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ESTIMATING STRUCTURAL STEEL

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Including Structural Aluminum and Miscellaneous Materials

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McGRAW-HILL BOOK COMPANY, INC.
New York *Toronto* *London* 1959

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Library of Congress Catalog Card Number: 59-8560

To my wife
JANE T. SAUNDERS

Preface

This book has been designed to provide a broad coverage in the estimating of structural steel, structural aluminum, and some of the miscellaneous items used in building construction. It can be used as a reference book by contractors and builders, by senior and junior or apprentice estimators, and by engineering students.

Both shop fabrication and field erection are included. Much of the major structural shop equipment is described, and its uses. Much of the equipment employed in connection with the erection of many types of structures is also covered.

Structural aluminum is becoming popular for use where light weight is desired, because it reduces maintenance costs, and because of its decorative value. Many steel fabricators have equipment which can be employed with aluminum, and with the adoption of some new techniques they can readily fabricate this material. The cost of aluminum is greater than that of steel, but other factors must be considered which will encourage the use of this material.

Included with the miscellaneous items are open-web, or bar, joists, Lally, or concrete-filled, columns, grating, steel stairs, studs and spirals used in connection with composite bridge stringers and girders, steel floors and decking, corrugated roofing, and siding and other coverings. Many fabricators include these and other items in their contracts, and hence an understanding of material other than structural shapes is advisable.

The author has been in the employ of several of the largest steel-fabrication companies: American Bridge Co., Levering and Garrigues Co. (merged with Bethlehem Steel Co.), Bethlehem Steel Co., Lehigh Structural Steel Co. These companies are all well known throughout the United States in connection with many of the major construction works. The author has gained experience in many branches of structural fabrication and erection, including the planning of field equipment, purchasing, traffic, drafting, template shop, inspection of fabrication, and erection. As chief structural estimator he has trained many men in estimating, and in connection with this training the need of a book such as this became increasingly evident.

In addition to the many drawings included in this book the photographs which appear in most of the chapters should materially aid in the understanding of structures and structural estimating. These photographs have been supplied by the following companies: American Bridge Division, U.S. Steel Co.; American Hoist and Derrick Co.; Bethlehem Steel Co.; Cleveland Punch and Shear Works; Clyde Iron Works; Harris Structural Steel Co.; Lehigh Structural Steel Co.; Lincoln Electric Co., Inc.; Pure Oil Co.; R. C. Mahon Co.; The Harnischfeger Co.; The Morgan Engineering Co.; Thomas Machine Manufacturing Co.; Standard Oil Co., N.J.; Underwriters' Laboratories, Inc.

There are many fabricators in this country who built outstanding structures similar to those shown in the photographs. It is regretted that many more examples could not be included. The photographs which have been selected are those which are applicable to the text.

Further data and information have been supplied by: Aluminum Company of America; American Hoist and Derrick Co.; American Institute of Steel Construction; Carolina Steel and Iron Co.; Cleveland Punch and Shear Works Co.; Hobart Bros.; Lally Column Co.; Lehigh Structural Steel Co.; Lincoln Electric Co., Inc.; Manning Maxwell and Moore; Nelson Stud Welding Division, Gregory Industries; Porete Manufacturing Co.; Reynolds Metals Co.; The Harnischfeger Co.; The Morgan Engineering Co.; Thomas Machine Manufacturing Co.

Thanks are due also to many persons who furnished photographs and other data and who made helpful suggestions and gave other assistance. Further acknowledgment is made in various parts of the book.

The following is a brief list of publications which will be of much value to an estimator:

"Alcoa Aluminum Handbook," Aluminum Company of America, Pittsburgh, 1957.

"Aluminum in Modern Architecture," vols. 1, 2, Reynolds Metals Company, Louisville, 1956.

"Civil Engineering Handbook," 3d ed., L. C. Urquhart, McGraw-Hill Book Company, Inc., New York, 1950.

"Contracts, Specifications, and Engineering Relations," 3d ed., D. W. Mead, Harold W. Mead, and J. R. Akerman, McGraw-Hill Book Company, Inc., New York, 1956.

"Design of Steel Structures," E. H. Gaylord, Jr., and C. N. Gaylord, McGraw-Hill Book Company, Inc., New York, 1957.

"Estimating Construction Costs," 2d ed., R. L. Peurifoy, McGraw-Hill Book Company, Inc., New York, 1958.

"Steel Construction Manual," 5th ed., American Institute of Steel Construction, New York, 1946.

"Steel Structures Painting Manual," Joseph Bigos (ed.), vol. 1, Good Painting Practice, 1954; vol. 2, Systems and Specifications, 1955; Steel Structures Painting Council, Pittsburgh.

"Structural Shop Drafting," vol. 1, 1950; vol. 2, 1953; vol. 3, 1955; American Institute of Steel Construction, New York.

The AISC "Steel Construction Manual" is a very useful book containing data from most of the largest mills. It will be found in the offices of most fabricators, and many contractors and builders have copies of it on hand. In addition to the data on dimensions of shapes, many practical tables are included, as well as standard specifications. Reference is made to the AISC Manual, as required, to explain certain conditions in connection with the design of the structures considered in this estimating book.

George A. Saunders

Contents

CHAPTER 1

Introduction

1-1. Estimating Structural Fabrication and Erection. Structural-steel estimating is the art of determining in advance of the actual building of a structure how much the cost should be for fabrication and erection. Fabricators do not manufacture or roll the steel shapes which they use; however, they must add the purchase price of the material to the estimate.

The senior, or chief, estimator is the person in the employ of a structural fabricator who is responsible for assembling all the figures, costs, and data from which a bid is prepared. It is obvious that a fabricator could not remain long in business if his final costs exceeded the amount which was bid for the production of the work.

1-2. Organization of the Department. An estimating department may consist of one man, in the case of a small organization, or of many men, in the case of the larger fabricators. In the larger organization the department head has the responsibility for the final figures.

Some of the personnel may be apprentices or juniors competent to do the simpler work, including the calculations of weights. Others will be fully experienced estimators capable of estimating any type of structure which the fabricator can contract. The experienced estimators may or may not develop final costs, depending on company policy.

It is possible for experienced persons to guess somewhere near the approximate cost of a structure but this entails a great risk of loss. Erected steel will cost several hundred dollars per ton, and an error of not too many tons can cost a considerable amount. Therefore it is advisable to make a careful estimate of all the work to be done in fabrication and erection and to apply the proper cost figures.

1-3. A Career in Estimating. The estimating of structural steel, structural aluminum, and miscellaneous iron is a very rewarding and interesting occupation. With most fabricators, it is no longer a secondary class of work in which a person may stay for a short while and then move on to a better position. Estimating now has taken its rightful position as a very important part of the fabricator's business, owing to many factors—new methods, new equipment, new designs of structure, and, not least,

the importance of obtaining the most accurate costs possible for inclusion in the bids for work.

The earnings of the chief, or senior, estimator are on a plane with the salaries paid to others at the top levels of the company. The junior, or apprentice, estimators at a grade below the chief estimator receive, with many companies, a rate of pay which should prove very attractive to many newcomers in this field.

Most high-school graduates have had sufficient mathematics for the calculations needed in estimating. It should be noted here that except for some figuring of angles and proper reading of the engineer's and architect's scales most of the calculations are performed by use of mechanical calculators. Therefore some understanding and experience in the use of these machines will be very helpful to the newer employees in the estimating department.

With many of the more progressive companies, properly qualified graduates of high schools may be given very important rounded training by means of what is generally called a "loop" course. The loop course may be for a period of about two years, divided into sections.

1-4. The Loop Course. Depending upon the individual company plan the several sections may be some or all of the following:

The first section of the course may be devoted to a study of drafting. This provides training in plan reading and some of the steps necessary to prepare the detail drawings for use by the shopmen. The period of time allotted will not permit a full study of all the drafting problems but will provide a good point from which to start.

In the shop, the use of the drawings in connection with the layout and fabrication of the material will be seen. Many other shop operations and functions will be observed during this section of the course. The trainee may also be permitted to take part in some of the shop operations. In other chapters the shop machinery and operations will be fully covered.

In the field section it seldom will be necessary actually to work on the erection of the steel. All the erection operations will be done by the regular experienced ironworkers. However, some of the work of the trainee may consist in aiding the engineers running the lines and levels for setting the slabs, or base plates. Other work may consist in assisting the timekeeper in the collecting of data required for the daily erection reports. Some opportunity may be afforded for study of the plans and details, to observe just how the work in the field is done.

Remaining sections of the course may include some training with the sales section and also possibly in purchasing, production control, and shop planning. Accounting is not usually included in a loop course, and traffic may or may not be.

This book will of course be useful in connection with loop courses.

1-5. Technical Study. In the event that a loop course is not available, it will be necessary to have some advanced study before proceeding with estimating. This book may be used for such study, as it covers both basic and advanced estimating step by step. At least some basic study and understanding of reactions, moments, shears, and stresses in the design of steel structure are necessary. For example, in order to estimate the proper connection the estimator will often refer to the value of the reactions at a joint. The draftsman may devote a long time to detailing some particular unit of work such as beam details, column details, or truss details. But in the limited time the trainee will spend on drafting a full coverage of this phase of work will not be done.

It will be necessary for the estimator to be able to read and interpret all plans and all classes of work. This alone makes the field of estimating as a career interesting and stimulating. Nearly every job will present some new problem or new method. This book will trace by progressive steps the proper methods of estimating structural steel and other structural materials as applied to buildings, bridges, and many other types of structures.

1-6. Material from the Rolling Mills. Steel rolling mills produce structural material which is purchased by structural fabricators. At the fabrication shops the shapes and plates will be cut, sheared, punched, drilled, riveted, welded, formed, machined, and worked upon in any manner required to build up the necessary components which will go into a structural frame. After completion of all assemblies the fabricated steel is loaded on cars, ships, or trucks and sent to a site of construction. It is here that the erection crew will perform all the operations needed to complete the setting up of the structure, including the fastening of the structural members with bolts, rivets, or welds.

The steel-producing mills roll a very wide variety of shapes, many of which are used in structural work. Figure 1-1 shows the general outlines of the shapes most used by structural fabricators. The views shown by these sketches are as seen looking at the ends of the sections: (*a*) Round bars. (*b*) Square bars. (*c*) Rectangular sections, which may be classified as slabs, plates, bars, or sheets. Certain size qualifications determine the names assigned to the flat sections. That is, sizes in the range of specified thicknesses and widths are termed "plates," and other designations are based on widths and/or thicknesses. (*d*) Beams, WF or H sections. (*e*) Channels. (*f*) Angles, or L sections. (*g*) Tees, or T sections. (*h*) Zees, or Z sections. (*i*) Rails, crane or railroad.

Subsequent chapters will provide detailed information relative to these various sections. Complete coverage of all sizes and shapes rolled by the various steel rolling mills may be obtained from catalogues furnished by most of the mills.

1-7. Structural Fastenings. In addition to the sections shown in Fig. 1-1 the fabricator will be obliged to purchase or manufacture the fastening materials. Figure 1-2*a* is a sketch of a rivet as manufactured by the fabricator, many of whom have rivet-making machines, or as purchased from a supplier. The "button head" shown in the sketch is the type of head most generally used except in cases where the clearance of other sections may require a different kind.

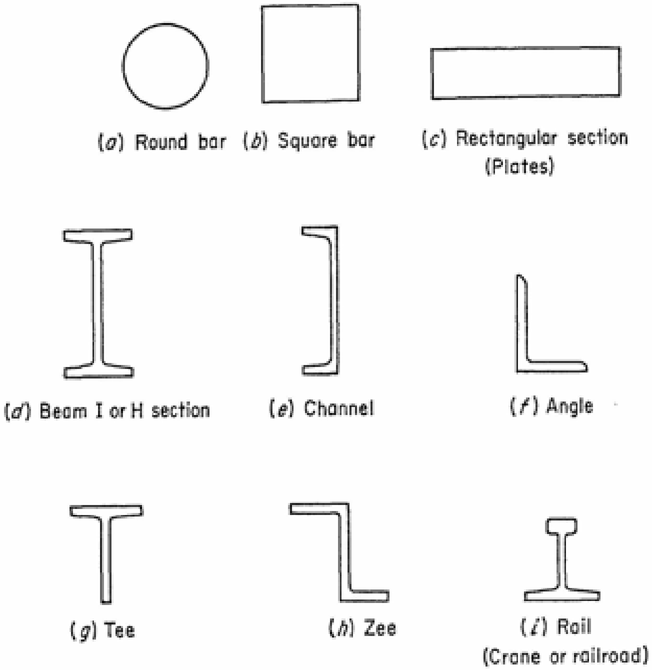


FIG. 1-1. Structural-steel shapes.

Figure 1-2*d* shows several different types of rivet heads. The rivet in its manufactured form will have the head on one end only. The shank will be of the proper length for the driving of the head on the other end after the assembly of the sections is completed or the piece is erected in the field.

The heads in Fig. 1-2*d* are as follows:

1. Button head both ends
2. Button head and countersunk head
3. Countersunk both ends
4. Button head and flattened head
5. Flattened head both ends

In Fig. 1-2*b* the bolt shown is called an "unfinished bolt" or sometimes a "regular machine bolt." It is manufactured with either a square or a hexagon head and is supplied with either square or hexagon nuts. It can be used with or without washers as determined by the specifications. These washers may be flat, beveled, or lock washers.

Figure 1-2*c* shows a bolt similar in appearance to the unfinished bolt

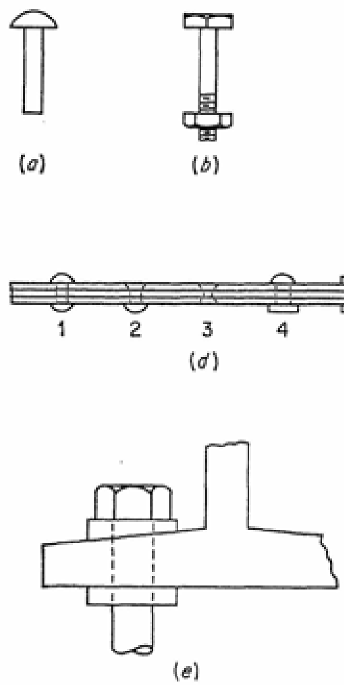


FIG. 1-2. Fastenings.

with the exception that two washers are required. This bolt is called the "high-strength bolt." It is being used on many structures as a replacement for the field rivet. As the name indicates, the steel in the bolt is heat-treated and quenched in a liquid medium, then tempered by being reheated to a certain specified temperature. The two washers which must be used, one under the head and one under the nut, must also be hardened. For the purpose of identification there are certain manufacturer's markings on the heads of these bolts. The heads and nuts will be hexagon, and the washers may be flat or beveled as required by the conditions or specifications. As shown in Fig. 1-2*e* the washer on top of the beam flange should be beveled.

It will no doubt be evident that there is considerable variation in the

cost of these fastening materials. The most expensive are the high-strength bolts and heat-treated washers.

The one other fastening material is the material used for welding. This is provided in the form of welding rods or welding wire and is supplied in several sizes. The specification will usually describe the quality and type, and the sizes may be indicated on the drawings or details.

CHAPTER 2

The Structural Fabricating Shop

2-1. The Fabricating Shop. Structural steel can be fabricated with a bare minimum of equipment. It is possible, for instance, to fabricate the material for a small structural frame by use of an oxyacetylene burning torch and also to do the necessary welding with oxyacetylene equipment. However, this book will be concerned, mainly, with major work, and most of the equipment used in modern fabricating shops will be described in this chapter. In addition to the heavy equipment to be described there will be a very large amount of supplementary equipment and the necessary departments for servicing tools and machines.

Some structures are designed by engineers in which all fastening, or the joining together of two or more parts or sections, is accomplished by means of rivets and/or bolts. Other structures are designed for welding. When a fabricator turns out a large tonnage of both riveted and welded work, it is usually advantageous to divide the shop in sections. The equipment used for riveted work will, to a great extent, be different from that required for a welded job, and it may be management's decision to keep separate these classes of work.

A fabricator with a diversity of work such as buildings and bridges may further divide up the plant and assign, for instance, one section to beam-and-column types of buildings and another area to the bridge or heavy structural work.

There are many kinds of shop layout and many ways of positioning machines. Some fabricating shops have had a complete plan and layout from the time of beginning operations. Others have expanded and added to the original plant. Some of the reasons, in addition to natural growth, might be the addition of welded work or the inclusion of heavy bridge work. Many modern structural fabricating plants perform all operations within completely enclosed buildings, except possibly the storage of finished work and the loading-out operation.

2-2. Plan of a Plant. Figure 2-1 gives a plan of a plant layout. It shows a comparatively compact plant and indicates, to some extent, the flow of work for this particular layout.

Structural steel in practically all cases is unloaded from cars or trucks at an incoming-material storage area, which is identified in Fig. 2-1. All the unloading and piling or stacking in the unloading yard are done with the aid of power equipment. The overhead, or traveling, crane operating

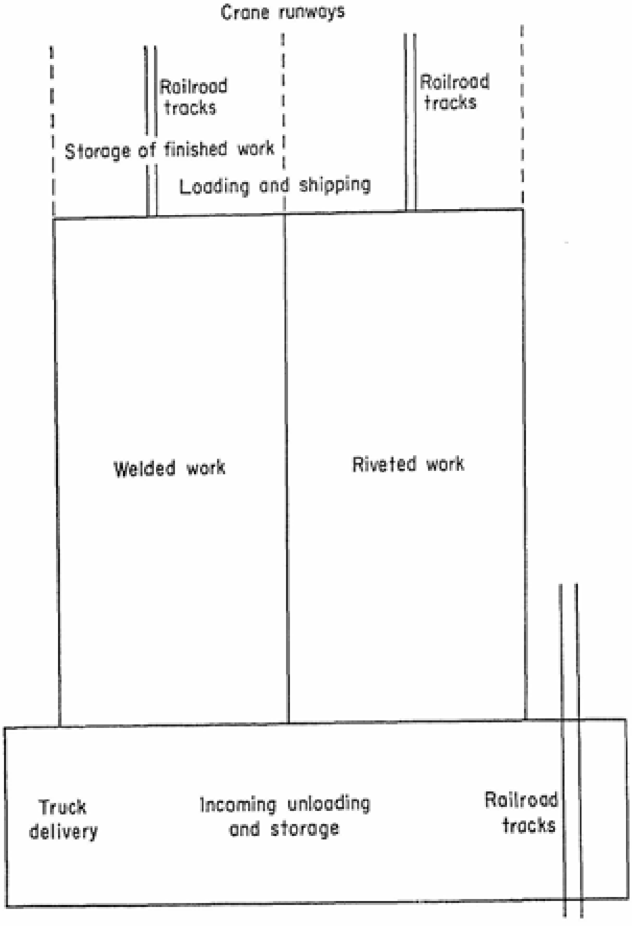


Fig. 2-1. Plan of a plant.

on a craneway is found at many fabricating plants. The craneway must be sufficiently high so that the stacks of steel may be built up as far from the ground as safety permits. With the overhead crane it should not be necessary to provide a roadway through the storage yard.

The crane may be operated from a cab suspended from it or in the case of smaller equipment by the use of controls which are hung from the crane and within reach of the loaders on the ground.

It is not mandatory to use cranes on craneways. Instead, either truck-

mounted cranes or tractor cranes which are mounted on caterpillar treads can be employed. The expense of constructing and maintaining the craneway can thus be saved; however, it may be necessary to provide a roadway through the storage area to permit the progress of the crane. The operation of these cranes must be controlled from within the equipment, and a truck-mounted crane may require the services of a truck chauffeur as well as the crane operator or engineer.

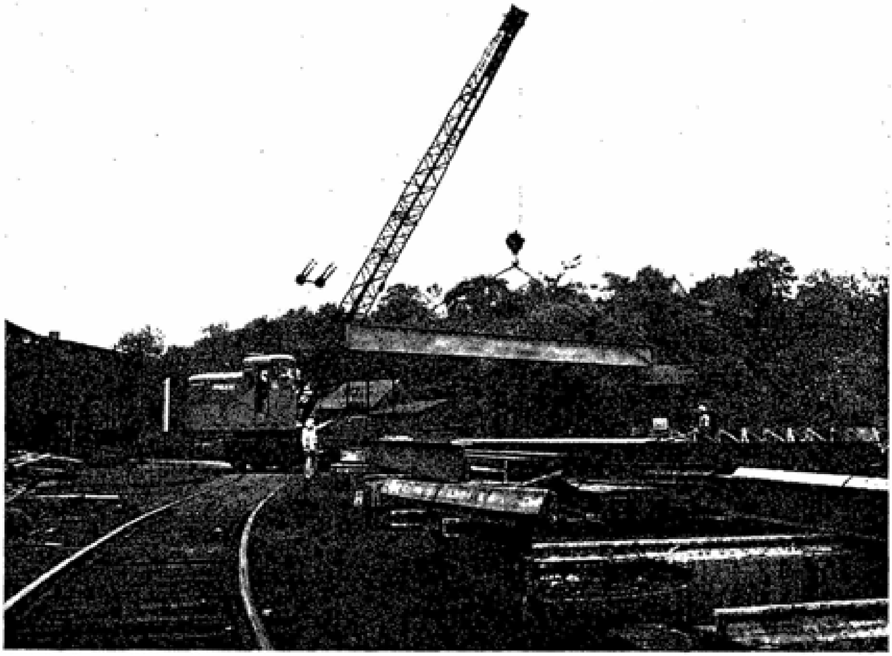


FIG. 2-2. Locomotive crane. (*American Hoist and Derrick Co.*)

Figure 2-2 shows a locomotive crane operating in the yard of a steel fabricator. This crane has diesel-engine propulsion. It can be noted that the steel has been fabricated, as evidenced by the holes in the sections and also the connection angles which appear on the beams. By close examination of the picture a coupling arm can be seen. This is a standard railroad-car coupling and can be used to attach loaded or empty freight cars, which in turn can be moved as required about the yard.

