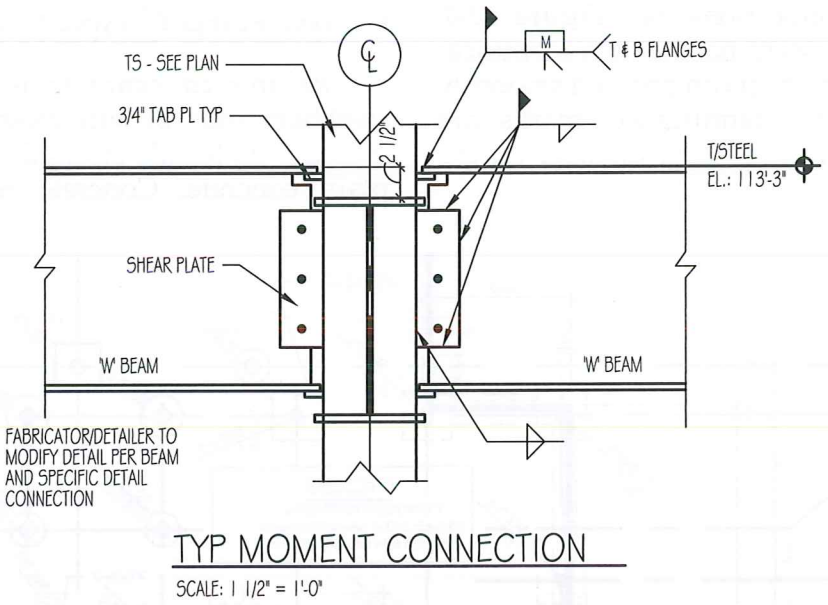


Figure 23-5. This detail shows how structural steel beams are to be connected to a column. The drawing indicates that the various parts are welded together. (Charles E. Smith, Areté 3 Ltd.)

structure. See **Figure 23-5**. Structural steel shapes may be fastened together by welds, bolts, or rivets. In years past, rivets were preferred, but in more recent times, welds and steel bolts have become the preferred methods of attachment. They are frequently used together in a common application. Welding is discussed in Chapter 26 of this textbook.

Special high-strength steel bolts are used for construction purposes. Common sizes include 3/4", 7/8", and 1" diameter. Specifications for steel bolts are provided by the American Society for Testing and Materials (ASTM).

Structural Steel Drafting

Structural steel drawings are generally either engineering design drawings or shop drawings. ***Engineering design drawings*** are made by a drafter in the engineer's office. ***Shop drawings*** are made by the steel fabricator.

The purpose of an engineering design drawing is to show the location and size of columns, beams, and other structural shapes. See **Figure 23-6**. Details and notes are an integral part of structural engineering drawings. The engineering drawings may be developed as plan or elevation drawings. In most cases, both are required. The plan view drawing shows the placement of columns in section. The locations of beams or girders are shown as thick, single lines or as centerlines. Girders are placed between columns to support smaller framing beams called ***filler beams***.

The fabricator uses the engineering drawings to make detailed shop drawings and erection plans. Shop drawings must be approved by the design engineer. The shop drawings show each part of the structure to be fabricated, the location of all holes, the connector details, and the size of all parts. Details are drawn at a larger drawing scale, and dimensions are included on all details

to clearly show connections. See **Figure 23-7**. Every structural element has its own identification mark so that erection can proceed smoothly and accurately. The identification marks are also shown on each individual member on the erection plans.