A layout of machinery and equipment is not shown in Fig. 2-1, for these are selected and located differently in almost every plant because of the type of work to be fabricated and the choice of equipment. One fabricator may use a spacing table for punching material, another may

use single and multiple punches, or a combination of equipment may be selected. Each plant will therefore be set up to provide the best usage of space and equipment.

At the completion of fabrication most structural material will receive a coat or coats of paint, which may be applied within the building, in a separate area or building, or in the yard. After painting, the fabricated material may be moved for storage in a shipping area or may be loaded directly on trucks or cars.

2-3. Lifting and Handling Equipment. Several methods of material handling may be in use throughout the fabrication sections of the shops. These are the overhead traveling, or bridge, cranes, the gantry cranes servicing the various machines, and equipment operated on the floor or ground, that is, hand- or power-operated flat cars or lift trucks. Flatcars are specially built to size and capacity as determined by the plant management.

2-4. Auxiliary Structures. Auxiliary structures may be required for supplementary operations. The threading of the ends of anchor bolts, sag rods, and tie rods may be done in an auxiliary building. The template shop may be adjacent to the main shop. It is advisable for template-

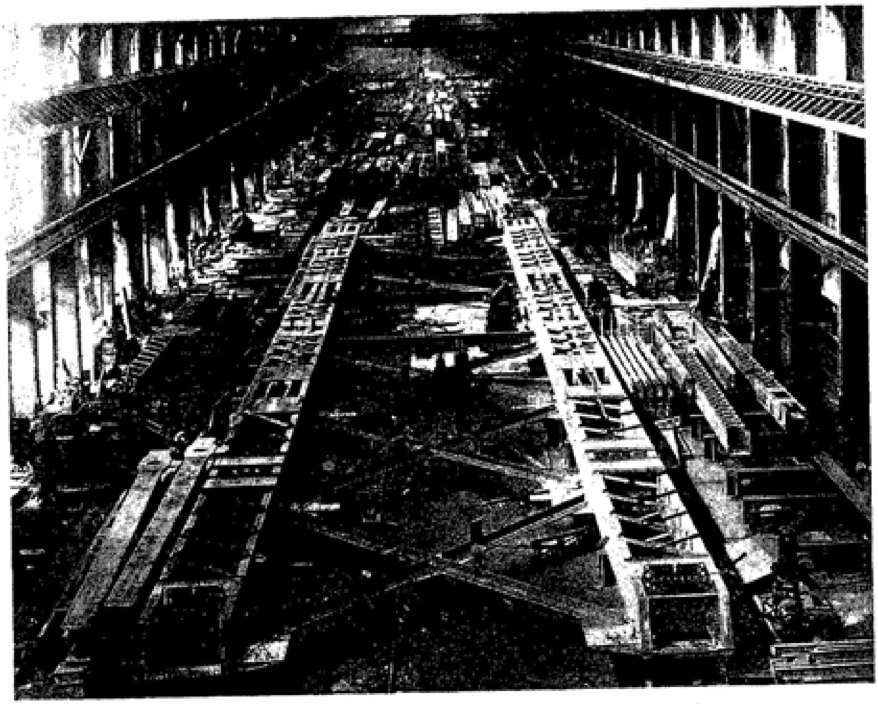


Fig. 2-3. Interior of a shop. (*Bethlehem Steel Co.*)

making personnel to be separated in order not to be interrupted in their work. The making of templates, which might in many cases be called patterns, is much like drawing a detail of work full size and should be done in a well-lighted and quiet section.

A machine shop for equipment and tool repair and maintenance will usually be part of the plant. Machining of bridge bearings may be performed in a section of the machine shop provided with the special equipment for this work. Other buildings may be provided for the storage of bolts, rivets, template lumber, and other template material.

Many fabricators also provide buildings and working areas for the storage and maintenance of erection equipment.

Figure 2-3 is a view of a bay, or aisle, of a steel fabricating shop. At the top center is seen one of the bridge, or overhead, cranes. Note that most shops of this size have two or more cranes on the runway. On the two runways, one on each side of the building, are seen several gantry cranes, which service the material to the various machines. Sections of car tracks are seen on parts of the floor, and much of the equipment for fabrication is in view throughout the shop. Many of the machines are located at the sides of the main working or assembly area. A large structural assembly is being processed, as shown in the center foreground of the picture.

2-5. The Bridge Crane. The bridge crane, or overhead traveling crane, has already been mentioned. However, since cranes are very important units of shop equipment, a more detailed description is in order. It might also be mentioned that estimators may be required to figure the weight and cost of fabricating many kinds of cranes, depending, of course, upon the type of structures the particular fabricator is equipped to build.

The crane consists of a built-up structural assembly on which is mounted the electrical and mechanical equipment for performing the action of lifting and lowering of material. Bridge cranes may be constructed to lift 5 or 10 tons up to 500 tons. The main supports of the crane consist of two or more heavy girders which span between the crane runway. These girders in turn are mounted on trucks which contain the wheels for traveling the length of the shop or crane runway. A carriage or carriages which contain the motors, cable drums, and other equipment mount on wheels. The carriages travel transversely along the bridge girders and can thus locate the lifting hook above the required work or area.

A bridge crane is shown in Fig. 2-4. The capacity of this crane is 25 tons, about the same as that of cranes found in medium and large structural fabricating shops. It is general practice to use two cranes on one

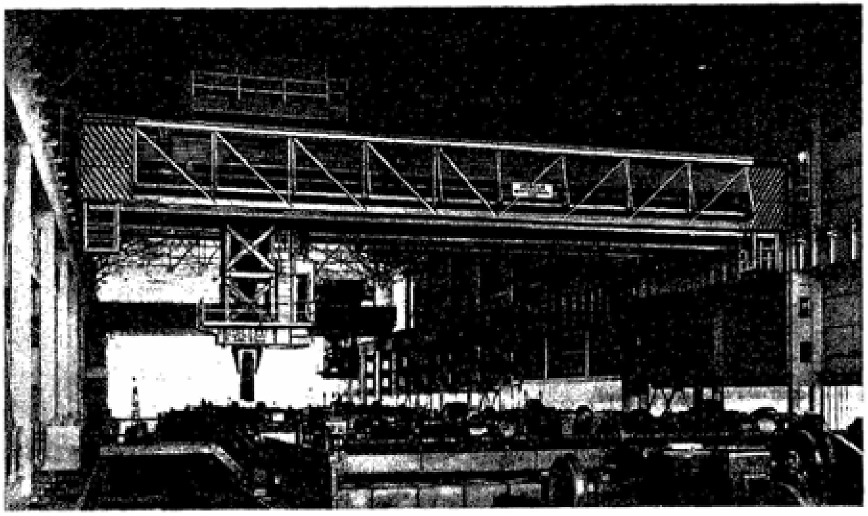


FIG. 2-4. A 25-ton crane. (*Morgan Engineering Co.*)

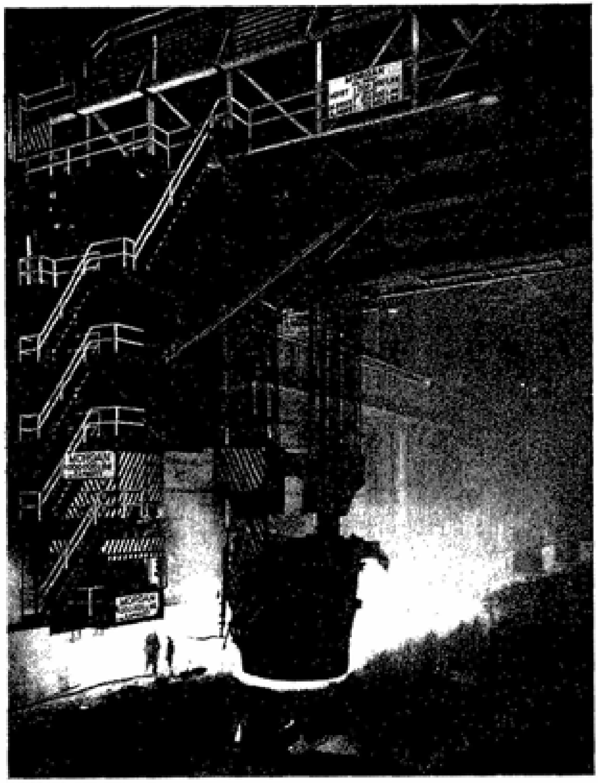


FIG. 2-5. Heavy mill crane. (*Morgan Engineering Co.*)

runway or craneway. They may be operated independently or jointly. When it is required to move a long or heavy assembly, the two cranes working together make a very satisfactory arrangement.

Figure 2-5 shows an extremely heavy capacity crane. Cranes of this size, of course, are not found in a structural fabricating shop in operation. However, some of the components of a bridge crane may be fabricated in a structural shop. For the benefit of those who have an interest in, or may be required to estimate, some of the sections an explanation and description of many parts will be included here.

The total weight of this crane (Fig. 2-5), without load, is 920½ tons. The lifting capacity is 500 tons on the main lift, and the auxiliary hoists have 75 tons and 25 tons capacity. The operator's cage is at the lower level to the left of the picture. An outstanding factor for those interested is that there are 76 parts in the reeving of the cable for the large trolley. The diameter of this cable is 1⅜ in. Crane-runway girders can be seen in the pictures. These girders may be built-up plate girders, built-up beam sections, heavy beam sections, and light beam sections, all of which depend upon the span between columns or supports and also upon the capacity and weight of the crane. Inside the buildings the columns may be so designed that they will support both the crane runway and other framing of the building, including the roof trusses. The supports of the craneway outside the buildings are also designed accordingly. The crane-runway girders and supports are described briefly here but will be more fully explained and considered in connection with the estimating of mill buildings.

The girders which support the crane equipment are called "bridge girders" and in the case of this 500-ton-capacity crane consist of two main and two smaller girders. The span of the bridge across the shop is 77 ft. Each main girder weighs 115,000 lb and is fabricated of plates. The web plate is 118¼ in. wide, which is 9 ft 10½ in., and the top and bottom cover, or flange plates, are 40 in. wide and 2¼ in. thick. These girders were assembled by means of welding by the automatic submerged-arc process. Further description of welded girders will be included in other chapters.

2-6. Storage Area for Incoming Materials. A storage area is shown in Fig. 2-6. One cab-operated crane is in complete view, and a portion of a second crane can also be seen. This storage area is completely enclosed and covered. The material in the left background consists of rivets or bolts.

The two cranes pictured in Fig. 2-7 are each controlled from the floor instead of by an operator in a suspended cab. The capacity of these cranes is 5 tons.

Smaller gantry cranes are located at the right and left sides of the

Fig. 2-6. Crane in storage area. (*Harnischefeger Co.*)

Fig. 2-7. A 5-ton crane. (*Harnischefeger Co.*)

shop. Note that the cranes on the right are pivoted at the columns and swing clear when not in use.

2-7. Fabricating-shop Equipment. In order that the reader may have a good understanding of the equipment and operations of a fabricating shop a detailed description of many of the machines will be included in this chapter.

The major shop operations of the more important machines are as follows:

Operation	*Machine or equipment*
Cutting or shearing	Shears, saws, and oxyacetylene-burning equipment
Drilling	Single and multiple drills
Punching	Single and multiple punches Spacing tables
Milling	Milling machines
Riveting	Yoke, or "bull," riveters and hand riveting tools Rivet-heating equipment
Welding	Power units, automatic equipment, and hand tools
Cleaning	Flame-cleaning equipment Sandblast and shot-cleaning equipment Scrapers, brushes, and hand tools
Painting	Spray equipment and hand brushes
Compressed air	Air supply for driving rivets, drilling, and reaming
Blacksmithing	Blacksmith-shop equipment, forges, heating furnaces, and blacksmith tools

2-8. Purchased Lengths of Material. Structural steel is ordered from the steel rolling mills in lengths for fabrication which will not require further cutting. This usually includes all the beam and column material required for a structure. Other material is ordered in lengths of 40 to 60 ft or more. This will be used for details such as connection angles, gusset plates for trusses, miscellaneous plate items, angle sections for trusses, and any other material on which the final lengths cannot be determined until after drawing details are made.

Much of the detail material could be ordered cut to lengths, as many details are made up in shop standard sizes. However, owing to mill cutting charges, the fabricator will elect to do the cutting of much material in the shop.

2-9. Cutting or Shearing. Cutting or shearing is done by one or all of the several methods. Plate, bar, and angle shears are machines on which utting blades are set or mounted. The material to be cut is positioned at the mark at which the cut is to be made, the pressure of the operator's foot on a bar or treadle actuates the motor, or drive, and the cutting is accomplished.

2-10. Plate- and Angle-shearing Machines. Figure 2-8 is a close-up of cutting jaws for shearing plates or bars. The upper blade is the diagonal part at the center of the picture, and the lower blade is horizontal and under, but offset from, the upper blade. The blades are changed by re-

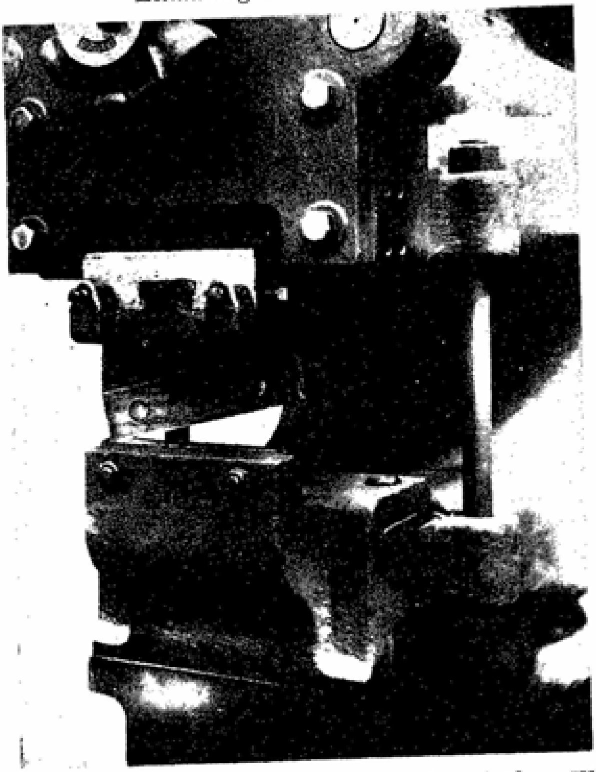


FIG. 2-8. Shear close view. (*Cleveland Punch and Shear Works.*)

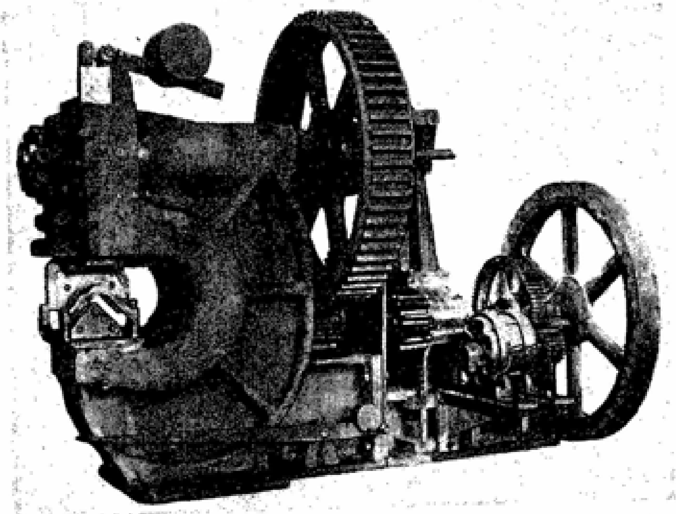


FIG. 2-9. Angle shear. (*Cleveland Punch and Shear Works.*)

moving the two bolts. These bolts are, of course, countersunk on the blade side. Figure 2-9 shows the complete machine. Interchangeable attachments may be set up on this type of machine. The attachment shown in the picture is for cutting angles. Other attachments are for punching, coping, and notching. Coping is the process of cutting out a section of a beam or channel to provide clearance for the adjacent framing. Notching is also the cutting out of a section of a member for clearance with another. It will be noted that the plate-cutting blades shown in Fig. 2-8 are quite short. Wide plates are cut on machines having longer cutting openings and longer knives. The method of operation is the same as with the smaller machines.

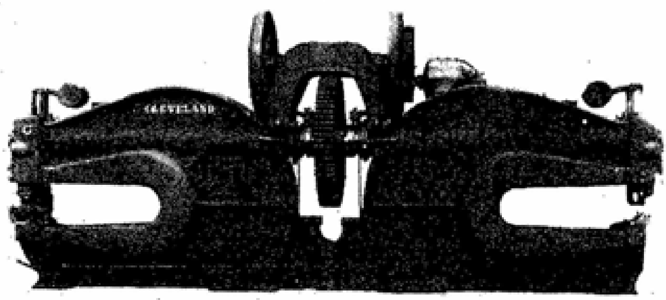


FIG. 2-10. Double-end machine. (*Cleveland Punch and Shear Works.*)

2-11. Double-end Machines. Figure 2-10 shows a double-end machine. The machine at the left is arranged with a shearing attachment, and the machine at the right is prepared for punching. Double-end machines have been found very practical in many fabricating shops.

2-12. The Friction Saw. The heavier sections, beams, channels, and columns can be cut with either the friction saw or the oxyacetylene torch. The friction saw is much like a large timber saw. The blades are made of material suitable for cutting steel. This saw cuts at high speeds and is used in the mills and fabricating plants.

2-13. Flame Cutting. Flame cutting may be used for any of the cutting operations, unless in rare cases it is prohibited by job specifications. Normally, it is not the responsibility of the estimator to decide the method of cutting to be used. However, in preparing certain costs it is necessary for the estimator to become familiar with the processes of flame cutting.

Three types of cutting are in general use: manual operation, semiautomatic, and fully automatic. In the manual operation the operator holds and directs the torch. With semiautomatic cutting the torch is

attached to a machine that operates on the pantograph principle. An electric-eye device is now available, and there are no limits to the variety of shapes and designs which can be cut.

Most torches in general are designed for use with a combination of oxygen and acetylene, but some use oxygen and propane, natural gas, or manufactured (city) gas. Shops may be supplied with bulk delivery

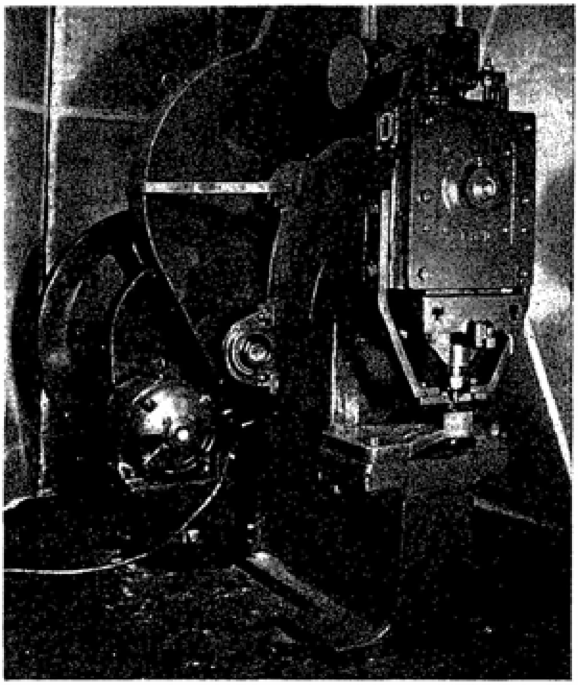


FIG. 2-11. Punch. (*Thomas Machine Manufacturing Co.*)

of oxygen to save the expense of moving the smaller cylinders around the plant. In this event the torches are connected to outlets provided throughout the plant.

2-14. Punching. The punching of holes accounts for much of the work in a structural-steel shop. Several different kinds of equipment are used for the punching of holes. These are the single punch, the multiple punch, the spacing table, the plate duplicator, and the angle duplicator.

The single punch is used where the number of holes or the pattern of holes will not permit multiple work. Much less power pressure is required for single punches, and consequently a smaller motor for driving the machine. Many small fabricators use this lighter equipment.

Figures 2-11 and 2-12 show single-punch machines. As can be seen, they give the complete machine and also a close-up view of the work

area. In the enlarged picture (Fig. 2-12) the parts clearly seen are the punch holder, the coupling nut, the punch, and the die block. By turning off the coupling nut the punch may be easily removed for replacement. The die is provided with a matching hole the size of the punch. After the punch cuts through the material, it enters the hole in the die to clear the punching. The two arms, one each side of the punch, are the strippers.

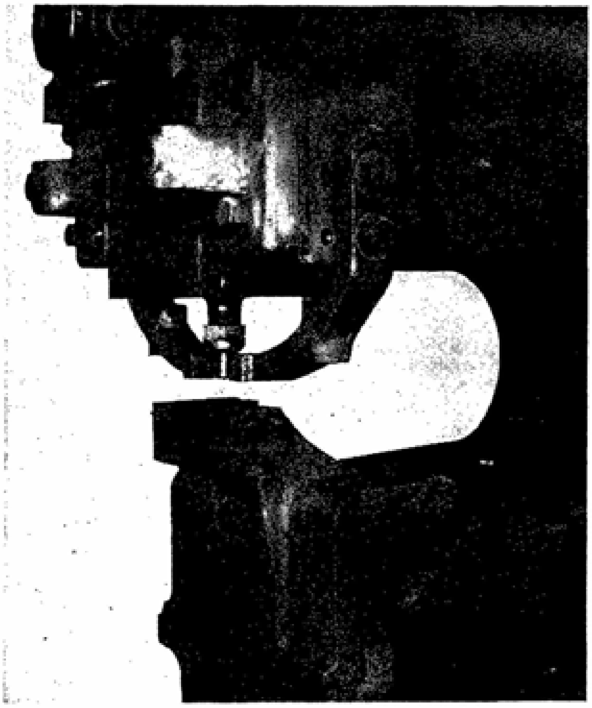


FIG. 2-12. Close-up of punch. (*Cleveland Punch and Shear Works.*)

These arms hold down the material as the punch is withdrawn preparatory to the next punching stroke.

A beam-type punch is shown in Fig. 2-13. Two sections of beams are seen in the picture, representing the material which is worked upon. The general construction of the punch clearly shows that many different arrangements of the punches can be made with the interchangeable parts.

2-15. Multiple Punching. Figure 2-14 shows a multiple punch for beams or channel sections. Two sample beam sections are seen in the picture. The section on the left can be punched with four flange holes simultaneously, and that on the right can have four web holes punched in one operation.

It should be obvious that multiple punching will save much time in

fabrication when the pattern of holes is such that this can be done. As already indicated these machines can be set up so that more than four web holes can be punched at the same time. Further flexibility is provided by gag levers located above the punches and connected to the long bars across the face of the machine. Operation of the handles to the right disengages punches not required for a given operation.

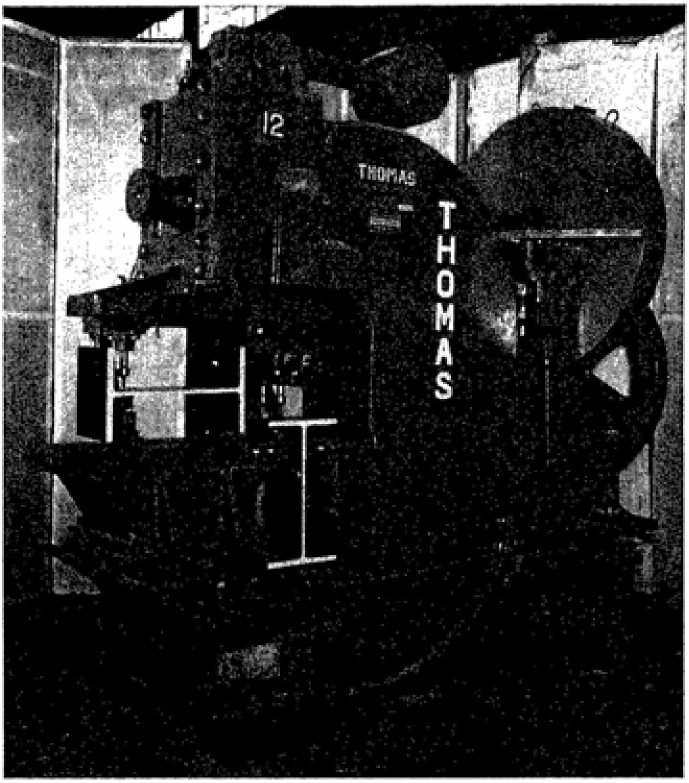


FIG. 2-13. Beam punch. (*Thomas Machine Manufacturing Co.*)

Figure 2-15 shows a multiple punch for punching plates or angles. The numbers and spacing of the punches will be as required for the work to be fabricated.

Though several of the pictures show gears and other moving parts exposed, in the interests of safety such parts are properly enclosed and protected when the machines are set up for shop operation. Safety is a major concern with all fabricators.

2-16. The Spacing Table. Automatic spacing tables (Figs. 2-16 and 2-17) are used for punching all classes of bridge and structural plates, etc. The spacing tables shown and described here are built by the

Thomas Machine Manufacturing Co., of Pittsburgh, Pa., and are covered by United States and foreign patents.

The punching operation is entirely automatic except for the actual working of the gag-controlled punches on the punching machine. However, the latter operation can also be controlled automatically when a large number of duplicate parts are fabricated.

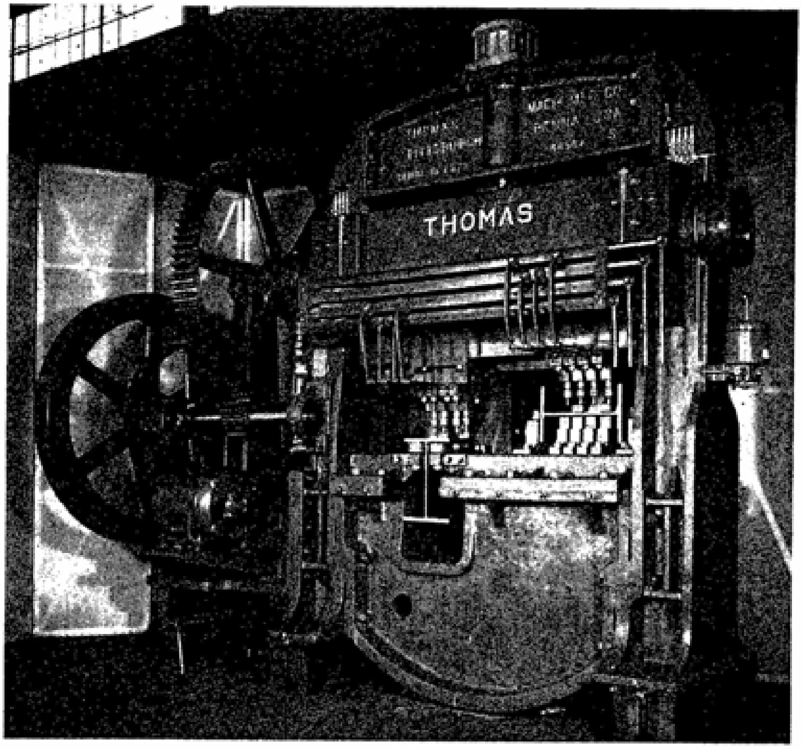


FIG. 2-14. Multiple punch. (*Thomas Machine Manufacturing Co.*)

The movement of the punch itself and the spacing carriage is synchronized, the carriage moving forward the instant the punches clear the material after stripping. The spacing movement of the carriage is controlled by means of a wood template which is fixed to the side of the table. The stopping mechanism is actuated by small steel pins in the template. The template lumber is ¾ in. thick and 2½ in. wide, and the template, of course, is prepared in the fabricator's template shop. A template is seen in Fig. 2-16, located at the side of the table. This shows up in a lighter color in the photograph. The carriage is also seen in this picture.

These machines, naturally, take up considerable shop space, as a table is provided on each side of the punches.

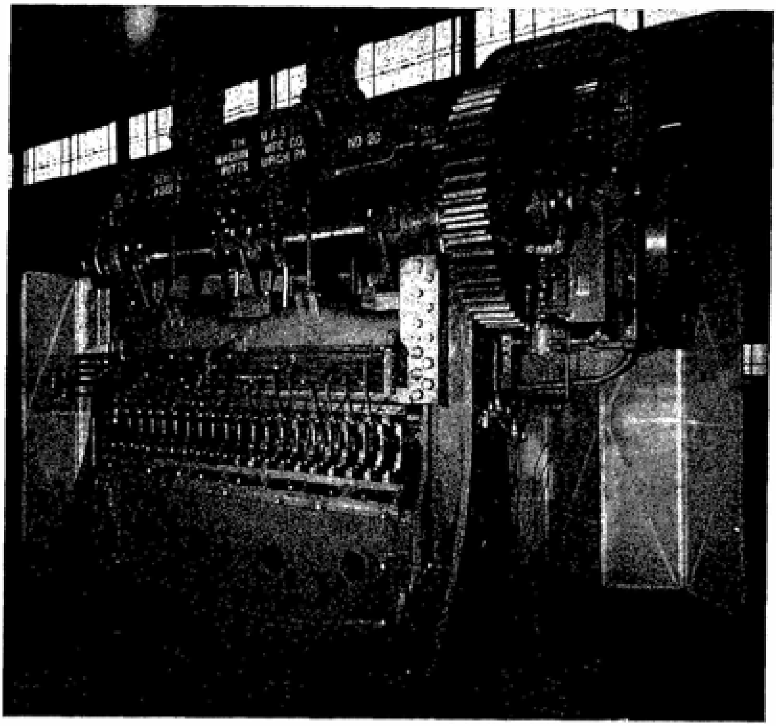


FIG. 2-15. Multiple punch. (*Thomas Machine Manufacturing Co.*)

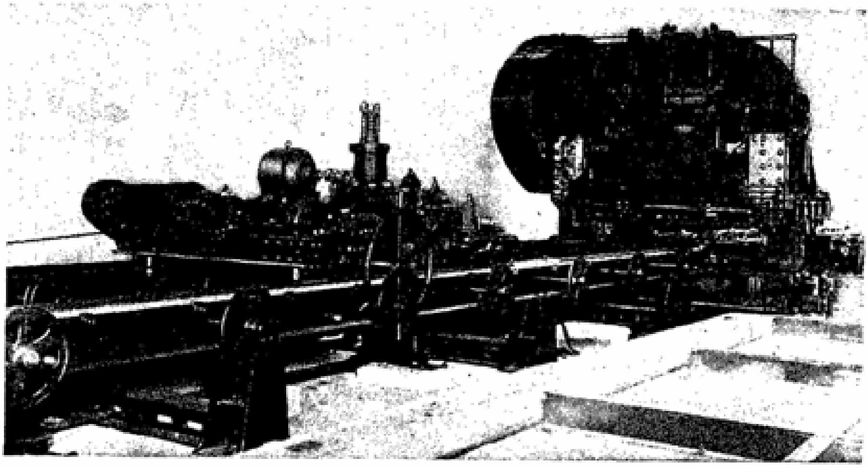


FIG. 2-16. Spacing table. (*Thomas Machine Manufacturing Co.*)

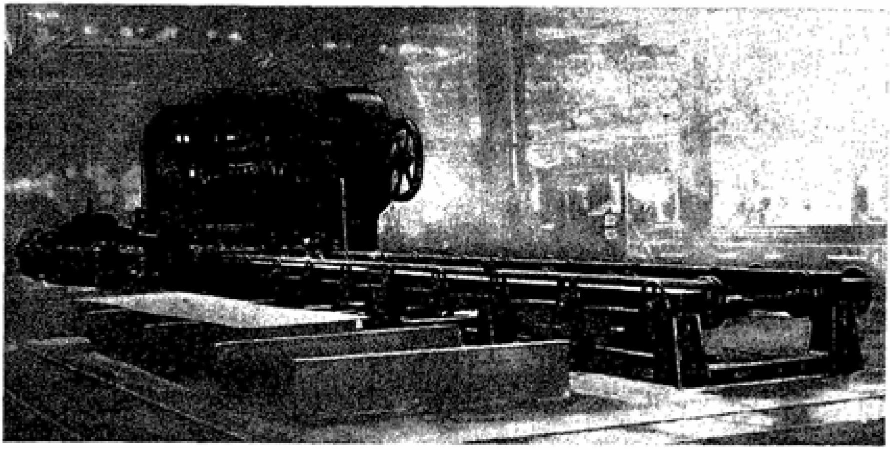


FIG. 2-17. Spacing table. (*Thomas Machine Manufacturing Co.*)

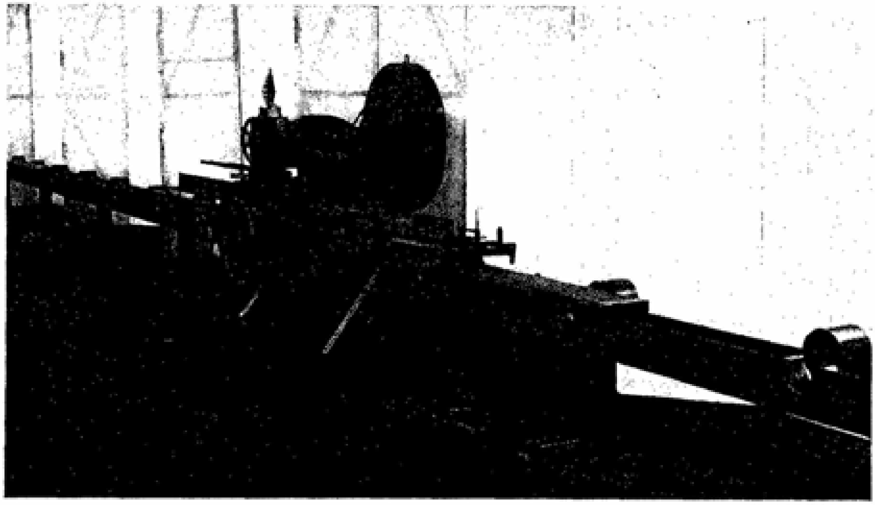


FIG. 2-18. Angle duplicator. (*Thomas Machine Manufacturing Co.*)

2-17. Duplicators. An angle duplicator is shown in Fig. 2-18. This is a simple machine consisting of a spacing mechanism used in connection with a vertical punch.

The plate duplicator (Fig. 2-19) is built for the rapid, accurate duplication of holes, slots, notches, and other operations on plates. The duplicator is designed for working from a template, which may be the first plate punched on the machine, or from a template made up in the template shop. The plate duplicator is primarily intended for irregular-shaped plates not suited for handling on the spacing table.

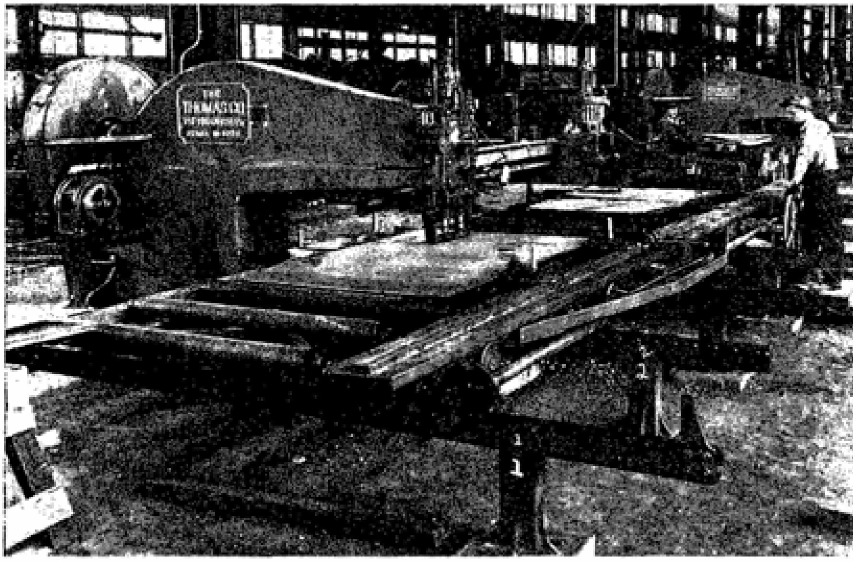


FIG. 2-19. Plate duplicator. (*Thomas Machine Manufacturing Co.*)

2-18. Drilling. Holes must be drilled when the thickness of the material is too great for the punches or in cases where the material is too wide to fit the punching equipment available in the fabricator's plant. A simple rule for the estimator to use in deciding whether punching or drilling is to be done is to select drilling in each case where the thickness of material is more than the diameter of the rivet. There may be a variation in this rule according to the methods of any given fabricator.

Both single-spindle drills and multiple drills are used. Drills are sometimes called "wall radial drills." They can be mounted on a building column or can be provided self-supporting.

All the heavier beam sections and all the heavier column sections require drilled holes. The heavy-gage angles required for girders must also be drilled. Therefore, a fabricator producing the heavier bridge and building work will use considerable drilling equipment. This applies, of course, to assemblies which will be riveted in their final form. Naturally, heavy drilling is avoided as much as possible on welded work. Although some holes are frequently required in welded work, it is usually planned to make use of material for the connections in sizes suitable for punching.

Certain specifications, including those prepared for railroad bridge work and highway bridge work, require subpunching and reaming. This means that material is to be punched with holes of smaller diameter than required in the finished work. After the punching is completed, a hand reamer is used to enlarge the punched hole to the final required size. These hand tools are either powered by air or electric-powered.

However, it should be noted that a hole which was drilled, not punched, in the beginning should not require reaming.

2-19. Riveting. After the various members have been punched or drilled, they are assembled in the final form. The sections may be temporarily held together by placing bolts through some of the matching holes, or, if practical, the sections may be fastened in place with tack welds.

The rivets are often heated by electric-resistance heaters, which are much easier to control and much cleaner than coal or oil forges. However, any of the three means may be used. After the rivets are properly heated, they are inserted in the holes which were designated to receive shop rivets. Rivets, when manufactured, of course, have a finished head on one end. A yoke, or bull, riveter is suspended over the work, and when the hot rivet is in place, the valve on the machine is opened and the second head is formed on the hot rivet. The bull riveter is built for much faster operation than that obtained by using the pneumatic hand gun or hammer. However, it is often necessary to use the hand gun in places which are inaccessible to the bull riveter.

It would be well at this point to explain the difference between the bull riveter and the pneumatic, or air, hammer. The air hammer, or riveting gun, is the same tool used in the field on the erection of structures. The compressed-air supply is brought into the gun barrel through two air ports, entering alternately as the piston travels back and forth. The piston strikes a die, or rivet set, which has been inserted in the outer end of the barrel. The end of the rivet set in contact with the rivet is concave and will form the second head on the rivet. The air pressure applied is 80 to 100 psi, and the successive blows caused by the striking of the piston, or "plunger" as it is called, upon the rivet set will form the head on the hot rivet.

The bull, or yoke, riveter is much too large and heavy to use outside of a shop, as it requires a gantry or other support with which it may be moved around, while the steel remains stationary on skids or other blocking. The bull riveter exerts a strong pressure of around 75 tons, and the hot rivet is headed and tightened in place with one stroke of the machine.

2-20. The Column-facing Machine. Figure 2-20 shows a rotary planer, or column-facing machine. These machines are necessary equipment in all large fabricating shops. The ends of column sections are not truly accurate when sheared or cut by the usual methods. Because columns and certain other structural members and assemblies must have true bearing against abutting surfaces, they must be milled. Column facing is the process of grinding off the ends of the section to obtain an absolutely smooth and flat surface. Column-facing machines have rotating

heads which are fitted with cutting blades and which hold the work in alignment while the facing is performed.

Heavy column bases or slabs and bearings for bridges must be faced or milled to provide smooth and true abutting surfaces. Bearings on bridges are placed under the opposite ends of girders, stringers, or trusses, and usually the bearings under one of these ends are beveled or rounded so as to permit a certain movement of the steel spans due to traffic or to temperature changes.

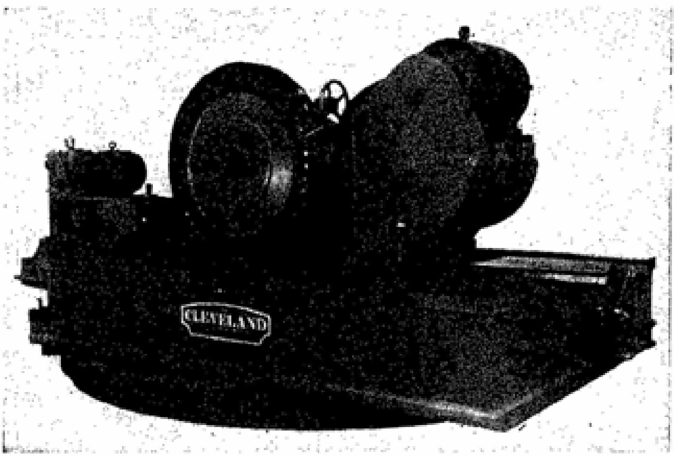


FIG. 2-20. Planer. (*Cleveland Punch and Shear Works.*)

2-21. Blacksmithing. Blacksmith-shop equipment and also bending and straightening machines are usually part of the fabricating-shop equipment. Some bending can be done without the use of heat. Other work must be heated in a furnace or forge before the bending or shaping can be accomplished. Heating can also be performed with the use of the acetylene torch. When used for heating steel, the torch is usually equipped with a heating tip which spreads the flame over a fairly large area without actually burning through the metal.

2-22. Welding. While the joining of structural assemblies by welding has been in use for many years, it may still be considered one of the more modern methods of fabrication. Welded structures are usually designed and engineered so that considerable saving of material is obtained. This, of course, provides a reduction in the final weight of the structure and in most cases results in a saving in the final cost of the structure.

Much of the welding in structural shops is done by operators who have been provided with very simple equipment, namely, the electrode holder, weld wire or weld rod, and protective helmet. Electrode holders

are insulated hand clamps into which the welding rods are inserted. The helmet is of very light weight but is provided with glass of very dark shade. There is considerable local spattering of material during the process of welding, and the helmet protects the face of the operator from this as well as from the flash of the arc. The operators also may wear certain articles of protective covering, such as chrome-leather gloves, aprons, and sometimes leggings.

Automatic welding is widely used in structural welding. The process has many advantages, not the least of which are saving in costs and improvement in quality.

With the use of the submerged-arc process there is no visible arc, which eliminates the necessity for the use of a head shield and which increases the operating factor for the job. The welding speed is two to ten times that of hand welding. Some of the machines for producing welding current are electric motor-generator sets, rectifier sets, engine-driven generator sets, and transformer-rectifier sets for producing both alternating and direct current.