Concrete Construction

Reinforced concrete is concrete that has steel bars, rods, or wire mesh embedded in it to increase its tensile strength. It is stronger than plain concrete. Concrete naturally has high

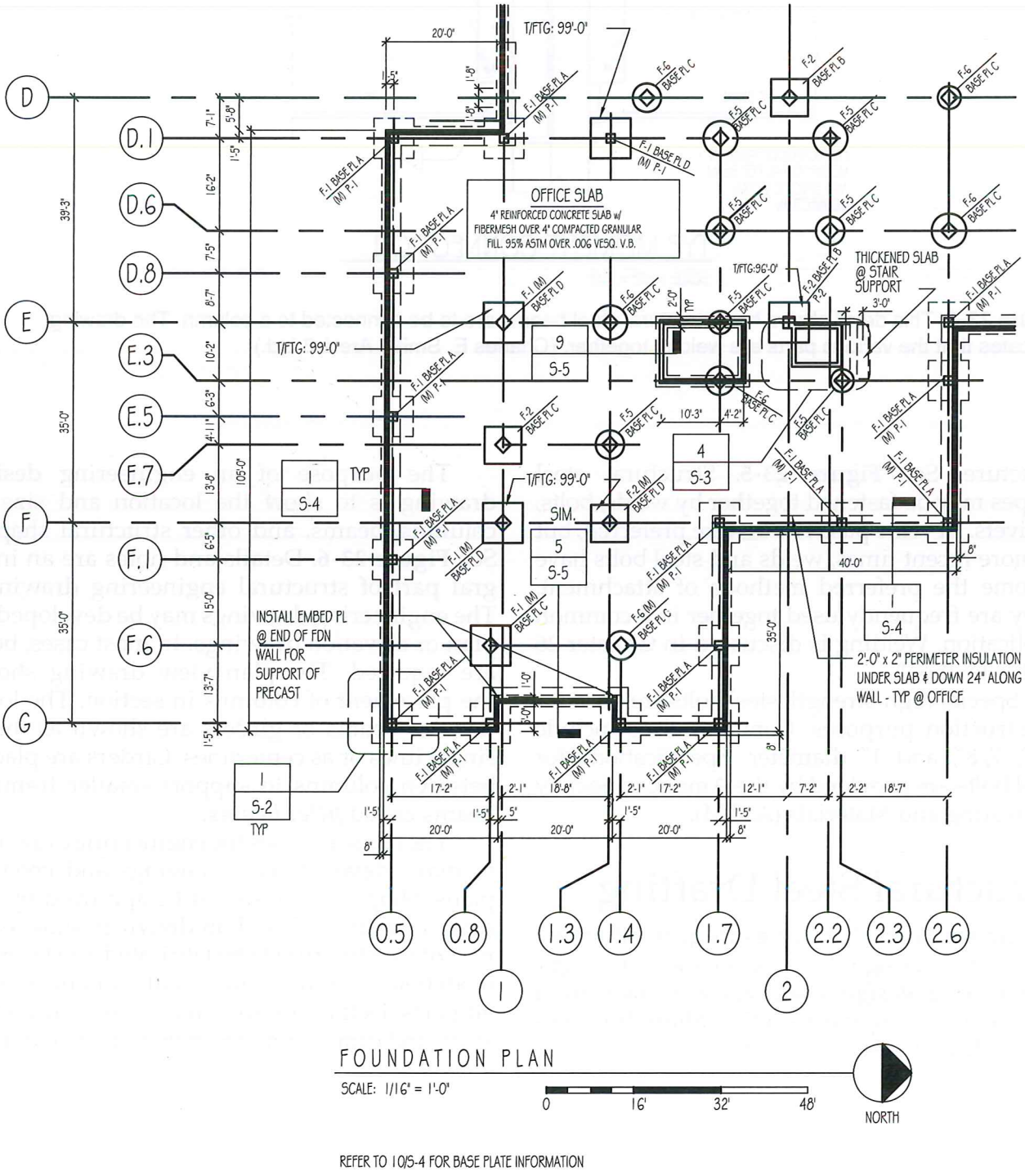


Figure 23-6. This drawing shows the location of column piers and beams for a portion of a commercial building. (Charles E. Smith, Areté 3 Ltd.)

compressive strength, but low tensile strength. By embedding steel, concrete has a much broader application as a structural material. Applications include cast-in-place roof and wall systems, foundation systems, and slabs. See **Figure 23-8.**

Prestressed concrete is made when steel wires or bars are stretched before the plastic concrete is poured over them. Prestressed concrete is stronger than reinforced concrete. It is generally used to make concrete panels used in roof and wall construction.