The location of equipment and arrangement of lead and ground wires are matters to be determined in connection with the shop layout.

Plate-edging machines are designed for economical edging of plates which are to be welded. They are found in shops where the amount of this type of work makes the purchase of an edging machine an economical investment.

2-23. Painting and Cleaning. A very large proportion of fabricated steel receives a coat of paint before it leaves the plant. Steel which is to be embedded in cement may not be painted, but most of the rest is painted immediately after fabrication to provide protection from the elements.

The equipment may be spraying apparatus or hand brushes. Spraying is accomplished by the use of an air gun, which requires a compressor for the air supply and the necessary hose lines.

The architect's and engineer's specifications may require special treatment of the unpainted steel before the paint is applied. Some treatments are simple and require only the use of wire brushes and hand scrapers. The more elaborate treatments and, of course, more costly in equipment are sandblasting, shot blasting, and flame cleaning. Each of these methods requires special equipment and also protection around the work to prevent the sand, for instance, from getting into other sections of the shop and perhaps into the moving parts of other machinery.

Flame cleaning is done with the burning torch. This type of torch, with its head especially constructed for use in cleaning operations, has a wide, flat spread of flame and covers a fair amount of area in each sweep over the steel.

CHAPTER 3

Important Factors for the Estimate

3-1. Introduction. An estimate of any steel structure must take into consideration the following items, some of which will, for better clarification, be explained more fully in other chapters of this book.

3-2. The Weight of the Structure. One of the most important requirements is to obtain the total weight of the structure. It is important that the estimated weight should be very nearly that of the final shipped weight as determined by calculations made from the final detailed drawings or from truck or railroad-track scales. However, it is inevitable that there will be some differences between the original estimate and the final weight.

3-3. Details. The estimator may decide to use certain types of details, of sufficient strength and correct for the purpose. However, the draftsmen or engineers may prefer details of a different design though of equal strength to those chosen by the estimator. Where a number of these changes occur between the time of the estimate and the final shipping of the contract, there will naturally be some differences in the two total weight items.

Because the final drawings, supplied by the buyer or his engineer, are more complete than the estimating drawings, careful study by the draftsmen may permit some savings in material or fabrication. This is a normal gain in favor of the fabricator, and it is important that his engineers or chief draftsman examine all work for the possible economies to be obtained.

3-4. Weight for the Shop. The weight of a contract is very important in the setting up of shop schedules. The shop superintendent or management will know the average monthly output of the plant and will wish to project the figures in the proper place in order to make shipments as scheduled in the contract with the buyer of the structure. The estimator may be called upon, after the contract is signed, to supply breakdowns of several classifications of work to the shop superintendent. He may wish to know, for instance, the tonnage of girders or trusses in order to set up assignments for certain sections of the shop.

3-5. Weight for Freight or Trucking. The complete weight of the structure is required to obtain the railroad freight charges or the trucking charges. It is necessary for the estimator to consult with the freight traffic department of his company or with the railroad freight department or the trucking companies offices to find out about extra charges. Such charges may be incurred when the individual pieces or assemblies are very heavy, when more than one car is required to load a single piece, where lighterage is involved, and where railroad yard cranes may be called upon for the loading of trucks.

Several of these charges will be more fully described in Chap. 10, Fabrication Costs.

3-6. Erector's Weight. The erector will require the weight of the structure in order to prepare his erection estimate in the event that his estimate is done independently of the fabrication estimate. The erector must know the longest piece and the weight of the heaviest piece.

3-7. Weight for Purchasing. The purchaser for the company or the purchasing department of the fabricator may be interested in the weight of the structure in order to plan and negotiate contracts with the rolling mills for the raw material.

3-8. Unit Weights. The information on unit weights has been taken, by permission, from the American Institute of Steel Construction's Manual and from the section devoted to the AISC Code of Standard Practice.

If bids are requested or submitted at a price per pound of fabricated structural steel delivered or erected, rather than on a lump sum job basis, the actual weighing of materials is often impracticable and inaccurate. It is desirable to calculate such weights according to the formula commonly used by fabricators, erectors and owners. While this formula does not produce actual weights, it is customarily used by fabricators and erectors in bidding on a price per pound basis because it obviates the necessity of meticulous and involved calculations or additional shop work that entail substantial expense. Fabricators and erectors use this formula to calculate weights of fabricated structural steel for all purposes, unless the invitation to bid or the owner's plans or specifications require the use of scale weights or some other method of calculation.

The standard formula or method of calculating weights of fabricated structural steel is as follows:

(a) The weight of steel is assumed to be 0.2833 of a pound per cubic inch and the weight of cast iron is assumed to be 0.2604 of a pound per cubic inch.

(b) Weights of shapes, plates, bars, castings, rivets, bolts and weld metal are calculated on the basis of detailed shop drawings and shop bills of material showing actual dimensions of materials used as follows:

1. Weight is calculated on the basis of rectangular dimensions for all plates and ordered overall lengths for all structural shapes from which the required material is cut, without deductions for copes, clips, sheared edges, punchings, borings, milling or planing. When parts can be economically cut

in multiples from material of larger dimensions, the weight is calculated on the basis of the dimensions of the material from which the parts are cut.

2. To the nominal theoretical weight of all universal mill and sheared plates and slabs there is added one-half the allowance for variation or overweight in accordance with the applicable table in the A.S.T.M. specifications.

3. To the nominal theoretical weight of checkered plates there is added the allowance for overweight in accordance with the published weights of the manufacturer of such plates.

4. The calculated weights of castings are determined from the detail drawings of the pieces. An allowance for standard fillets for such pieces and an average over-run of 10% are added.

(c) The weight of shop rivets is calculated according to the following table:

Diameter of rivet	*Calculated weight per 100 rivets*
½ inch	20 pounds
⅝ "	30 "
¾ "	50 "
⅞ "	100 "
1 "	150 "
1⅛ "	250 "
1¼ "	325 "

The weights of field rivets, shop and field bolts, nuts and washers, are taken at their actual weights.

(d) The following percentages of the calculated weight of material so protected are added for painting or galvanizing:

For each shop coat of paint.......	½ of 1%
For each coat of oil..............	¼ of 1%
For galvanizing by hot dipping....	3½%

(e) The weight of shop welds and of field welds in work erected by the fabricator, is calculated on the basis of the gross weight of electrode required to lay the weld as follows:

1. For standard equal-leg fillet welds:

Specified weld size	*Gross weight of electrode (Pounds per foot of weld *)*	
(Inches)	*Continuous*	*Intermittent †*
⅛	.08	.09
3/16	.15	.17
¼	.25	.28
5/16	.36	.40
⅜	.50	.55
½	.83	.91
⅝	1.25	1.40
¾	1.75	1.95
⅞	2.35	2.60
1	3.00	3.30

* Net length as called for on the drawings, exclusive of starting and stopping ends.

† Weld length less than 32 times the specified size.

2. For unequal-leg fillet welds, the weight in the above table corresponding to the small leg is multiplied by the ratio of the longer leg to the smaller leg.

3. For all groove welds, the weight of electrode is calculated by adding 100% to the weight based upon the net theoretical weld cross section and length. The net theoretical volume of a square groove weld with zero root opening is calculated as if 1⁄32" open.

3-9. Material. The price of the rolled steel as purchased from the steel mills is compiled from the combination of the following cost components:

a. The base price of material
b. Mill extra charges
c. Transportation charges

The method of accumulating and applying these charges to obtain the total cost of rolled steel will be explained in full in Chap. 10, Fabrication Costs.

3-10. Introduction to Fabrication Costs. Fabricators have various methods of determining the costs to be used in estimating. One of the most accurate of these methods is to consider and indicate in the proper way the work to be done on each piece of steel.

Every item received from the mills has some labor expended upon it in varying degrees. A minimum might be required for an angle to be used as a single-angle lintel. Such an angle is likely to be part of a multiple-length angle as ordered from the mill. For instance, 10 lintels of the same size angle, each 5 ft long, might come from the mill in one length approximately 50 ft long. The actual length ordered can be extended slightly to compensate for the amount of material taken out by the cuts. Such a piece then requires labor expended in unloading, in marking out lengths, in shearing or flame cutting, in adding the piece marks and painting, in storing in the loading yard, in loading on cars and trucks, and in moving through the shops by cranes or other equipment.

The labor expended increases depending upon the complexity of fabrication required, reaching its maximum in the preparation of such assemblies as bridge trusses, heavy plate girders, conveyor work, hoppers, and welded assemblies. The methods of indicating the work to be done in the shop will be explained in a subsequent section.

3-11. Shop Equipment. When the estimator is required to complete the pricing of an estimate, he should have a thorough knowledge of all the machines and equipment which are in use in the fabricator's shop. The more information the estimator is furnished, the more accurate and complete his estimate should be.

In this connection the value of the loop course should be evident. In the event that an estimator has not had the loop course, he should be indoctrinated in shop methods and practices.

3-12. Assignment of Machines. When the estimator is able to determine, for instance, which machines to use in punching, namely, single punch, multiple punch, duplicator punch, and spacing table, he will embody this information in his cost figures. Also he will know when it is necessary to drill holes instead of passing the material through the punches.

3-13. Study of Cost Factors. A competent estimator or estimating department will have many of these data available for reference. It is not possible properly to recall all the information without adequate records.

3-14. Selection of Equipment. It is not usual for the estimator to have the final decision on the selection of equipment to be applied to a given piece of work, this being the choice of the shop management or superintendent. In fact some shops may operate on a machine loading plan, in which a production control division may decide or suggest the methods of operation. A machine loading plan is the assignment of a certain portion of work for a predetermined period of time to any particular piece of shop equipment. This planning of work is done by many modern fabricators in an effort to utilize each unit of shop equipment as near to its maximum as possible.

PLANS AND SPECIFICATIONS

3-15. Kinds of Plans. Plans are drawn in various ways. Each structural engineer has his own way of expressing himself in the preparation of his design and drawings. Upon receiving a set of design drawings, the estimator first checks to see that it is complete for the work to be quoted upon.

3-16. Plan Numbers. When a letter of transmittal accompanies the drawings, the drawing numbers noted in the letter must be carefully checked. Some work will have a title sheet on which the drawing numbers are indicated. Also, the specifications may contain a list of drawing numbers.

3-17. Variations in Plans. The drawings for steel construction in most cases indicate only the structural steel. These drawings are, of course, the simplest to use in delineating an estimate. However, there are many variations in plans. The estimator must be exceedingly careful to note all the structural steel for each specific job or quotation. Plans issued by Federal and state governments and by municipalities often follow a set pattern. For instance, the highway bridge structures of a given state may tend to have spans of approximately the same length.

3-18. Other Trades. In all cases where the work of other trades is shown on the same drawings as the structural steel, the estimator is cautioned to be very careful to locate and list all the structural steel. Some steel drawings have references to architectural drawings, and in such cases the

references must be investigated and proper record made of them. It will be noted from the above that all plans must be carefully examined and studied. The estimator should, in all cases, spend sufficient time in looking over the plans completely before beginning his estimate.

3-19. Miscellaneous Items. Many fabricating plants combine certain other classes of work with structural steel. A description of many of these items will be found in other chapters in this book under various headings. Briefly some of these items are bar joists, open-web joists, stairs, railings, gratings, metal siding, J&L joists, and concrete-filled columns.

3-20. Specifications. Specifications must be read carefully and noted, as they may list conditions which very materially affect the cost of the work. Specifications are prepared in many forms. Many states have standard specifications on bridges and buildings. School boards sometimes have standard specifications; also, other municipal divisions have standard specifications.

The AISC Manual contains standard specifications which are used and referred to by many structural engineers. Some large utility companies have standard specifications. In many cases, specifications are written for a specific job. In other cases, one of the drawings may include specifications under the heading of General Notes.

PREPARING THE ESTIMATE

3-21. The Note Sheet. After having examined the plans and carefully read the specifications or general notes from the drawings, the estimator now prepares a "note sheet," which will become part of the estimate. This note sheet contains any or all of the following information:

1. Complete list of all drawings which will be used in the estimate.

2. The latest date of each drawing. In the case of a revised drawing, this is the latest revision date and the number of the revision, if any.

3. The page numbers of the specifications which apply to the structural steel, and the date of specifications.

4. Material designation, that is, ASTM A7, A373, A141, and many other designations.

5. Paint. The kind of shop paint, if indicated, and the number of coats. The method of cleaning the steel for painting, which may be one of the following: by wire brush, flame cleaning, sand- or shotblasting, or any other method specified.

6. Inspection. Note the amount of money per ton, or per unit, which the specification indicates to be used. If inspection is required to be done by persons other than the fabricator's regular shopmen, this fact must be recorded on the note sheet,

7. Erection. Include the kind of field fastenings which are to be used, rivets, welding, high-strength bolts, or regular machine bolts.

8. Shop. Note whether the shop connections are to be riveted, welded, or bolted.

9. Bid. Usually the quotation is requested as a lump sum for all the work or as a pound price, which will be a price per pound, based on the actual shipping weight of the steel.

Note carefully the alternates which may be required as part of the bid and all addenda and addenda to the alternates.

Further notes are added to the note sheet as required to point out or to take exception to anything shown or called for on the plans, anything which may require clarification, or anything which is to be excluded from the bid.

3-22. Sequence. The estimating may be done in any convenient sequence. The following method has proved to be very practical for most tier and manufacturing types of buildings. In a later section, a suggested method for bridges and other structures will be taken up.

1. For tier buildings, bases and footing material, including grillage.

Table 3-1. Structural Shapes

Item	Symbol	Description	Sizes
1	WF	Wide-flange section	8″ to 36″
2	I	American standard	3″ to 24″
3	C	American standard	3″ to 15″
4	L	Angles, even legs	$1 \times 1 \times \frac{1}{8}$ to $8 \times 8 \times 1\frac{1}{8}$
5	L	Angles, uneven legs	$1\frac{3}{4} \times 1\frac{1}{4} \times \frac{1}{8}$ to $9 \times 4 \times 1$
6	BL	Light beams	12×22 to 12×16.5 10×19 to 10×15 8×15 8×13 6×16 6×12
7	BJ	Joists	12×14 10×11.5 8×10 6×8.5
8	J&L	Junior beams	6″ to 12″
9	J&LC	Junior channels	10″ and 12″
10	T	Tees	3″ to 18″
11	SC	Shipbuilding channels	3″ to 18″

2. Columns, including column bases, splices, and caps.
3. Beams.
4. Plate girders. Girders are listed on separate pages.
5. Trusses. Trusses are also listed on separate pages.

3-23. Symbols for the Structural Shapes. A number of symbols are in common use to indicate the kind of section required in the framing. Table 3-1 gives these symbols and also some remarks for clarification of the various sections. The symbols are used in the subsequent steps in the estimate.

THE STRUCTURAL-STEEL TAKE-OFF

3-24. Selection of Forms. Most fabricators have designed standard take-off forms which are to be used by their estimators. It is not practical to select one type of form for illustration; instead, a composite form will be described. There is very little difference in the way the take-off material is listed and classified, and an estimator on his initial employment with a fabricator should be able to "follow along" after having made the proper study of the material presented here.

3-25. Description of Take-off Forms. Figure 3-1 shows examples of take-off forms. All take-off forms should have these column headings:

a. Heading indicating the number of pieces in the item
b. Heading indicating the material
c. Heading indicating the weight per foot
d. Heading indicating the length of the section

The weight per linear foot is uniform for nearly all structural shapes except that:

The weight of railroad rails is per linear yard.

The weight used in connection with a few materials may be per square foot.

When material is listed on other than a linear-foot basis, note should be made, on the take-off opposite the listing, as per linear yard or per square foot.

Additional columns may be included at the right and possibly the left of the columns provided for the listing of the material. These additional columns are used for the placing of various information, including the total weights of the various sections.

Headings as required are shown on the take-off form. They may include the estimate number, the title of the work, the date, the sheet number, the number of the drawing being used in connection with the particular take-off sheet, and the estimator's name or initials.

Estimate No.	Name			By Sheet No.		Date
No.	**Description**	**Length**	**Weight, lb/ft**	**Total weight, lb**	**Unit price**	**Total price**

Name of Structure				Estimate No. Date		Sheet No. By	
No.	**Material**	**Length**	**Weight, lb/ft**	**Class**	**P**	**CF**	**F**

Fig. 3-1. Estimate forms.

CHAPTER 4

Estimating Beam and Column Framing

4-1. Foundation Plan. Figure 4-1 represents a plan of the steel required for a simple type of foundation. Figure 4-2 represents a schedule of columns and an enlarged detail of the base of a typical column. This column

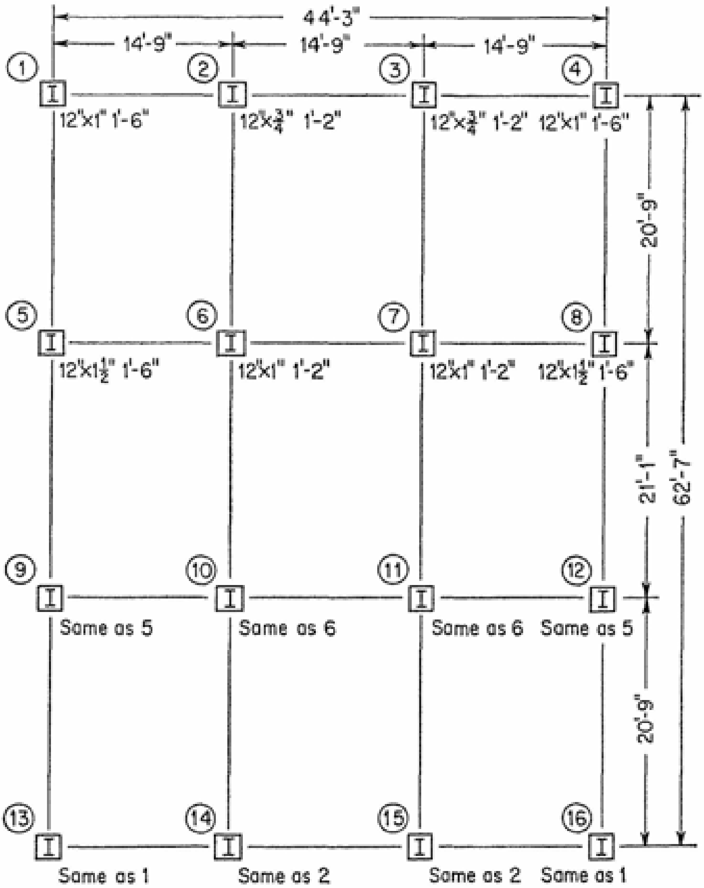


FIG. 4-1. Foundation plan.

schedule could apply in conjunction with the base material shown in Fig. 4-1.

4-2. Footing or Base Material. The take-off will now be made of the material shown on the foundation plan (Fig. 4-1).

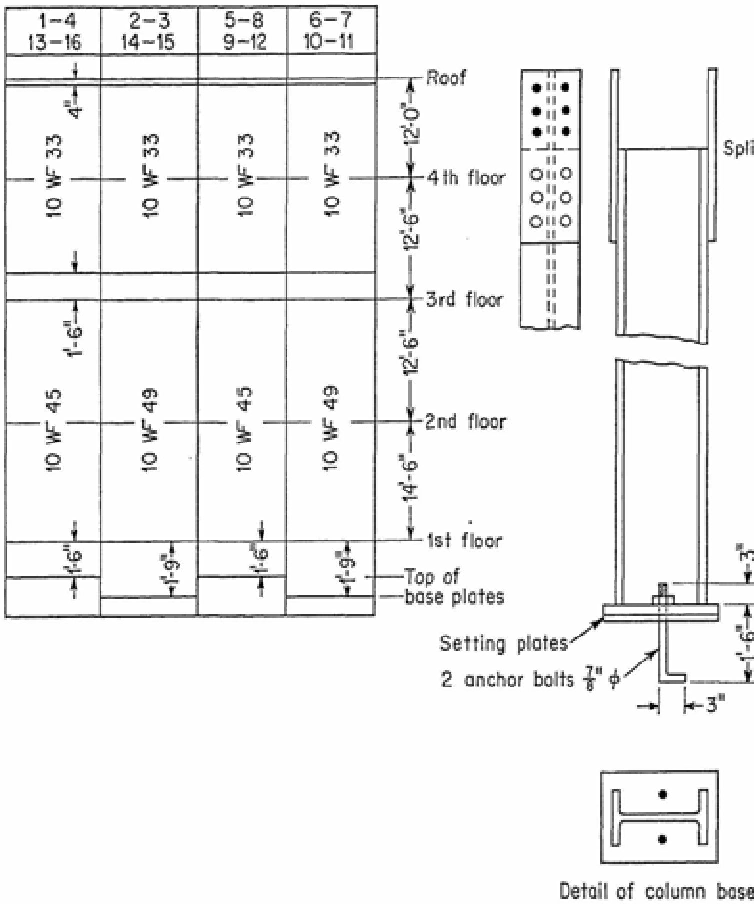


FIG. 4-2. Column schedule.

The numbers in the circles represent the number given to each of the 16 columns. These columns are indicated by the symbol I, which is placed in the square. The square itself represents the outline of the base plate, and the figures represent the dimension of the base plate. Refer to the three sets of figures at column 1. These are 12 in. × 1 in. × 1 ft 6 in. The figure 12 in. and the figure 1 ft 6 in., or 18 in., represent the measurements at each of the two sides of the base plate. The base plates are rectangular. Therefore only these two figures are necessary to indicate the dimensions at the perimeter.

The final figure not previously described is 1 in. and is the thickness of the plate. Where there is an indication on the drawing, "Same as . . . ," this should of course be self-explanatory.

4-3. Listing the Material. To list the material on the take-off form (Fig. 4-3), the required information is entered at the top of the form, including the drawing number, in this case Fig. 4-1. Then an identification of the type of work which is being estimated, which is Column Bases, is entered on the upper part of the page under the Material heading.

4-4. Reading the Plan. The normal reading of the plans will be from the upper left-hand corner. The first entry to be seen here is the base plate, having the size of 12 in. by 1 ft 6 in. long and 1 in. thick. The size will be listed in the material and length columns, but a check of the plan will be made before listing the number of pieces so that any reasonable combination of figures can be made. Columns 4, 13, and 16 also have the same size base plates. Therefore the number of pieces alike is four, and this is duly listed.

4-5. Calculating Weights. In many fabricators' estimating departments the take-off estimator is not required to compute the weight of the various items, or, as it is called, make the extensions. However, it is important that the process be described here.

A weight per foot is required of a plate 12 in. wide and 1 in. thick. There are many prepared tables showing the weights of rectangular plate sections in pounds per linear foot. One set of tables is contained in the AISC "Steel Construction Manual." Reference to this table indicates that the weight is 40.8 lb per lin ft, and this weight is placed in the weight column on the take-off form.

4-6. Basic Weight Units. It has previously been noted that the weight of 1 cu in. of steel is approximately 0.2833 lb. Starting with this figure, the following basic weight information may prove to be of use when the tables are not conveniently available or for sizes not specifically included in the tables.

One cubic inch of rolled steel weighs 0.2833 lb. One square inch 1 ft long weighs 3.4 lb. One square foot 1 in. thick weighs 40.8 lb.

4-7. Weight of a Base Plate. Apply the above figures to the 12×1-in. base plate which is being considered, instead of going to the table: A plate 12 in. wide, 1 ft (12 in.) long, and 1 in. thick will contain 144 cu in. Then 144×0.2833 equals 40.7952 lb, or, to one decimal place, equals 40.8 lb per ft. The value 40.8 lb per ft times the length of 1 ft 6 in. equals 61.2 lb total weight of one plate.

The complete weight of the plate may be found in one operation; thus, $12 \times 18 \times 1$ in. $\times$ 0.2833 lb equals 61.1928 lb, or, to one decimal, 61.2 lb. The number of pieces (four) may also be included in this operation to complete the entire calculation. The weight of 245 lb for the four plates

will be entered in one of the right-hand columns on the take-off, as can be seen.

4-8. Mechanical Calculators. Practically all calculations of estimate extensions are done with the aid of mechanical computers. Particularly with the use of machines having accumulative multiplication, the solving of the above problem is very simple, and the weights of flat plates may be obtained without reference to tables. This method is particularly helpful in the calculating of the weights of heavy slabs. (Note that "slab" is the designation of a very heavy and thick section of flat steel.)

4-9. Listing the Material (Continued). The proper entries for the balance of the material indicated on this foundation plan will be placed on the take-off form. A check count will be made from the plan, and the total of 16 pieces will be found to balance.

Depending upon how the pricing of the fabrication is accomplished the notation "16 base plates" may or may not be placed at the left of the sheet. In the case of this example the notation is included.

4-10. Specifications for Setting Bases in the Field. The AISC specification section relating to the setting of steel and cast-iron bases reads as follows:

> All steel grillage, rolled steel bearing plates, cast iron or steel bases, shall be set and wedged or shimmed by the steel erector to grade or level lines, which shall be determined and fixed by the Buyer, who shall grout all such parts in place. Before grouting the Buyer shall check the grades and levels of the parts to be grouted, and shall be responsible for the accuracy of the same. For steel columns or girders with bases fabricated as an integral part of the member the foundation shall be finished to exact grade and level, ready to receive the steel work so that shims or wedges shall not be required for plumbing or leveling of steel work.

4-11. Grouting. Grout is a thin mortar or cement which is placed between the steel and the concrete base or pier. Some job specifications may require the grouting to be done by the erector. Further, a special type of cement may be specified. Mention of such requirements must be made by the estimator in the erector's notes. Special quick-setting cement costs much more than ordinary cement.

4-12. Other Base Material. Figure 4-2 is a column schedule. It also includes a sketch at the base of the column, indicating setting plates and anchor bolts.

Much additional work may be necessary on the part of the concrete contractor in finishing the piers to an exact elevation in cases where the base plates are fabricated as an integral part of the column. Therefore, to overcome some of this cost for the work of the concrete contractor, the steel fabricator may be required or requested to supply setting plates.

These are plates usually having the same exterior dimensions as the base plates but ¼ or $\frac{5}{16}$ in. thick.

On this estimate the two items of ¼-in. plates are the setting plates. The notation "Setting plates" may, if desired, be placed at the left of the entry.

Shims. Some fabricators may furnish small plates 2½ or 3 in. square and of various thicknesses in place of or in addition to setting plates. These may be placed on the concrete pier, which may be an inch or two below finished grade. The shims will then fix the finished elevation of the setting plates or set the finished elevation of the base of the column.

The assumption will be made here that the concrete on this job is down 1¼ in. below finished grade. If ¼ in. is deducted for the setting plate, then 1 in. of shims will be required. Taking 4 shims to each base, the required number for 1 in. is $4 \times 16 \times 4$ equals 256, and this is duly entered.

4-13. Anchor Bolts. The anchor-bolt material is now included in the estimate take-off. This material is listed as noted. In this case the nuts are listed separately. When anchor bolts have heads and nuts, they may be listed as bolts or as rods with two nuts. Sometimes it is not practical to head a long rod, and it may be threaded at both ends instead.

A sketch indicating bent rods may be placed in the left-hand column.

4-14. The Column Schedule. Figure 4-2 is a drawing of a column schedule. Column schedules for multistory buildings usually are not drawn to scale. The required main dimensions are shown, but it may be necessary to refer to plans for certain other dimensions. Often the foundation plans must be consulted to locate the top or bottom elevation of the base plates.

4-15. The Splice Line. The nominal distance of the splice above the floor line will be assumed to be 1 ft 6 in. unless otherwise indicated. This distance is general designing practice.

It may be necessary to locate the tops of upper columns from the plans. Column schedules do not always show distances from the finished floors to the tops of columns which stop underneath beams in the structure, for example, columns which support offset beams or girders.

4-16. Columns Drawn to Scale. A column schedule is not always prepared for one- or two-story manufacturing buildings and similar types of structures. Instead, the columns are shown with other framing on the elevations and in these cases may be drawn to scale.

The column schedule (Fig. 4-2) has combined columns which are alike, and the figures at the top correspond with the numbers on the foundation plan. All dimensions are shown on this drawing. The application of the distances will be explained as the description of the take-off

work progresses. The drawing includes enlarged sections of the foot of the column and of the splices above the third floor.

4-17. Column Erecting. The take-off of the foundation-plan material includes setting plates. An advantage of setting plates here is that the first lengths of these columns are about 30 ft and, while the column will stand fairly secure on the flat level base usually provided, it will not be so easy to manage and hold upright on a less stable support. The setting of the column does not, of course, generally concern the estimator, but this item does give an idea of some of the work in the field.

4-18. Column Take-off. In making the take-off of columns (Fig. 4-3), there are several conditions which must be kept in mind. All columns, unless otherwise noted, are milled on both ends and finished to the exact lengths. One major exception to this rule is the column sections supporting the roof beams or roof framing. These will not be milled unless so indicated, for instance, if provision is to be made for the addition of future floors. Unless indicated to the contrary, all splices will be 1 ft 6 in. above the finished floors. Column schedules are not usually drawn to scale.

All columns will be taken off to the exact lengths as shown on the column schedule, plus some additional length to be added for milling. Columns for multistory buildings are usually two stories in height.

Proceeding with the take-off of the columns shown in Fig. 4-2, the heading on the take-off sheet will read Columns—Second and Third Floors. From the column schedule, it can be noted that the first length of columns will carry the second- and third-floor framing. Columns numbered 1, 4, 5, 8, 13, 14, 15, and 16 are all the same size and length and will be combined. The length of each is 1 ft 6 in. plus 14 ft 6 in. plus 12 ft 6 in. plus 1 ft 6 in.-30 ft, to which is added 1 in. for milling. The balance of the first-length columns is done in the same way. The second length of columns supports the fourth floor and roof, and now these will be listed. The length of this section is 24 ft 6 in. less 1 ft 6 in. and 4 in., as indicated on the plan. The length required is then 22 ft 8 in.—no extra length has been included for milling because enough has been added to the lower column to provide the necessary additional weight for this estimate. It will be noted that all these columns are alike and all have been combined.

4-19. Column Details. Enlarged details of the column are shown at the right of the column schedule. The base-plate, setting-plate, and anchor-bolt data have been included with the take-off of the foundation material. All 16 columns will be spliced above the third-floor level. A detail of a splice is shown in the drawing at the top of the enlarged column section.

Both upper and lower sections of the column are 10 WF. There will

Estimate No. Drawing No.				By Date		Sheet No.	
	No.	Material	Wt, lb	Length	Matl. cost	Weight of plates, lb	Weight of WF VI lb
COLUMN BASES	4	12 × 1	40.8	1′-6″		245	
	4	12 × ¾		1′-2″			
	4	12 × 1½		1′-6″			
	4	12 × 1		1′-2″			
16 base plates							
	8	12 × ¼		1′-6″			
	8	12 × ¼		1′-2″			
16 setting plates							
Shims	256	3 × ¼		0′-3″			
	32	⅞″ ϕ		2′-0″			
32 anchors	32	⅞″ nuts					
	COLUMNS—SECOND AND THIRD FLOORS						
	8	10 WF	43	30′-1″			10,830
16 columns M2E	8	10 WF	49	30′-4″			
	COLUMNS—FOURTH FLOOR AND ROOF						
16 columns M1E	16	10 WF	33	22′-8″			
		Splices					
	16	10 WF to 10 WF					
		Plates	46				
		Rivets	12				

Fig. 4-3. Take-off of columns and bases.

be 16 splices, and these will be listed as noted on the take-off form. The weights of the material for the splices, plates, and rivets have been obtained from a set of standard tables. Most fabricators prepare a set of these tables as drafting standards, and the estimator is usually provided with a set.

Two notations may be placed in the left-hand column of the take-off

opposite the listing for the column take-off. These are the total number of columns and the abbreviations or symbols M2E and M1E. M2E indicates that the column is milled on two ends, and M1E indicates milling at one end. If it is the practice of the fabricator to do so, these data may be included in the take-off for use in obtaining the fabricating costs. As has been pointed out several times, each fabricator has certain methods of assembling costs which may be peculiar to his own organization.

4-20. Classification of Extensions. The material listed on the first line of the column take-off has been extended for weight. This weight is placed in a column at the right of the take-off form under the heading WF VI. The symbol WF used here indicates, of course, that the steel section is a wide-flange shape and the Roman numeral VI is used to indicate the mill extra charges applicable to the WF shape of this particular size and weight. The other extensions have not been made.

4-21. Material Extra Charges. The rolling mills add extra charges to nearly all sections which they roll. Fabricators have various methods of including these charges with the material costs, and many estimating departments have prepared tables or listings for reference. No universal rule can be set down here, but the extra charges will be assessed by the mills and must be taken under proper consideration.

A complete discussion of mill extras is given in Chap. 10, Fabrication Costs, in connection with other pricing information. The size extra for the section here in question is about 8 per cent of the base price of material. However, this unit of percentages will vary as the base prices change or when the mill extra lists are revised.

4-22. Beam Connections. Before proceeding with the take-off of the floor framing as shown in Fig. 4-4, it will be well to study connections which will be used on this framing. Referring for this to the AISC Manual, Standard Beam Connections—B Series, it will be noted that the 12-in. wide-flange beams will use the connection marked B3. From examination of this connection, it is seen that there will be six rivets in the outstanding legs for field connecting. Observe that the notation of six rivets may be changed to six unfinished bolts if permitted by notes on the plans or by the specification or, of course, the same number of high-strength bolts, should they be required. The standard beam connections will be used for all connections required on this framing except the connections to the web of the column. A chart of web connections is also shown in the AISC Manual in the table headed Stiffened Beam Seats. Many other types of connections are used, to be described in a later section.

4-23. The Scale. Figure 4-4 is a plan of floor framing. The estimator will always note the scale as shown on drawings, but dimensions must be used in all cases where they are indicated. The tops of all beams in this drawing will be assumed to be the same distance below the finished

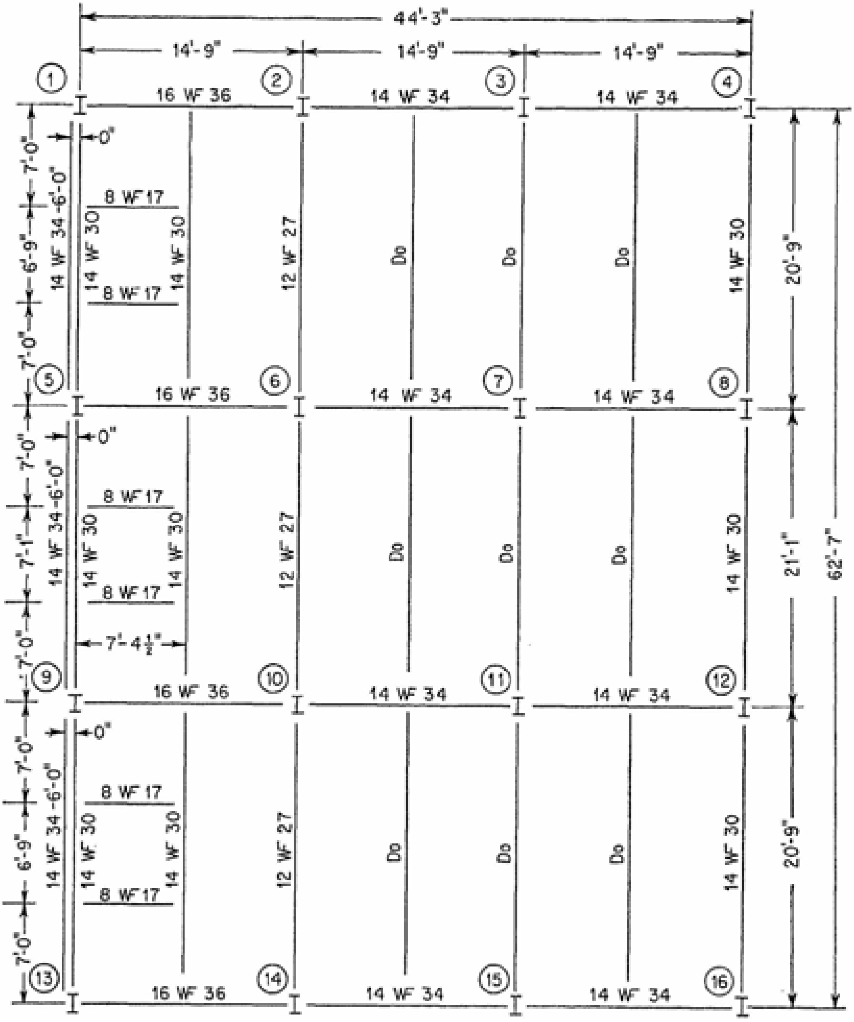


Fig. 4-4. Floor plan of second floor.

floor except in three cases, indicated minus 6 ft 0 in. Working from the upper left-hand corner of the plan, the listing of the steel will be shown on the take-off sheet (Fig. 4-5).

4-24. The Beam Take-off. First, a heading is entered on the take-off sheet, reading Second Floor. The first beams to be listed are four 16 WF 36 framing between columns. These are all similar and may be combined. The length of 14 ft 9 in. center to center of columns is reduced by 1 in. The figure of 1 in. is obtained by deducting one-half the web thickness of each column plus the allowance for mill tolerance; therefore, the length used in the estimate is 14 ft 8 in. This entry may now be made.

These four beams connect to the columns as indicated. Seated connections on the columns will be assumed and the beam will be assumed to require only punching in the shop. As previously stated, it is necessary for

Estimate No. By
Drawing No. Date Sheet No.

	No.	Material	Wt, lb/ft	Length	Matl. Cost	Class	
	SECOND FLOOR						
	4	16 WF	36	14′-8″		P	
	6	8 WF	17	7′-3″		CF	
	8	14 WF	34	14′-8″		P	
18							
	2	14 WF	34	19′-10″		P	
	4	14 WF	30	19′-10″		P	
	2	14 WF	30	20′-8″		CF	
	4	12 WF	27	19′-10″		P	
	4	12 WF	27	20′-8″		CF	
	1	14 WF	34	20′-2″		P	
	1	14 WF	30	20′-2″		P	
	1	14 WF	30	21′-0″		P	
	2	12 WF	27	20′-2″		P	
	2	12 WF	27	21′-0″		CF	
	1	14 WF	30	20′-2″		P	
24							
		Connections					
	12	8″	11.3				
	48	12″/14″	12.9				
	16	14″ seated	24.0				
	8	16″ seated	29.0				
	308	¾″ ϕ F.R.					
	120	¾″ ϕ F.B.					
		Shop rivets, 15%					
42 pieces total							

Fig. 4-5. Take-off of plan of second floor.

the estimator to follow the procedure set up by the fabricator by whom he is employed in giving the information on the take-off for reference in the pricing. However, for assistance in understanding the various operations a notation P for "punched" is made in the second column to the right of the length column on the take-off form.

Next list six pieces of 8 WF 17. The dimension indicated of 7 ft 4½ in. will reduce 1 in., and also the remaining fraction of ½ in. will be discarded. The estimated length of these beams is to be 7 ft 3 in., which is now entered. The usual method is to place connections at each end. Also, as these beams are flush top with the adjacent beams, it is necessary to cope, or block off, part of the top flanges of the 8-in. beams to provide clearance. The description may be shown on the take-off sheet as CF (cope and frame).

The eight pieces of 14 WF 34 connect to the columns as indicated. Deducting 1 in., the estimated lengths are 14 ft 8 in., and the listing of these eight sections is made. The situation here is the same as that for the first item, and the notation of P for punched is entered.

Before turning the plan 90°, or sideways, a count of all the pieces taken in this direction will be made. The count of 18 shown on the take-off is found to agree with the total of 18 seen on the plan. The number 18 may be entered at the left, both to verify the count and for use later.

The plan has now been turned. The 14 WF at the upper left and upper right are alike in size and length and will be combined. The references −6 ft 0 in. and the distance 0 in. show that the 14 WF 34 is 6 ft below the 14 WF 30 section, and the figure 0 in. indicates that one is directly over the other, the two center lines being at the center of the columns.

To obtain the length of the section, first consider the columns which were shown on the column schedule previously considered and which are 10 WF sections. These several 10-in. column sections average approximately 10 in. in depth. Exact dimensions may be found in the AISC Manual or steel-mill handbooks. Deducting a total of 10 in. from the center-to-center dimension plus 1 in. additional, the final figure is 19 ft 10 in. The listing of these beams will now be made, and as the connections will usually be placed on the columns the beams may be listed as P, or punched.

The 14 WF 30 sections between columns 13/9, 5/1, 16/12, and 8/4 are similar to the two 14 WF 34 sections which have been entered on the take-off and also have the same lengths, 19 ft 10 in. Entry is now made, also with the work symbol P for punched.

Next is a 14 WF 30 framing between two 16 WF sections. A similar beam is in the other 20-ft 9-in. bay at the left of the plan. Both beams will be combined, and the length entered will be 1 in. less than the center-to-center figure, or 20 ft 8 in. These beams may have framed connections attached at each end and will be coped to clear the 16-in. beams. The work entry may be CF, that is, coped and framed.

There will be four 12 WF 27 shown in the two bays which are connected to a column at each end. The estimated length of these four beams will be 19 ft 10 in. This is obtained by deducting half the depth of two

columns, which is 5 in. $\times$ 2 equals 10 in., and 1 in. for clearance, or 11 in. total, from the center-to-center distance of 20 ft 9 in. which was shown in each of the two bays. Connections for these four sections are assumed to be attached to the column, and the beams are described as P (punched).

The following items are four sections 12 WF 27 framing between the 14 WF beams. The lengths of all are 20 ft 9 in. less 1 in., or 20 ft 8 in., which is listed on the take-off sheet. These four beams will be described as CF, or coped and framed. The connections will be assumed to be attached in the shop.

The eight beams in the 21 ft 1 in. bay will now be estimated, starting with the 14 WF 34 at the −6-ft 0-in. elevation. The figure of 11 in. which was used for beams connected similarly in other bays is used for the several beams shown between columns in this bay.

The estimated length of the 14 WF 34 section and also the two 14 WF 30 sections and two of the 12 WF 27 sections will be 20 ft 2 in., and these several sections will be listed thus on the take-off form. These five beams will be described as punched beams, P.

Finally the two 12 WF 27 sections are seen to frame between two 14 WF beams. Deducting 1 in. from the dimension of the bay, these beams will be estimated at 21 ft 0 in. each. The work entry will again be CF (coped and framed).

The total number of pieces included in the take-off sheet is 24, and the count of beams shown on the plan is also 24.

At this point a listing has been made of all the so-called main material. The beams will be identified as main material and the connections and other fittings as detail material.

4-25. Estimating Beam Connections. The connections may be estimated as a percentage of the main material, but a much more accurate method is to list each connection as shown on the take-off form. Like connections are combined.