Cast-in-Place Concrete Roof and Floor Systems

Cast-in-place concrete is concrete cast at the site of construction. There are four basic cast-in-place concrete roof and floor systems commonly used in commercial construction. These are the pan joist, waffle, flat plate, and flat slab systems. They are discussed in the following sections.

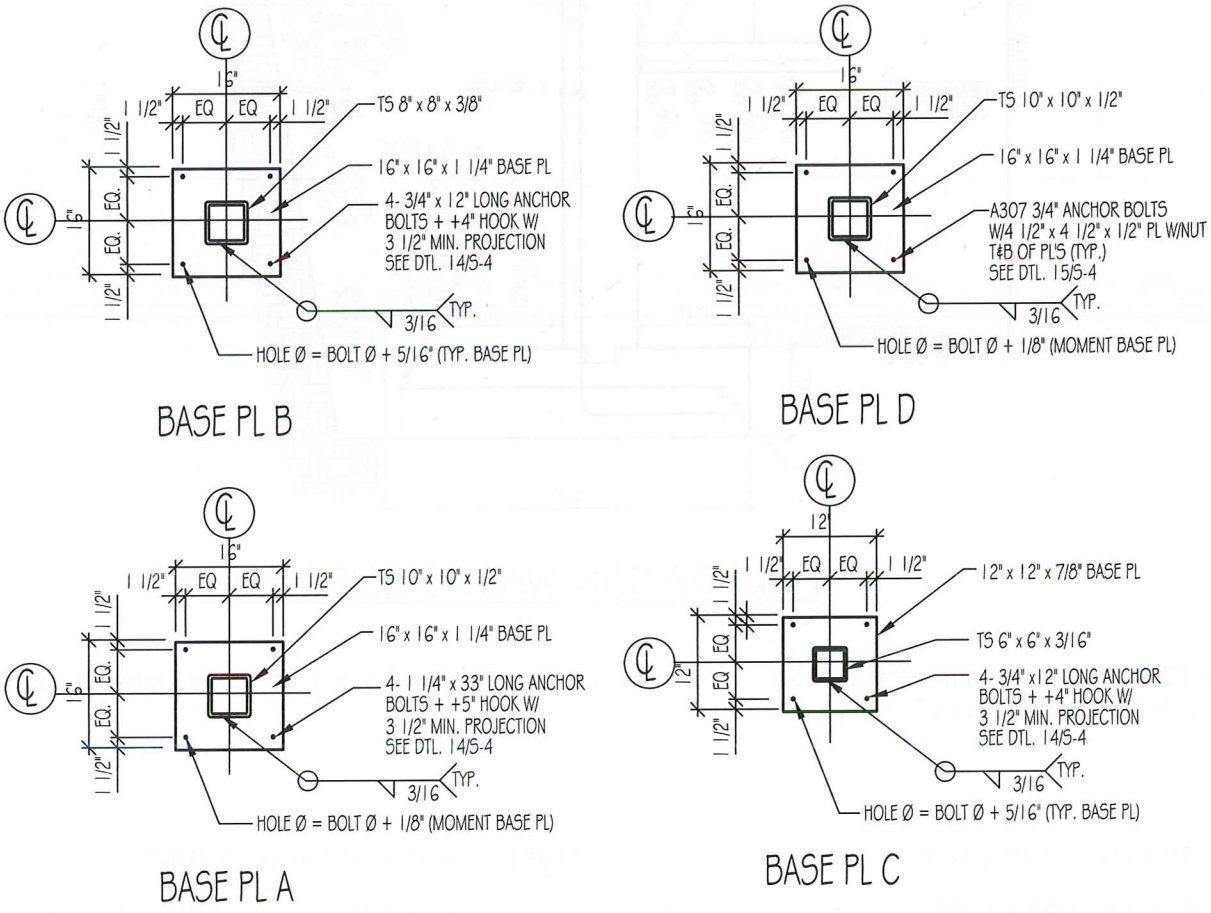


Figure 23-7. These details show specifications for the various base plates to be used in the structure illustrated in **Figure 23-6.** (Charles E. Smith, Areté 3 Ltd.)