The six pieces of 8 WF 17 each has two connections. Therefore the quantity 12 has been entered. The connections at the webs of the columns are described as seated connections. These are found to be 8 for the 16-in. beams and 16 for the 14-in. beams. All remaining connections are listed as framed connections. There are 24 for the 12-in. sections and 24 for the 14-in. sections. These are combined, as the connections for either 12- or 14-in. sections will be alike.

The shop rivets required for the connections may be counted but the use of a percentage may also be accepted. The percentage figure will be fully explained in Chap. 6, Connections. A percentage of 15 is used at this time.

Based on the usual specifications, connections within 3 ft 0 in. of the column will be riveted. The intermediate connections may be bolted with regular machine bolts.

The quantity and weight of bolts and rivets will be required in connection with the total weight of the job. Also, the erector may wish to know the quantity of each in estimating his cost and planning his work.

4-26. Rivets and Bolts. A complete study of the number of rivets required for various connections will be given in Chap. 6, Connections. However, the quantities required here are shown in the following tables:

Rivets

Column	No. columns	Rivets, each column	Rivets, total
1, 8, 12, 13	4	18	72
5, 9	2	30	60
2, 3, 14, 15	4	16	64
6, 7, 10, 11	4	22	88
4, 16	2	12	24
Total..........	16	..	308

Bolts

Size of beams	No. beams	Bolts, each beam	Bolts, total
8 WF	6	8	48
14 WF	2	12	24
14 WF	1 (has common connection, bolts included with 2 beams on line above)		
12 WF	4	12	48
12 WF	2 (have common connections, bolts included with 4 beams on line above)		
Total.......	15	..	120

The presence of common connections, that is, connections opposite each other, may cause a slight confusion in reading the quantities of rivets or bolts. Common connections require bolts (or rivets) only for joining two adjacent connections, hence reducing the number of bolts (or rivets) from that needed for two independent connections.

4-27. Calculation of Beam Weights. The weights will be extended and classified in whatever form is determined by the individual fabricator. In this particular description the classification for material pricing is determined by the base price of material plus the extra charges applicable, and the proper column for listing like material is identified by a Roman numeral. This Roman numeral in turn appears on a classification chart which has been prepared for use by the estimators.

With the use of mechanical calculators it is of course necessary to apply the decimal part of a foot in place of the inches listed in the take-off. Many fabricators do not use the figures of feet and inches, but the estimator converts to the decimal directly at the time of listing the lengths.

As has been explained, the formula to be used to obtain the weight of a section is number of pieces times weight per linear foot times length equals total weight of the section. Note that in a few cases, previously described, weight per yard or square foot may be required to be used.

Weight of a Section

$$TW = n \times w \times l$$

where n = no. pieces
w = wt per lin ft
l = length, ft and in. or ft and decimal
TW = total wt section

SPANDREL SECTIONS

Figure 4-6 shows a small section of a floor plan of an elementary school and provides an opportunity to study further arrangements of floor beams. Spandrel sections are shown in Fig. 4-7. The location of these sections can be seen on the floor plan.

The spandrel sections are identified by the letters *CC* and *EE* cut along two lines of beams. These sections would occur at the outside walls of the structure. Assume all columns on this plan to be 12-in. sections.

4-28. Framing to Column Flanges. Beginning the take-off, as usual, from the upper left-hand section of the plan, it will be seen that the first beam, an 18 WF 50, frames to the outside flange of the columns. This connection will evidently be neither a standard framed nor standard seated connection. Instead, both the beam flanges may be cut back and

the beam web connected to the column flange. Also, some other arrangement for connection may be provided, depending on the final draftman's or engineer's decision. Therefore, when the details are prepared for the

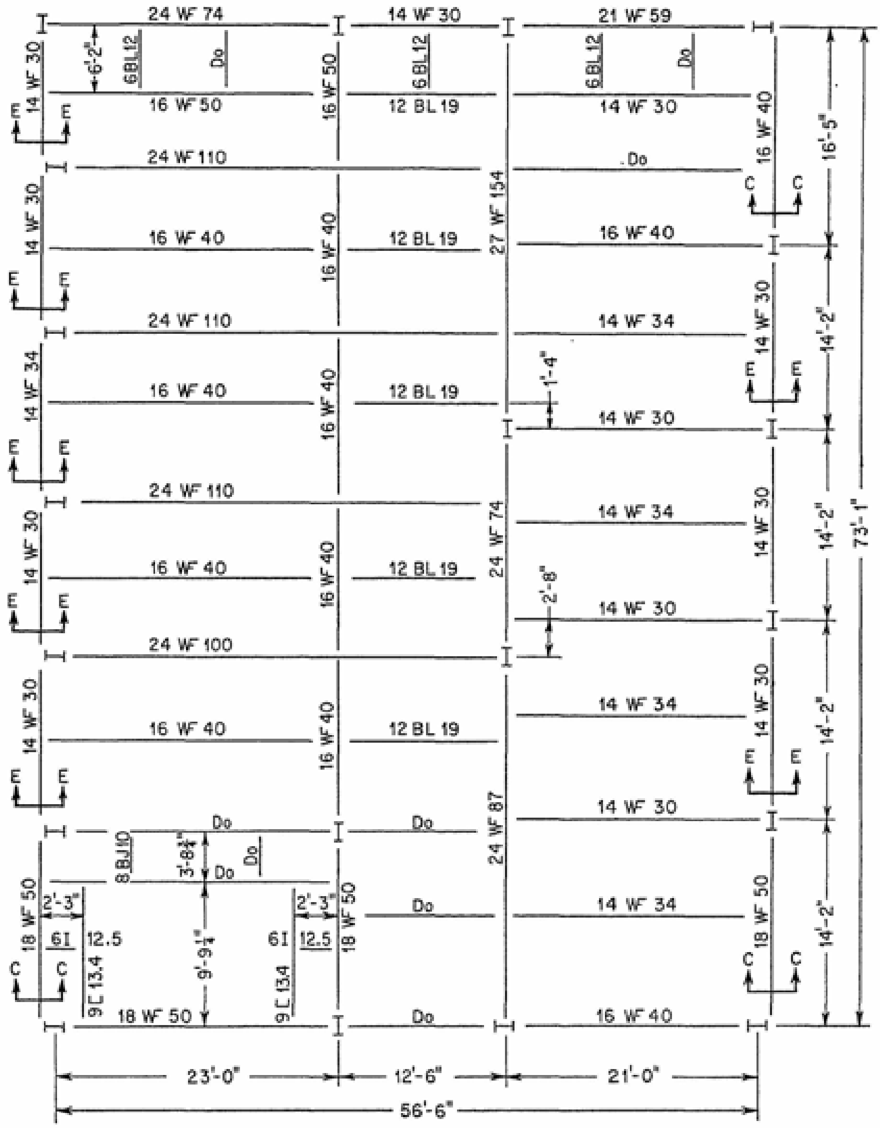


Fig. 4-6. Floor plan with spandrel framing.

shop, one of several arrangements may be followed. One detail might be the adding of seat angles or seat and top angles to the column flange. Another might be punching the web of the beam and connecting directly

with rivets to the column flange. This method may require the use of fillers, which are small plates employed to fill up the gap between the column flange and the web of the beam. A detail of this arrangement is shown in Fig. 4-8. For the purpose of the estimate the connections may be considered coped and framed (CF).

The next four sections, two 9-in. channels and two 8-in. BJ, will be listed to the lengths indicated, less 1 in. for the usual clearance. All four of

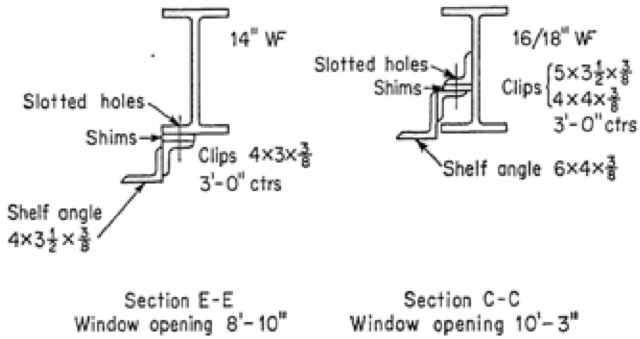


FIG. 4-7. Detail of spandrels.

these sections are coped and framed, or cut CF. After deducting the 1-in. figure, also drop the remaining fraction of the dimension.

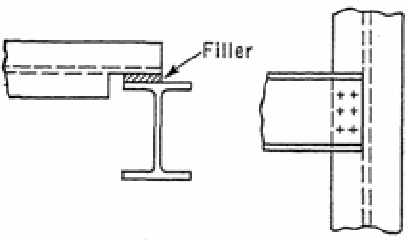


FIG. 4-8. Connection to face of column.

There should be no difficulty listing the balance of the sections. The proper deductions must be made before entering the item on the take-off form. As an illustration, consider the 24 WF 87. This beam frames to the web of one of the columns and to the flange of the column on the opposite end. Start with the two dimensions 13 ft 6 in. plus 12 ft 2 in., which equal 25 ft 8 in. Deduct 6 in., which is one-half the depth of the column at the right end of the beam, add 1 in., and deduct this total of 7 in. from the dimension of 25 ft 8 in. The remaining figure of 25 ft 1 in. is the estimated length of the section.

4-29. Spandrel Details. The listing of all the sections is shown on the take-off sheets (Fig. 4-9) except the spandrel material. Spandrel details are shown in Fig. 4-7.

In section *CC* the shelf angle supports the masonry or other finishing material above the window openings, and the clips, which are placed about 3 ft centers, connect the shelf angle to the floor beam. Note that the beams have been previously included with the other floor framing.

It may be preferred to include the spandrel material and the beams at one point in the take-off. Shims as noted are provided for vertical adjustment of the angles, and the slotted holes will permit horizontal adjustment.

Estimate No.
Drawing No. Sheet No.

	No.	Material	Wt. lb/ft	Length
	1	18	50	13′-5″
	2	9 C	13.4	9′-8″
	2	8 BJ	10	3′-7″
	1	18	50	12′-5″
	1	24	87	25′-1″
	1	18	50	13′-7″
	1	14	30	12′-1″
	1	16	40	11′-7″
	3	14	30	13′-1″
	1	14	30	11′-8″
	1	16	40	11′-8″
	1	24	74	15′-10″
	1	14	34	12′-9″
	1	16	40	12′-9″
	1	14	30	12′-1″
	1	16	40	12′-1″
	1	27	154	28′-3″
	1	14	30	10′-1″
	5	6 BL	12	6′-1″
	1	16	50	10′-1″
	1	16	40	15′-10″
29				
		Connections framed		
	14	6″	6.2	
	8	8/10″	11.3	
	40	12/14″	12.9	
	35	16/18″	17.4	
	1	21″	25.6	
	10	24″	30.9	
	2	27″	36.2	

Estimate No.
Drawing No. Sheet No.

	No.	Material	Wt. lb/ft	Length
	1	16	40	19′-11″
	4	14	34	21′-5″
	2	14	30	20′-11″
	1	14	30	20′-11″
	1	16	40	20′-11″
	2	14	30	21′-5″
	1	21	59	20′-5″
	1	12 BL	19	11′-11″
	7	12 BL	19	12′-5″
	1	14	30	12′-5″
	1	18	50	22′-5″
	1	6 I	12.5	2′-2″
	1	6 I	12.5	2′-5″
	5	16	40	23′-5″
	1	16	40	22′-5″
	1	24	100	34′-11″
	3	24	110	34′-11″
	1	24	74	21′-11″
	1	16	50	23′-5″
36 =	65 pieces total			
		Connections seated		
	12	12/14″	24.0	
	3	16/18″	29.0	
	1	21″	36.0	
	4	24″	45.0	
	434	¾″ ϕ F.R.		
	338	¾″ ϕ F.B.		

FIG. 4-9. Take-off of floor plan.

Section *EE* is a spandrel section in which the shelf angle is supported by the clip angles, which in turn connect to the bottom flange of the floor beam.

A listing of all the spandrel material is shown on the take-off form of Fig. 4-10.

The estimator must be very careful in reading the identification of sections. Some engineers will skip sections such as one section *EE* on the

Estimate No.			By			
Drawing No.			Date		Sheet No.	
	No.	Material	Wt, lb/ft	Length		
		SPANDRELS				
EE	8	4 × 3½ × ⅜		9′-6″		
	32	4 × 3 × ⅜		0′-6″		
	32	3 × ¼		0′-6″		
	128	¾″ ϕ S.B.				
CC	3	6 × 4 × ⅜		10′-11″		
	12	4 × 4 × ⅜		0′-6″		
	12	5 × 3½ × ⅜		0′-6″		
	12	3 × ¼		0′-6″		
	24	¾″ ϕ S.R.				
	48	¾″ ϕ S.B.				

Fig. 4-10. Take-off of spandrels and detail of shim.

lower line of beams in this plan. This section is not shown cutting one of the beams but obviously is intended to apply. There are many other methods used by engineers to indicate sections, and it is important to read and study all plans carefully to find all section identifications.

4-30. Shims. The size of shims is estimated at 3 in. × ¼ in. × 0 ft 6 in. Two shims are provided for each clip angle, and this will permit a correction of ½ in. in the elevation. A length of 6 in. will allow for two rivet or bolt holes. The draftsman may decide, or the erector may ask for shims of other than the ¼-in. thickness, but the figure used here of ¼ in. will provide for the normal number to be furnished.

Figure 4-10 has a sketch of the usual type of shim supplied for use in adjusting spandrels or hung lintels. These shims may be added or removed without removing the bolts and in this way provide a much safer method for adjustment.

4-31. The connections will now be added to the take-off, and the count will be made of the rivets and bolts for field connections. Here it will be assumed that the specifications indicate that connections within 3 ft of

columns will be riveted and all other connections are to be made with regular machine bolts.

4-32. Pound Price Estimates. An estimator may be required to produce a figure from an incomplete set of plans and on a pound price basis. This means that the owner or buyer will accept and pay for the total weight of the structure as determined after fabrication. The estimator may be required to approximate the tonnage for information of the erector, the shop, and possibly the buyer.

A take-off of a representative portion of the structure should be made. Then the weight of a square foot of this section should be calculated and applied to the whole area of the final structure. The weight of the beams, girders, and a one-story length of columns should be included for the selected area.

It may be preferred to obtain the weight of only the beam framing independent of the columns. Then select the average column, and multiply the weight of this column by the total number of columns. Both total weights will then be combined for the approximate weight of the structure.

CHAPTER 5

Irregular, Sloping, and Wall-bearing Framing—Trusses

5-1. Irregular Framing. Figure 5-1*a* shows an example of irregular floor framing. The several beams have been given numbers from 1 to 7.

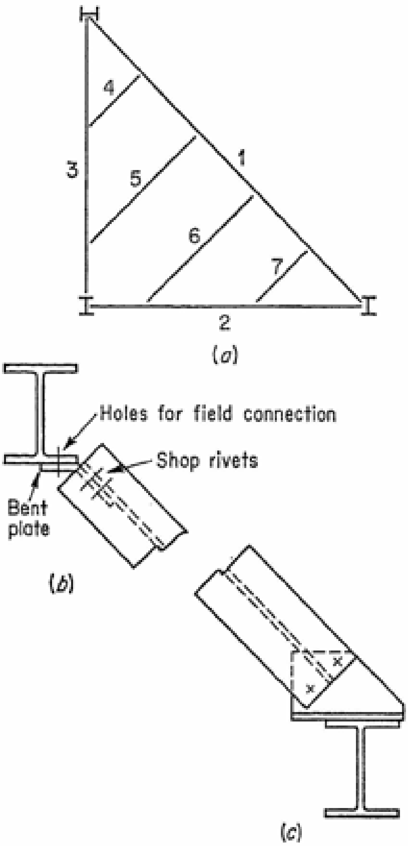


FIG. 5-1. Irregular framing.

Beam 1 frames to the flanges of the two columns, but in each case this connection is at an angle with the face of the column. The framing of the beam to the column may be accomplished by several methods. Figure 5-1*b* and *c* gives two methods which may be used. In Fig. 5-1*b* the connection is made with a bent plate. This plate is bent and attached to the beam in the shop. Holes for the field are provided in the column and in the plate as shown. The connection shown in Fig. 5-1*c* is an angle having sufficient width in the outstanding leg so that the connection can be made as indicated. Stiffener angles, if required, are placed under the seat angles.

In regard to the shopwork, the connection in Fig. 5-1*b* requires the bending of the plate, usually a blacksmithing operation. In Fig. 5-1*c* there is no blacksmith work, but the seat angle requires cutting as shown.

The connections provided for beams 2 and 3 may be standard right-angled connections framed and seated as required. Beams numbered 4, 5, 6, and 7, as shown in Fig. 5-1*a*, connect to beam 1 at a right angle,

and the usual standard connection can be provided. The connections to beams 2 and 3 are not the right-angled connections. It is necessary to use either angles bent to the proper bevel or a bent plate, particularly where the angle between the joining beams is large. Additional shop

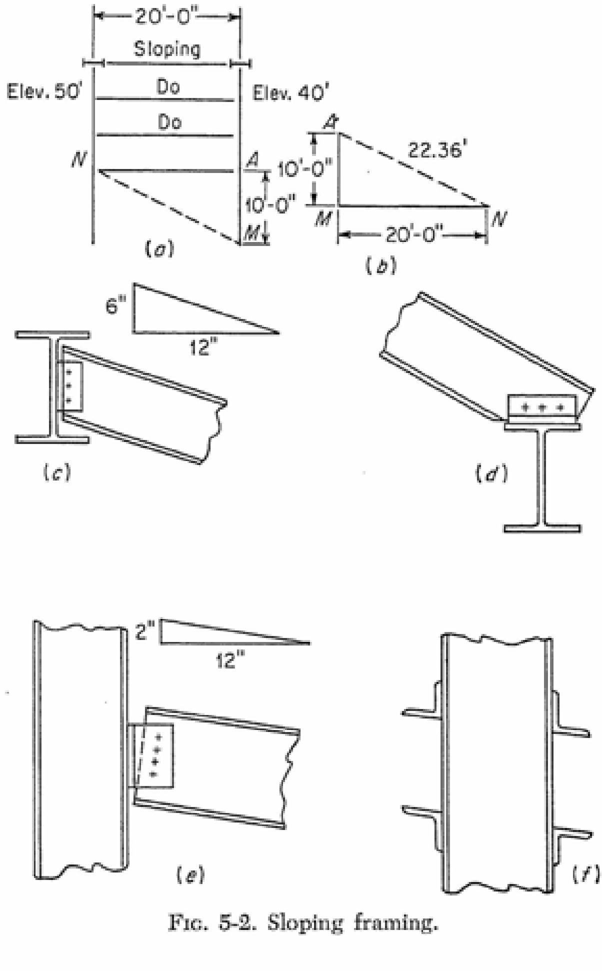


FIG. 5-2. Sloping framing.

labor must be considered in the cost of these bent connections in that heating will no doubt be required, in addition to the other shopwork on the connections.

In order to include sufficient extra material in the estimate, a good rule to follow is to increase the weight of the connection by one-half when the bevel or skew is 60° or more. In place of listing special connections a simple method is to take off 1½ regular standard connections at each point at which bent connections are required.

Where the plan or layout of a structure is similar to that seen in Fig. 5-1*a*, dimensions for beams 4 to 7 may not be included in the plan. The estimator will carefully scale the various lengths of all sections for which no dimensions have been included in the plans.

5-2. Sloping Beams. Figure 5-2 shows a section of plan indicating sloped framing. Unless otherwise noted, the dimension shown of 20 ft 0 in. is the horizontal distance between the two supporting beams or members. Therefore it will be necessary to obtain the lengths of the beams marked sloping.

The distance between elevation 50 ft and 40 ft is, of course, 10 ft. The required length can be obtained as indicated in Fig. 5-2*b*. This can be done by simple triangulation (the square root of the square of side a plus the square of side b equals side c).

The estimator may scale all distances directly on the plan as shown by the letters and dotted line in Fig. 5-2*b*. The method is this: Lay off point M from point A, which in this case is 10 ft 0 in. (elevation 50 ft to elevation 40 ft). Scale the distance MN, which will be approximately correct. It is not practical or required to read the scale down to as close as the distance obtained by triangulation.

A connection for a sloping beam is shown in Fig. 5-2*e*. This is a connection which may be used for connecting to a column. Where conditions are such that it can be used, it will prove to be the most economical, as no cutting or blocking out of the beam is required. The detail of Fig. 5-2*f* shows a condition where both the top and seat angles are bent to receive a beam which is on a slope. Figure 5-2*c* gives a type of beam-to-beam connection, and in this case it is required to block out a section of the beam which is on a slope. Figure 5-2*d* shows a method of connecting where the framing-in beam rests upon another beam. This method also requires the blocking out of the bottom flange and web of the sloping beam. Usually these four or five conditions will require no more than the standard quantity of detail material, but it is usual practice to indicate or classify sloping beams and other framing as such because, as can be seen, the shopwork will be increased under nearly all conditions.

Bent, Curving, and Mitered Sections. Figure 5-3*a* shows a circular section. Circular sections are seen most often in connection with rotating equipment or platforms, for instance, in unloading towers or swing bridges. The lengths of the material can be obtained from the usual formula, π times the diameter of the circle; or, as is frequently done, the circle may be segmented on the plan as shown by MNP, etc., in Fig. 5-3*a*. The short segments are measured with the proper scale and the distances accumulated until the end is reached. Then the total figure is entered on the take-off form. Note that the length of circular or curved sections can be obtained with automatic measuring scales. These scales have a small

wheel which is moved along the distance to be measured, and the length is read off from the dial on the scale.