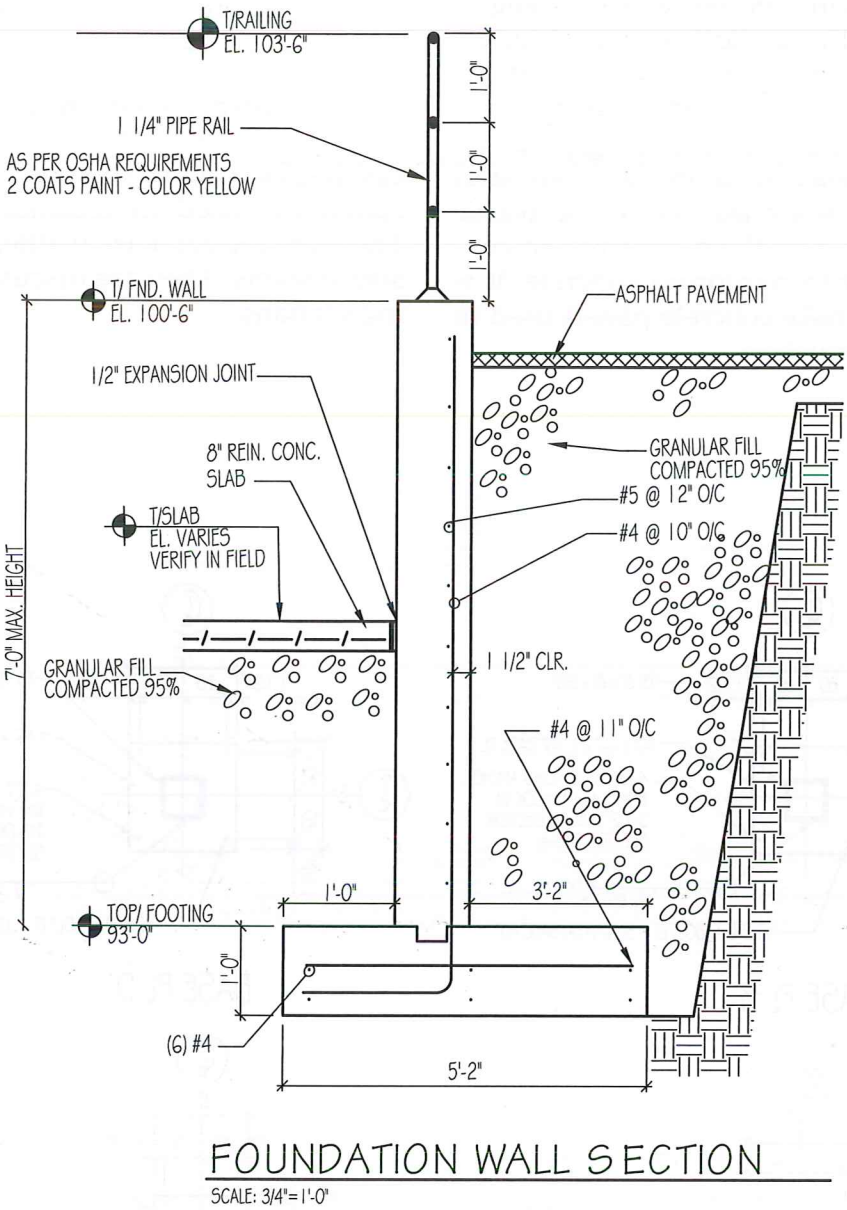


Figure 23-8. This foundation section shows the use of reinforcing bars and wire mesh to strengthen the footing and foundation wall. (Charles E. Smith, Areté 3 Ltd.)