During fabrication it may be necessary to divide the material in short sections in order to do the bending, depending, of course, on the equipment available in a particular shop. The circle may be assembled before shipping if the final diameter is not too large for railroad or road clearance. Otherwise connections must be provided for field assembly. Circular framing may have rails, castings, or other mechanical parts mounted upon it before shipping. The estimator will investigate these items, and when shop assembly and matching are required, an additional shop cost must be included.

Balcony or other framing may be curved or bent, possibly as shown in Fig. 5-3*b*. The lengths of the material are most easily found by segmenting short sections and adding the segments for the length of the piece.

Figure 5-3*c* and *d* may represent framing round an opening. The shopwork can be done by burning out the material which is not required after bending, and the necessary welding will be applied to make up the section as designed.

Many structures are designed to have framing like that shown in Fig. 5-3*e*. This may be canopy framing or framing required for other architectural features. The framing here is a beam with a V-shaped section cut out of the web, the lower flange being bent up and welded to the remaining section of web. A section similar to this may be created by welding three plates instead of cutting a beam. All-welded work requires additional welding, and it will also be necessary to cut a plate to make the web section.

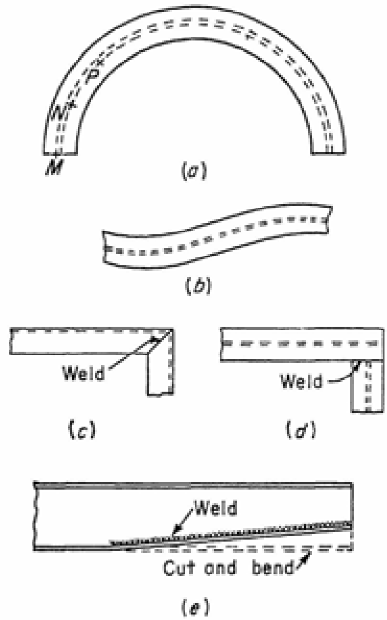


FIG. 5-3. Bent and curved framing.

5-3. Wall-bearing Beams. Beams which rest upon a steel plate which in turn rests upon the masonry are referred to as "wall-bearing beams" or "channels," depending, of course, on the section required in the framing of the structure.

Figure 5-4*a* and *d* shows partial plans which show wall-bearing framing. In the case of Fig. 5-4*a* this could represent a section of a structure which would have the exterior beams bearing on masonry, the balance of framing to be beam to beam and beam to column. Many structures are

designed with the masonry brought up from the cellar or basement level to the ground level. For one reason it may simplify the waterproofing of the section below ground to pour a wall right up to the ground or perhaps a little above.

Take-off of Wall-bearing Framing. An estimate take-off of the wall-bearing framing shown in Fig. 5-4*a* is given in Fig. 5-5. The lengths of

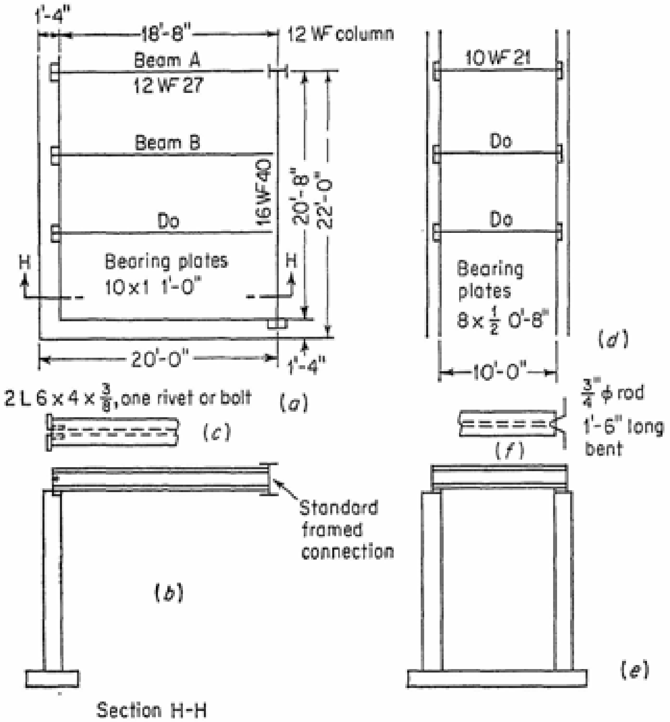


Fig. 5-4. Wall-bearing beams.

the various sections should be readily obtained from the dimensions given, and the shop operations should also be evident and are noted with the material take-off. The sizes of the bearing plates are listed as shown on the plans. The wall anchors are listed and will be further explained.

Figure 5-4*b* shows an elevation cut at section *HH* as indicated. Figure 5-4*c* is a plan view looking at the top of the beams in an enlarged detail. Here a wall anchor is indicated which is composed of two angles. Some arrangement for anchoring is provided at the ends of wall-bearing beams, in this case a pair of angles which may be about 3 in. long and which are secured to the beam web with a single rivet or bolt. When the depth of the beam is considerable, two angles near the top flange and two near the bottom flange may be required. When angle anchors

such as have been described are required, it is general practice for the engineers to include a sketch in the estimating plans or a note in the specifications.

Framing over passageways is often provided, as shown in Fig. 5-4*d*.

No.	Material	Wt, lb/ft	Length	Fabrication details	Total weight, lb
	Take-off of plan, Fig. 5-4*a*				
1	12 WF	27	18′-11″	Framed	
2	12 WF	27	19′-5″	Framed	
1	16 WF	40	21′-5″	Framed	
	Connections				
3	12″ framed				
1	16″ seated				
18	Field bolts				
4	10 × 1 bearing plates		1′-0″		
	Anchors				
6	6 × 4 × ⅜		0′-3″		
6	Shop rivets				
	Take-off of plan, Fig. 5-4*d*				
3	10 WF	21	11′-4″	Punched	
6	8 × ½ bearing plates		0′-8″		
6	Govt. anchors	3 lb ea.			

Fig. 5-5. Take-off of wall-bearing framing.

This may be simple framing as indicated. The length of beams shown here is 10 ft 0 in. plus (2 × 8″) equals 11 ft 4 in. No deduction is made from the lengths of these beams.

Figure 5-4*e* is an elevation of the plan. Figure 5-4*d* and *f* shows an enlarged section looking at the top of a beam. A bent rod is indicated as an anchor. This type of rod has been designated as a "government anchor" for many years. It is merely a piece of ¾-in. rod bent as seen

and passed through holes in the ends of the beams at the bearing ends.

Included in the take-off (Fig. 5-5) is a complete listing of all bearing plates and all anchors as shown or required. In the event that neither bearing plates nor anchors are shown or specified, it is customary to include both bearing plates and anchors unless otherwise instructed by the employing fabricator.

The weights of bearing plates range from about 12 lb for beams 10 in. deep to about 150 lb for 36 in. beams. The weight of angle anchors is about 6 lb per pair and of government anchors about 3 lb each. If the dimension indicating the width of bearing is not shown, it should be about the depth of the beam up to 12 in. and not less than 12 in. for all sizes of section 12 in. or over, provided, of course, that the width of wall is sufficient. When beams in the structure are 18 in. or larger and no dimension is shown for bearings, the estimator should try to obtain the figures from the engineer or buyer of the structure.

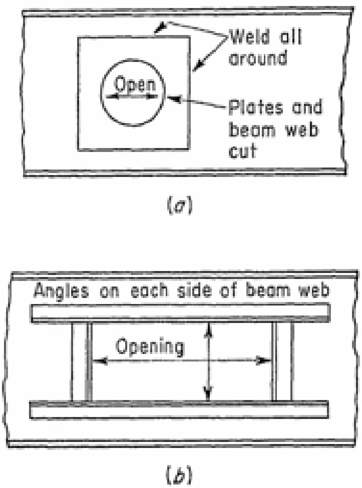


FIG. 5-6. Framing around openings.

5-4. Framing around Openings. In many structures that are now air-conditioned, the installation of large ducts may be required. It is usual practice to run these through the webs of beams instead of having them suspended below the ceiling line in the case, of course, of flat ceilings.

In the event that the sections are to be cut from the beam webs, considerable reinforcement will be necessary. The engineers may include details on the plans which will show the quantity of reinforcing material required and the sizes of this material. However, it is the responsibility of the estimator to include material in the estimate whether or not the engineer has detailed it.

Many fabricators have established a rule to require reinforcing of all cuts above a certain size or diameter. Figure 5-6*a* and *b* shows two methods of reinforcing the web of a beam. Figure 5-6*a* makes use of a plate on each side of the opening. A simple way to fasten these plates is by welding. They may also be riveted if desired. Figure 5-6*b* is a very usual way of reinforcing around air-conditioning ducts. Angles will be placed all round the opening and on both sides. They may be secured by rivets or by welding.

It is unusual to cut a flange of a beam or channel, but in cases where it

has been done, it is again necessary to replace material of equivalent strength to that which has been removed. This point of providing reinforcements where required cannot be too forcibly stressed, as it can become a costly item in the event it is overlooked and then found to be required after the contract is signed and the price set.

In many cases the estimating plans may not be too clearly marked or the openings indicated. When it is possible that openings are required but the information is not complete, the estimator must make the necessary exception in the bid notes.

5-5. Introduction to Trusses. A truss may have a total weight of less than a ton and a comparatively short span. Trusses supporting the roof of a structure may have spans of 30 or 40 to 200 ft and over. The larger trusses, including those of bridges, are very heavy. Either riveting or welding may be used to connect the components. There is usually a very considerable saving in the quantity of material in a welded truss as compared with a truss in which the members are fastened with rivets or high-strength bolts. This factor will be more evident when examples of each type of truss are described in detail.

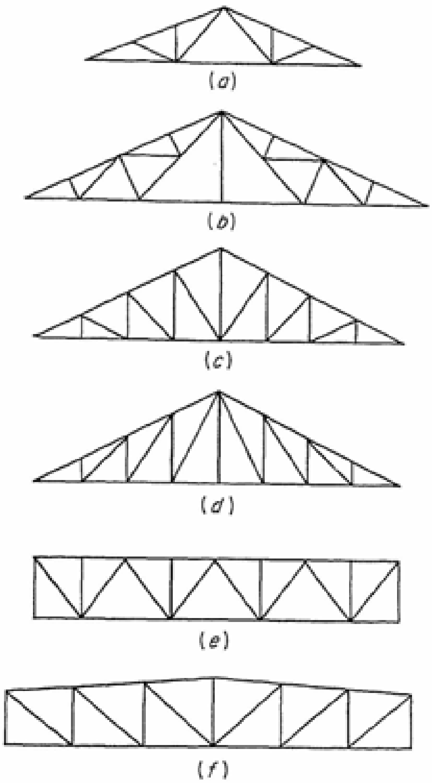
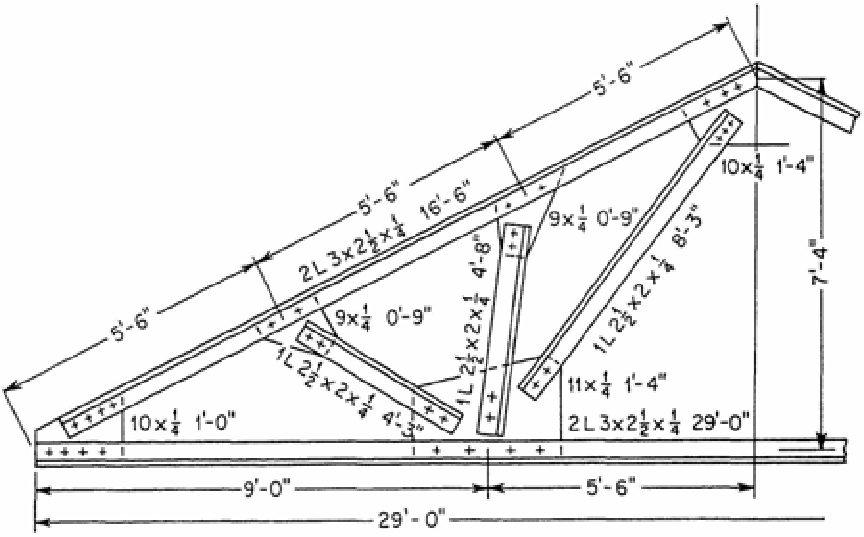


FIG. 5-7. Types of trusses.

Outlines of several types of trusses are shown in Fig. 5-7. Other types of trusses or open-web arches are also used for long, clear spans as required for hangars, aircraft plants, gymnasiums, field houses, convention halls, and similar structures. Arches may have solid webs in place of the open webs.

A simple lightweight truss is detailed in Fig. 5-8. It will be noted that a span of 29 ft is indicated. Complete detail of all sizes has been shown. The plates provided to connect the angles at the panel points are called "gusset plates." The spacing of the rivets has not been included in this detail as this does not particularly concern the estimator except in cases where he is interested in obtaining the exact sizes of the gusset plates.

A complete estimate take-off of the truss has also been made and is



No.	Material	Wt, lb/ft	Length	Main material, lb	Detail, lb	Rivets, lb	
4	3 × 2½ × ¼	4.5	16′-6″	297			
2	3 × 2½ × ¼	4.5	29′-0″	261			
2	2½ × 2 × ¼	3.62	4′-3″	31			
2	2½ × 2 × ¼	3.62	4′-8″	34			
2	2½ × 2 × ¼	3.62	8′-3″	60			
	Details						
2	10 × ¼	8.5	1′-0″		17		
2	11 × ¼	9.4	1′-4″		25		
4	9 × ¼	7.7	0′-9″		23		
1	10 × ¼	8.5	1′-4″		11		
8	4 × 3 × 5/16	7.2	0′-7″		33		
78	¾″ Rivets, lb ea.	.5				39	
	Main material		683 lb				
	Details		109 lb	16% of main material			
	Rivets		39 lb	6% of main material			
			831 lb				

Fig. 5-8. Take-off of truss.

included with the detail of the truss. The lengths of all the main material may be obtained by the scale. The sizes of the details have been shown in the drawing, and the number of rivets may also be counted from the details.

The estimate plans which include trusses may show the complete or nearly complete details. On the other hand, the trusses may be shown only by an outline of the main members.

Some estimating departments have tabular material to show the percentage of weight of details to the weight of the main members. Other fabricators prefer other methods of establishing the weight of a truss.

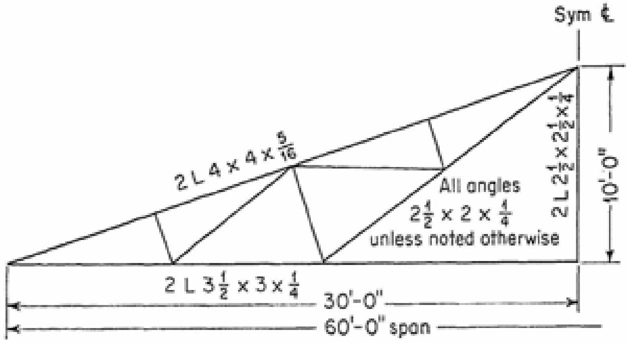
An extension of the weights of all the material in the example of Fig. 5-8 has been included in the take-off. It will be noted that the percentage of details equals 16 per cent of the main material and the percentage of rivets is 6 per cent.

There is a considerable difference in the percentage for gusset plates in various truss designs, but it will be found that the percentage of rivets remains at 4 to 6 per cent, and many estimators use a figure of 5 per cent on practically all estimates of riveted trusses. There is no reason for not using an actual count of rivets when this can be obtained. In fact, when an estimator has had either designing or drafting experience, he may lay out or calculate the number of rivets in each point in cases where the truss is not detailed on the estimate plans. To calculate the number of rivets at a point, it is necessary, of course, to have the several stress figures given on the estimate plans from which the number of rivets may be calculated.

Figure 5-9 is a sketch of a truss in which only the outline of the members has been shown. Below the sketch is a take-off of the material which has been shown on the drawing. A figure of 15 to 20 per cent of the weight of the main material may be assumed for the weight of detail material and 5 per cent for the weight of the rivets. However, to show what the actual weights are, a complete take-off of a complete detail of this truss is shown in the right half of the take-off. It will be seen that actually the weight of detail material is 12½ per cent of the weight of the main material and the weight of rivets 4¼ per cent. The figure of 12½ per cent will not obtain for all trusses of similar design, but these comparisons are given to indicate the value of a complete take-off of all material whenever it is possible.

To obtain a check on a take-off of a truss, count the number of individual sections comprising the main members, and check this result against the total of these pieces as listed on the take-off form. If these two totals agree, a correct take-off has been obtained. Certain designing engineers prefer to identify the several members of a truss as shown in

Fig. 5-10*a*. The truss in the example will be assumed to be symmetrical about the center line. The symbols at the left of the center line identify the individual members, and the numbers in the right-hand section of



	No.	Material	Wt, lb/ft	Length	Total wt, lb
	2	3½ × 3 × ¼	5.4	60'-0"	648
	4	4 × 4 × 5/16	8.2	31'-6"	1,033
	4	2½ × 2 × ¼	3.62	2'-8"	49
	2	2½ × 2 × ¼	3.62	5'-4"	39
	2	2½ × 2½ × ¼	4.1	10'-0"	82
	8	2½ × 2 × ¼	3.62	8'-6"	246
	4	2½ × 2 × ¼	3.62	16'-9"	242
26					2,330
		Details 20%			466
		Rivets 5%			117
		Total for truss			2,913

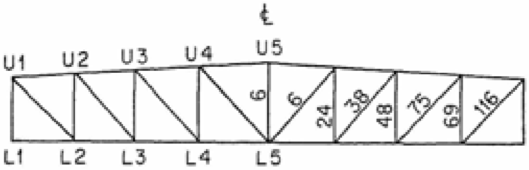
No.	Material	Wt, lb/ft	Length	Total wt, lb
2	3½ × 3 × ¼	5.4	58'-9"	635
4	4 × 4 × 5/16	8.2	30'-9"	1,009
4	2½ × 2 × ¼	3.62	2'-3"	33
2	2½ × 2 × ¼	3.62	4'-11"	36
2	2½ × 2½ × ¼	4.1	9'-8"	79
8	2½ × 2 × ¼	3.62	7'-1"	206
4	2½ × 2 × ¼	3.62	15'-7"	226
				2,224
	Details			
2	16 × 5/16	17.0	1'-4"	45
4	5½ × 5/16	5.8	0'-8"	16
2	8¼ × 5/16	8.8	2'-6"	44
1	12 × 5/16	12.8	2'-5"	31
2	9¾ × 5/16	10.4	1'-0"	21
2	9½ × 5/16	10.1	1'-3"	25
2	8¼ × 5/16	8.8	0'-11"	16
1	5½ × 5/16	5.8	0'-8"	4
				202
10	6 × 3½ × ⅜	11.7	0'-8"	78
				280
170	¾" rivets, lb ea.	.5		85
38	Washers, lb ea.	.2		8
		Total weight of truss		2,597

FIG. 5-9. Comparative take-off of truss.

the truss layout indicate the stress in the members. Owing to the truss being symmetrical, the symbols and the numbers apply to either half of the truss.

The tabulation (Fig. 5-10) indicates the material composing the members of the truss. For instance, the top chord is identified by U1, U5, and the section as tabulated is two L $8 \times 6 \times 7/16$. It is relatively easy to continue with a listing of the section as listed in the table.

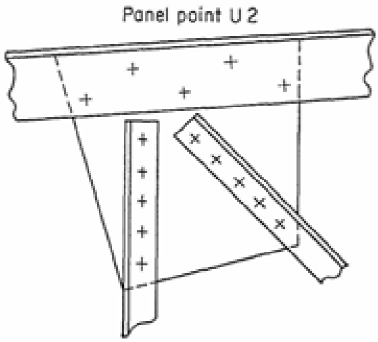
No size for the material in member U1-L1 has been given. This would



(a)

Member	Section
U1-U5	2 L 8x6x$\frac{7}{16}$
L1-L5	2 L 6x6x$\frac{1}{2}$
U1-L2	2 L 5x3$\frac{1}{2}$x$\frac{7}{16}$
U2-L2	2 L 4x3x$\frac{3}{8}$
U2-L3	2 L 4x3$\frac{1}{2}$x$\frac{5}{16}$
U3-L3	2 L 3$\frac{1}{2}$x3x$\frac{1}{4}$
U3-L4	2 L 3x2$\frac{1}{2}$x$\frac{1}{4}$
U4-L4	2 L 3x2x$\frac{1}{4}$
U4-L5	2 L 3x2x$\frac{1}{4}$
U5-L5	2 L 3x3x$\frac{1}{4}$

(b)



(c)

$\frac{7}{8}$"φ Rivets $\frac{7}{16}$" Gussets

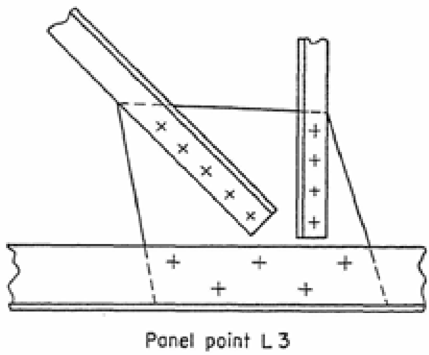


FIG. 5-10. Identification of truss symbols and layout.

be a condition where the column supporting the truss extends to point U1.

Figure 5-10 shows the layout for two of the panel points of this truss. They are U2 and L3.

When an estimator has information such as has been given in Fig. 5-10, then layouts as shown in Fig. 5-10*c* and *d* can be made. Such layouts afford a reasonably close detail of the gusset plates and result in a more accurate estimate of the weight of the truss.