Pan joist roof and floor system

Pan joist construction is a one-way structural system using a ribbed slab formed with pans. See **Figure 23-9**. This system is economical because the standard forming pans may be reused. Standard pan forms produce inside dimensions of 20″ to 30″ and depth dimensions from 6″ to 20″.

Waffle roof and floor system

Waffle construction is a two-way structural system that utilizes waffle pans or forming domes to form a ribbed slab. See **Figure 23-10**. Waffle pans and domes are available in standard sizes but may be custom made for a particular job. The forms can be reused. Standard square domes are available in 19″ × 19″ and 30″ × 30″ sizes. Depths range from 6″ to 20″.

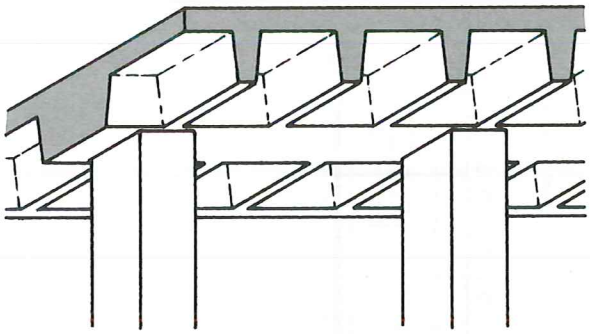


Figure 23-9. Pan joist roof construction is a one-way structural system using a ribbed slab formed with pans. Spans of up to 50′ are common.

Flat plate roof and floor system

The main features of the flat plate system are minimum depth and architectural simplicity. See **Figure 23-11**. The flat plate system is a two-way reinforced concrete framing system utilizing the simplest structural shape—a slab of uniform thickness. Slabs generally range in thickness from 5″ to 14″ thick.

Figure 23-10. Waffle construction is used in this structure to form the roof slab. Spans of up to 60′ are possible.

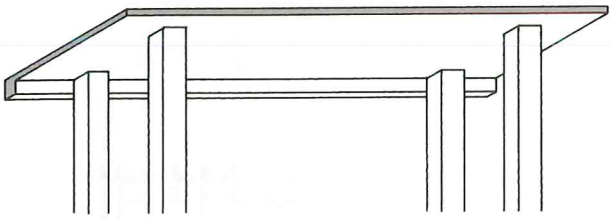


Figure 23-11. A flat plate roof utilizes a two-way reinforced concrete framing system. It has a slab of uniform thickness.

Flat slab roof and floor system

The flat slab system is a two-way structural system designed for heavy roof loads with large open bays below. The flat slab system has a supporting panel in the area of each column for added support. See **Figure 23-12**.

Precast Concrete Systems

Precast concrete is concrete cast for subsequent use in construction. Precast concrete units for walls, floors, ceilings, and roofs can be mass produced at the factory or job site. Precast concrete units include tilt-up panels, standard-shaped concrete panels, and concrete window walls.

Tilt-up panels

Tilt-up panels are usually cast at a factory and trucked to the site where they are lifted into position. Tilt-up construction is one of the fastest-growing construction methods in the United States. This is mostly due to reasonable cost, low maintenance, durability, and speed of construction. Tilt-up construction is especially suited for buildings greater than 10,000 square feet with 20′ or higher side walls that incorporate repetition in panel size and appearance. See **Figure 23-13**.

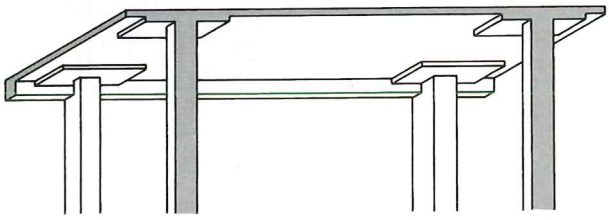


Figure 23-12. A flat slab roof utilizes a two-way reinforced structural system. It includes either drop panels or column capitals to carry heavier loads.

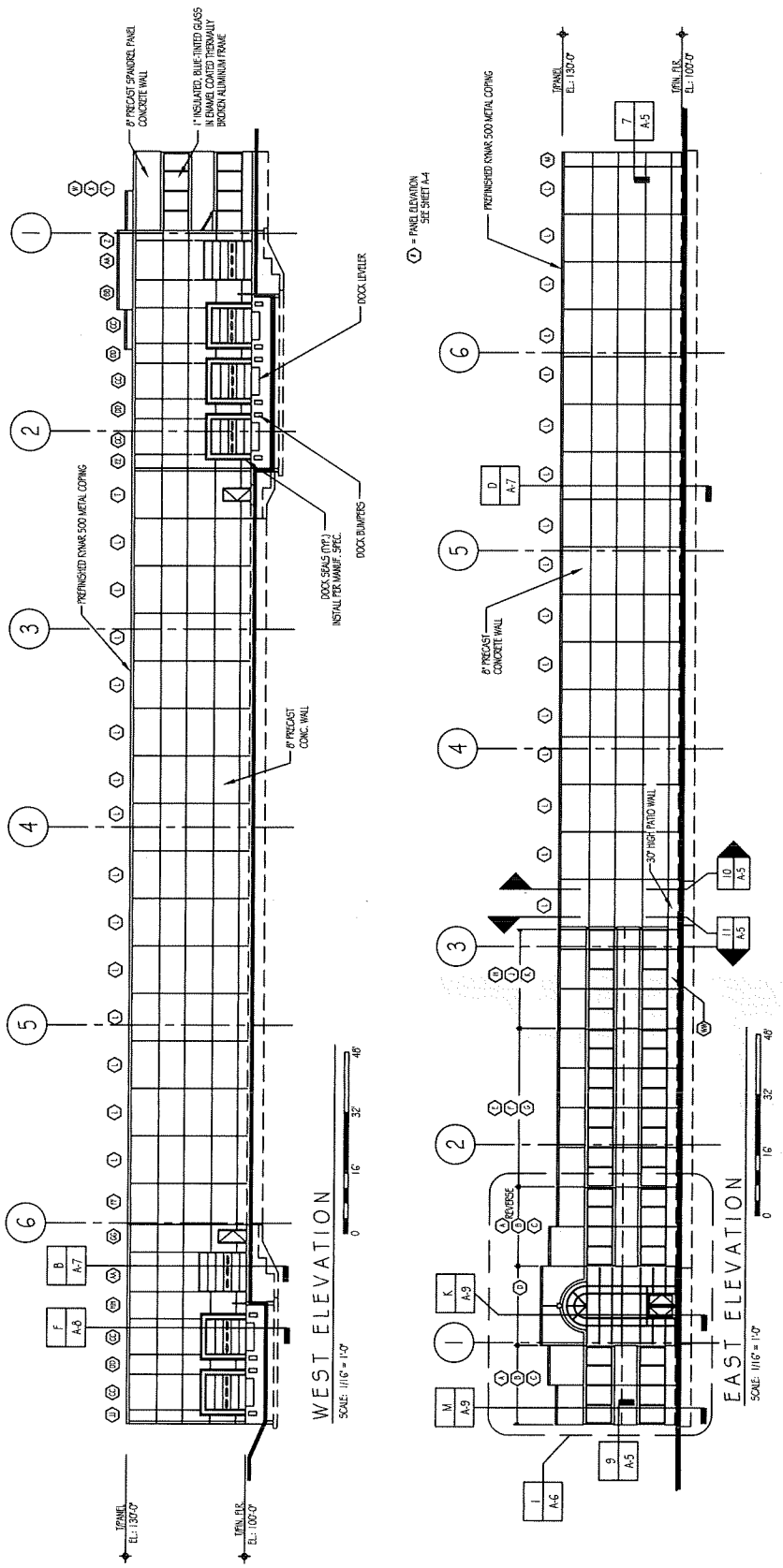


Figure 23-13. Exterior elevations of a warehouse and office building constructed using tilt-up panels. (Charles E. Smith, Areté 3 Ltd.)

Standard-shaped prestressed concrete panels

Standard-shaped prestressed concrete panels have many applications in structural designs. These precast units are crack-free and highly resistant to deterioration. Some of the most common designs include double-tee units, single-tee units, and hollow-core panels. **Figure 23-14** illustrates the use of a single-tee unit.

Precast concrete window walls

Precast concrete window walls may be cast as curtain walls or load-bearing walls. Forms or molds used to produce complicated designs are made from plastic, wood, or steel. Precast window walls can be one-story or multistory units.

Concrete Construction Drafting

The preparation of drawings involving reinforced or prestressed concrete is not for the novice. To aid in the process of design and drafting, the American Concrete Institute (ACI) has developed the Manual of Engineering and Placing Drawings for Reinforced Concrete Structures. This is a very helpful reference that provides a guide to the complex process of design and drafting for concrete construction.

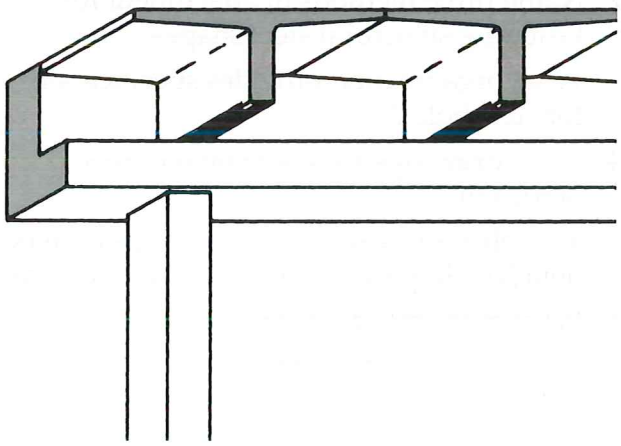


Figure 23-14. Single-tee precast, prestressed concrete units are generally used for very long spans. Typical spans are from 30′ to 100′.

Normally, two types of drawings are prepared for reinforced concrete structures—an engineering drawing and a placing drawing. The fabricator of the reinforcing steel usually prepares the engineering drawing. The ***engineering drawing*** describes the structure and shows the size and reinforcement of each member with notes to explain the designer's intent. This drawing is used to prepare forms for the concrete.

A ***placing drawing*** shows the sizes and shapes of reinforcement and supporting devices such as stirrups and hoops. The various parts are usually arranged in tabular form to assist the building contractor.

Chapter Summary

Structural drafting is the preparation of drawings for the design and construction of structures such as buildings, towers, bridges, and dams. Structural drawings may be developed as plan view drawings, elevations, details, or pictorials.

Advanced drawing skills and knowledge of the specific subject field are necessary to produce acceptable drawings used in structural drafting. The primary materials that the structural drafter needs to be familiar with include wood, structural steel, and reinforced concrete.

Wood is a traditional structural material. The most common species used for structural members include Douglas fir, spruce, redwood, southern yellow pine, oak, and poplar. Wood members can be fastened together using nails, screws, lag bolts, machine bolts, steel plates, and special timber connectors. Timber members used for structural applications are usually kiln dried and surfaced on all sides.

Structural steel used in steel-framed structures is available in a variety of different shapes and grades. Drafters making structural steel drawings must be familiar with the common shapes of steel and the physical properties of different grades of steel.

Structural steel drawings are generally either engineering design drawings or shop drawings. The purpose of an engineering design drawing is to show the location and size of columns, beams, and other structural shapes. The fabricator makes shop drawings that show each part of the structure to be fabricated, the location of all holes, the connector details, and the size of all parts.

Reinforced concrete is concrete that has steel bars, rods, or wire mesh embedded in it to increase its tensile strength. Applications include cast-in-place roof and wall systems, foundation systems, and slabs. Prestressed concrete is made when steel wires or bars are stretched before the plastic concrete is poured over them. Prestressed concrete is stronger than reinforced concrete.

The preparation of drawings involving reinforced or prestressed concrete is not for the novice. The American Concrete Institute's Manual of Engineering and Placing Drawings for Reinforced Concrete Structures provides a guide to the complex process of drafting and design for concrete construction.

Additional Resources

Publications

Builder
www.builderonline.com

Building Design & Construction
www.bdcnetwork.com

Concrete Construction
www.hanley-wood.com

Resource Providers

American Concrete Institute (ACI)
www.aci-int.org

American Forest and Paper Association (AF&PA)
www.afandpa.org

American Institute of Steel Construction (AISC)
www.aisc.org

American Iron and Steel Institute (AISI)
www.steel.org

American Society for Testing and Materials (ASTM)
www.astm.org

The Engineered Wood Association (APA)
www.apawood.org

National Center for Construction Education and Research (NCCER)
www.nccer.org

Portland Cement Association (PCA)
www.cement.org

Review Questions

1. Name the three primary structural materials used in the construction of buildings and other structures.
2. Name four species of wood that are available for structural timber.
3. The American Forest and Paper Association (AF&PA) provides information about the _____, _____, and other properties of wood species commonly used in construction.
4. Name five common structural members made from wood.
5. Split-ring metal connectors are frequently used between wood structural members to increase _____.
6. What is the actual size of a finished 4″ × 6″ beam?
7. Dry lumber has _____ percent or less moisture content.
8. Wood post and beam construction uses framing _____, _____, and _____ that are larger and spaced farther apart than conventional framing members.
9. Most of the weight of a post and beam building is carried by the _____.
10. What three factors generally determine the size of the wall footings or piers in a post and beam structure?
11. Structural steel is produced in a wide variety of standard shapes. Name five.
12. Name three methods of attachment for fastening structural steel shapes.
13. What organization provides specifications for steel bolts?
14. _____ drawings are made by the steel fabricator.
15. The fabricator uses _____ drawings to make detailed shop drawings and erection plans.
16. What is *reinforced concrete*?
17. _____ concrete is made when steel wires or bars are stretched before the plastic concrete is poured over them.
18. Cast-in-place concrete is concrete cast at the site of _____.

19. There are four basic cast-in-place concrete roof and floor systems commonly used in commercial construction. Name them.
20. Why is tilt-up construction one of the fastest-growing construction methods in the United States?
21. Identify the three common designs of standard-shaped prestressed concrete panels.
22. What are the two types of drawings that are normally prepared for reinforced concrete structures?

Problems and Activities

The following problems are designed to provide you with the opportunity to apply knowledge gained in your study of structural drafting and to help you become familiar with the procedures used. They require you to apply your problem-solving skills. The problems can be drawn manually or with a CAD system. Complete each problem as assigned by your instructor.

1. Prepare a detail drawing of a roof truss connector plate for a timber truss made from 4″ × 8″ timber. The plate is to be used for the truss apex. The truss has a 6:12 slope and the joint is mitered.
2. Prepare a shop drawing of a wide-flange floor beam (W-beam) that is 14′-0″ long. The beam is 6″ wide by 12″ high. Attach two angles at each end that are 4″ × 3 1/2″ × 5/16″. Use three bolts on 3″ centers to attach the angles to the beam. The total number of angles required is 4. The number of bolts required is 6. Do not detail the bolts.
3. Make a section drawing of a double-tee concrete panel that is 16″ deep by 4′ wide. The slab is 3″ thick at the edge and the web is 8″ thick at the bottom. Show the reinforcing bars, concrete material symbol, and overall dimensions.