The size of the rivets as indicated on the truss drawing (Fig. 5-10) is $7/8$ in. diameter; the thickness of gusset plates $7/16$ in. The allowable

load for $\frac{7}{8}$-in. rivets in double shear (AISC Manual) is 18.04 kips (the kip equals 1,000 lb), and the bearing value on $\frac{7}{16}$-in. plates is 15.3 kips.

The layout will be made to any convenient scale, and the three sections meeting at U2 will be drawn to scale in the exact same pattern as the diagram of the truss.

To find the approximate size of the gusset plate, the number of rivets for each of the web members will now be obtained. The stress in U2-L2

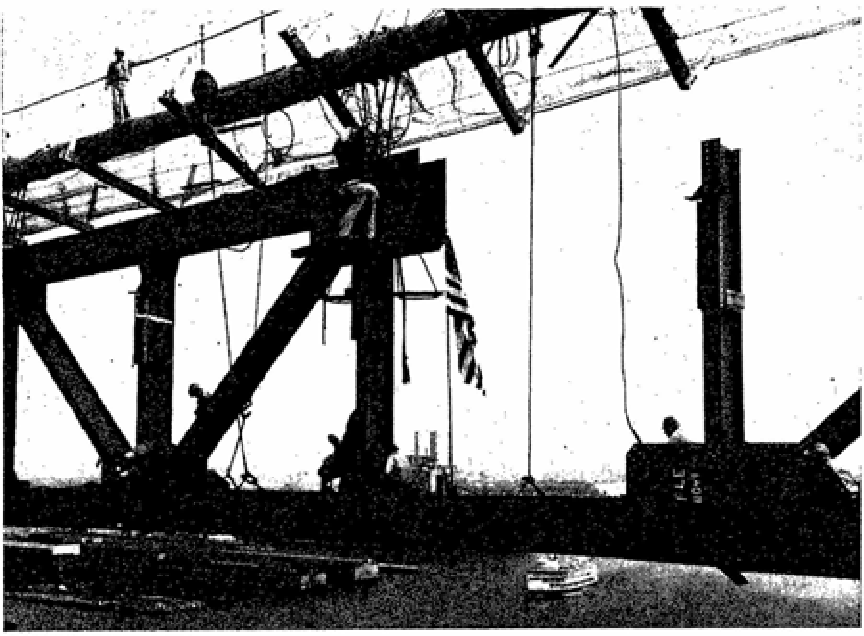


FIG. 5-11. Bridge truss. (*Bethlehem Steel Co.*)

is 69 kips; therefore, $69 \div 15.3 = 5$ rivets. The stress in U2-L3 is 48 kips; therefore, $48 \div 15.3 = 4$ rivets. *Note.* The next nearest whole number of rivets will be taken.

Lay out the two lines of rivets at 3-in. centers (3 in. is an arbitrary spacing; other spacing may be taken if preferred), allow edge distance for the end rivets, and draw in the outline of the gusset plate. This will be scaled and will be accepted as the approximate plate size.

The point at L3 will be worked out in the same way, as will the remaining points. (Note that the same number of rivets will be required in the opposite ends of each member.)

After the size of gusset plates is obtained for each panel point, a complete listing of all the truss members may be made on a take-off form. Also, the number of rivets may be counted. The result will be a very close estimate of the weight of the truss.

Trusses thus far described have been made up of angle sections. Heavier trusses may be composed of any of the other sections, beam sections, WF sections, H sections, or many combinations of rolled sections.

Figure 5-11 shows part of a bridge structure. The bridge is of the suspension type. The continuous truss will carry the roadway girders and also stiffen the structure. This truss is composed of wide-flange and built-up sections as may readily be noted. The view was taken at about

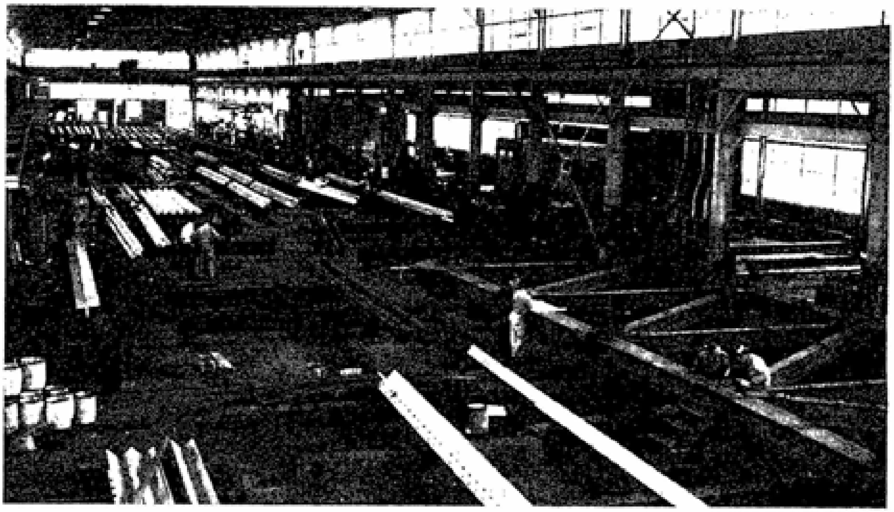


FIG. 5-12. Truss in fabricating shop. (*Lehigh Structural Steel Co.*)

the center of the span which brings the main cables close to the truss. Two sets of suspender cables may also be seen.

Figure 5-12 is a view taken in a fabricating shop. In the right foreground the assembly of a truss composed of WF sections is proceeding.

Trusses composed of WF or built-up sections such as are seen in these two pictures will have two gusset plates at each panel point. These plates may be observed in the pictures. The estimator must be alert to this condition so that the full amount of material will be included in the estimate. In addition to the gusset plates at the panel points several filler plates may also be required owing to the difference in the depth of the connecting members.

Figure 5-13 shows an aircraft hangar. The trusses and framing at the center of the structure support trusses on each side. The center of the building is designed for maintenance shops and offices and each side area for the storage or servicing of airplanes. There are no column supports at the outside ends of the trusses.

The framing at the center of the hangar is similar to the truss framing which can be seen in Fig. 5-12. The lighter framing which is seen in the picture below the trusses is for the support of wall covering and usually is not designed for support of the trusses.

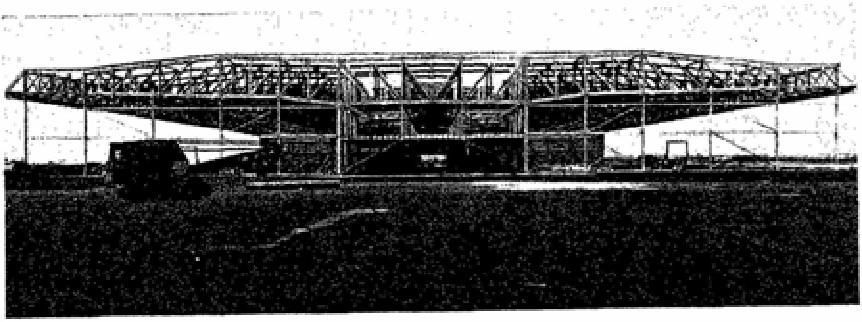


FIG. 5-13. Hangar cantilevered truss. (*Lehigh Structural Steel Co.*)

In the estimating of truss work the estimator may be obliged to know the shipping limitations as regards rail or truck transportation. It may also be necessary to take into consideration the conditions at the site. When the trusses cannot be shipped completely assembled, it may be necessary to supply the erector with complete information relative to the number of field rivets or bolts and any other data requested, such as the largest piece, the number of pieces for the field assembly, and the total weight of the complete truss.

CHAPTER 6

Connections

It may have been noted from the work done thus far that a very large proportion of the shopwork on certain types of structures consists in preparing and attaching the connections. Many different types of connections are used. For special conditions, the estimator may be obliged to employ a substitute for the final designed and detailed connections. Two possible reasons for this are lack of complete information on the estimating drawings and lack of architectural drawings and details. For example, the estimating drawings seldom show reactions of the beams and do not always show the distance between the web of the beam and the face of the column. Many times, there are special conditions where connections are made for beams framing diagonally to columns, and there are many other different situations.

Reference has been made to the standard beam connections as shown in the AISC Manual. So far, in this book, standard beam connections (Series B) have been used and also some stiffened beam seats, that is, seated connections.

Connections for girder beams are required to be stronger to carry the heavier load which these beams support. The type of connections generally used here is designated in the AISC Manual as H or HH, K or KK.

6-1. Standard, or Basic, Framing. A few basic examples of framing have been shown and discussed so far in this book. This type of framing is usually referred to as "beam-and-column framing," and it will be found frequently in office and multistory buildings, in schools and institutional buildings, and in other structures of these types.

A large portion of the fabrication is concerned with the preparation of connections and the assembly of these to the beams and columns. Therefore it is well for the estimator to study and become familiar with many different types of connections. Except in certain cases where special connections are required, there will be very little information shown on the plans and therefore it becomes incumbent upon the estimator to select a suitable connection.

6-2. Standard Connections. The standard connections as shown in the AISC Manual are accepted for use in very many structural shops. However, unless they are definitely specified, it is not necessary for the fabricator to use those shown in the Manual. He may design and use connections of his own choice, which, of course, must be sufficient properly to support and carry the imposed loadings.

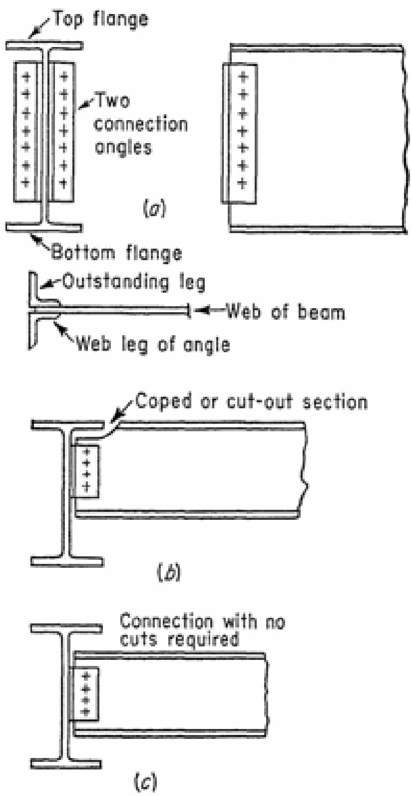


FIG. 6-1. Framed connections.

6-3. Framed Connections. Figure 6-1 shows several of the more common types of connections. A standard connection consisting of a pair of connection angles is given in Fig. 6-1*a*. The detail shown would be used for a 27 WF beam with no cutting of the flanges.

Figure 6-1*b* gives a standard connection for 16 WF or 18 WF beams and also for the American standard 15-in. I beams. This detail shows the condition which obtains when the adjacent beams are flush top. It is very usual for framing to be designed to have tops flush. Figure 6-1*c* shows framing where the flanges of the adjoining sections are separated by enough distance to allow connecting without cutting flanges.

6-4. Seated Connections. In Fig. 6-2 the details show several types of seated connections. Face *A* is a detail of one side of the web of a column. The upper sketch shows a connection composed of a top and seat angle. All holes in the top angle will be filled with rivets or bolts in the field. (The choice of rivets or bolts is dependent upon the job specification.) The angle is left loose until after the beam is set because this will permit easier erection of the beams within the webs of columns.

6-5. Seat and Top Angles. The seat angle is riveted to the column at the shop, and the several bolts or rivets will be placed in the field to complete the connection. The detail at the lower part of the web of the column is similar to the one at the top except that the seat angle is further strengthened or supported by the stiffener angle. This type of detail is used where heavier loading obtains from the connecting members.

The stiffener angle is on the top or outside of the seat angle, and a filler plate will be placed behind it to fill out the open space. The thickness of the filler, of course, is the same as the thickness of the seat angle.

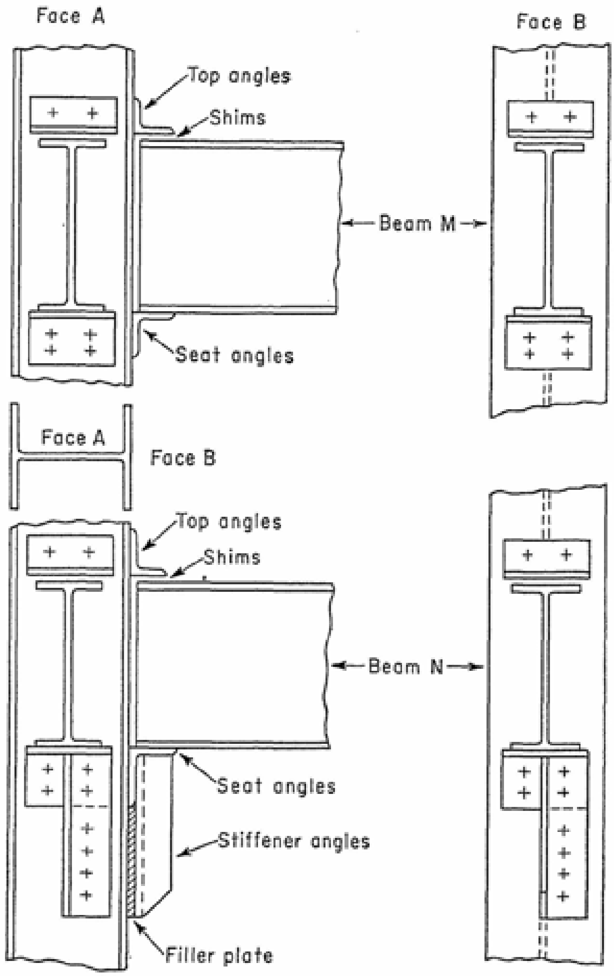


FIG. 6-2. Seated connections.

Face *B* shows one face of a column flange, and the beams shown in the detail have been projected to show a side view as well as front view. These two connections are similar to the connections in the web of the column except that the top angles are shop-riveted. Shims are often provided as shown, because of possible variation in the depth of beams.

6-6. Side Connections. In Fig. 6-3 additional details of connections of beams to columns are given. The detail on face *A* in the web of the

columns shows the beam with the top angle replaced with a clip at the side of the web of the beam. This is a condition which might be found at the top section of a roof column. The stiffeners shown under the seat angle are composed of two angles.

The detail on face *B* is sometimes described as a "knifed connection," in which the connecting beams are slipped down between the two adja-

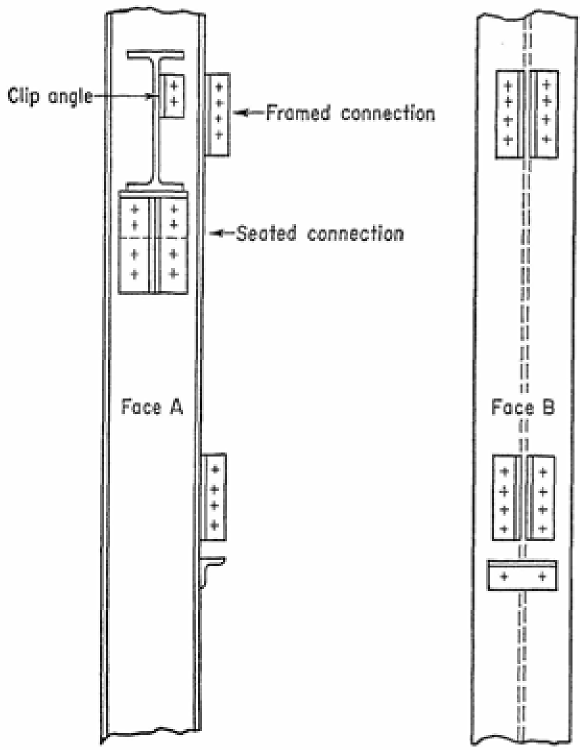


FIG. 6-3. Column connections.

cent connection angles. As shown in the lower part of the sketch, a seat angle may be provided. Both the vertical connection angles may be shop-riveted, or one may be left for fastening in the field. These are conditions which will usually be decided in the drafting room after a study of erection clearance has been made.

6-7. Connections off the Center Lines of Columns. Figure 6-4*a* shows a type of framing that is often used. The section of 8 BL 13 shown here or sections of any other size which may be desired by the designing engineer will generally be shown or marked on the plans. The two connection angles will be included in the estimate, and the assembly of the 10-in. section with the stubs and connections attached may be fabricated complete

in the shop. This will leave but two bolts or rivets to complete the work in the field.

A rather simple type of connection is shown in Fig. 6-4*b*. This connection consists of a seat angle riveted on in the shop and a connection

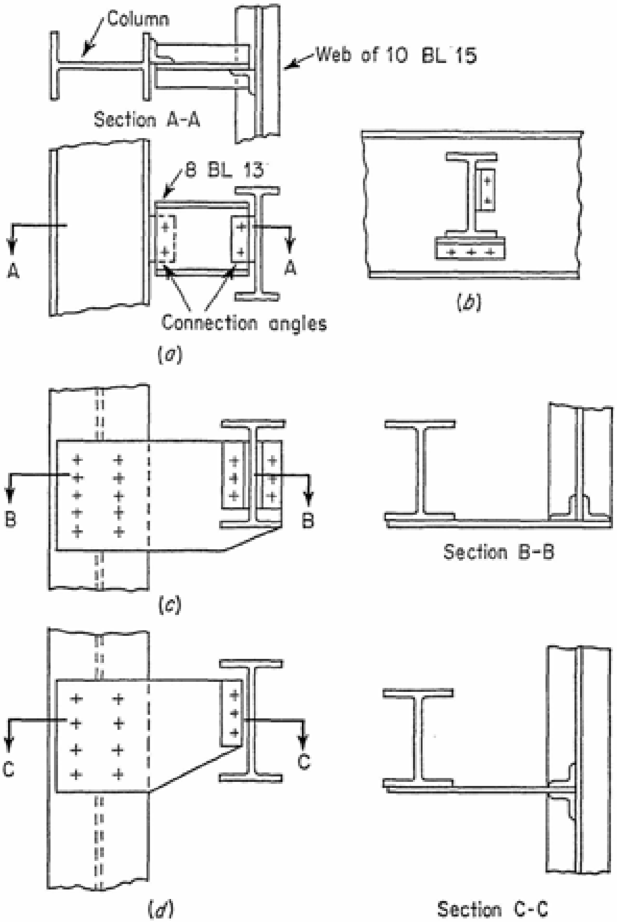


Fig. 6-4. Brackets.

angle at the upper part of the beam web, which may also be connected to the beam in the shop.

6-8. Brackets. Figure 6-4*c* and *d* shows two treatments of a bracket type of connection supporting beams which are a short distance away from the columns. Figure 6-4*c* shows a double-angle arrangement. It would be necessary, however, to use this bracket at the end of the beam which is being supported, whereas the bracket of Fig. 6-4*d* may be attached at any point on the supported beam.

6-9 More than One Connection to the Same Flange. Two beams framing to the flange of a column are seen in Fig. 6-5*a*. Because of the limited space for attaching the connection a single angle connected to one side of the beam web is used. The connection of the second beam is by means of a bent plate, which is shop-riveted to the beam. It is also necessary to cut one side of the bottom flange of the beam to clear the bent plate. Figure 6-5*b* shows the connection for a channel which is framed to the column at a sharp angle. This connection is formed by use of an angle and a bent plate.

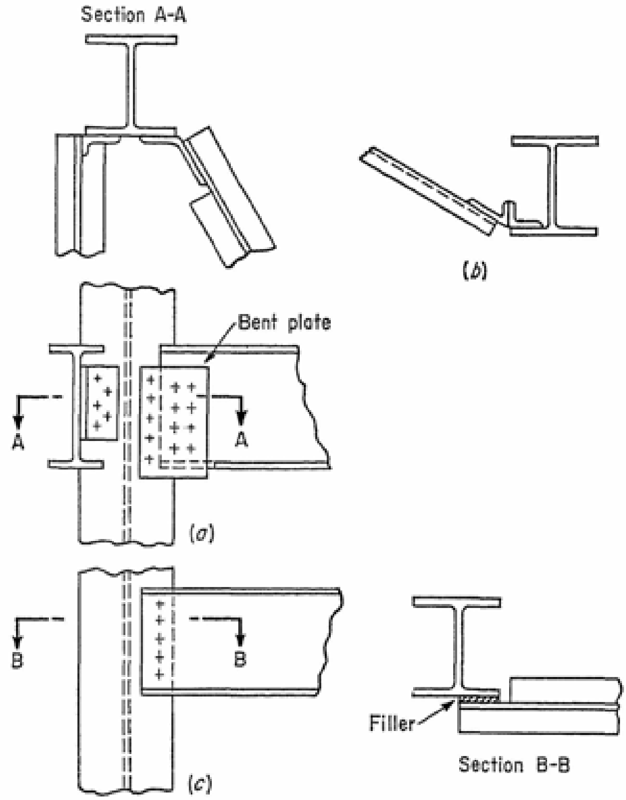


FIG. 6-5. Special connections.

Figure 6-5*c* shows a very common type of beam framing, where the beams pass the outside face of columns. Top and bottom flanges on one side of the beam are cut to clear the column flange, and it may be necessary to pack out the open space between the beam web and the column flange by supplying a filler. Sometimes the design of the structure and the location of beams under conditions similar to those of Fig. 6-5*c* will

be such that connection may be made directly to the column flanges without fillers, but if there is any open space remaining, sufficient thickness of filler must be used to fill it completely.

6-10. Welded Connections. Some examples of welded connections are shown in Fig. 6-6. Figure 6-6*a* is the detail of a beam-to-beam connection

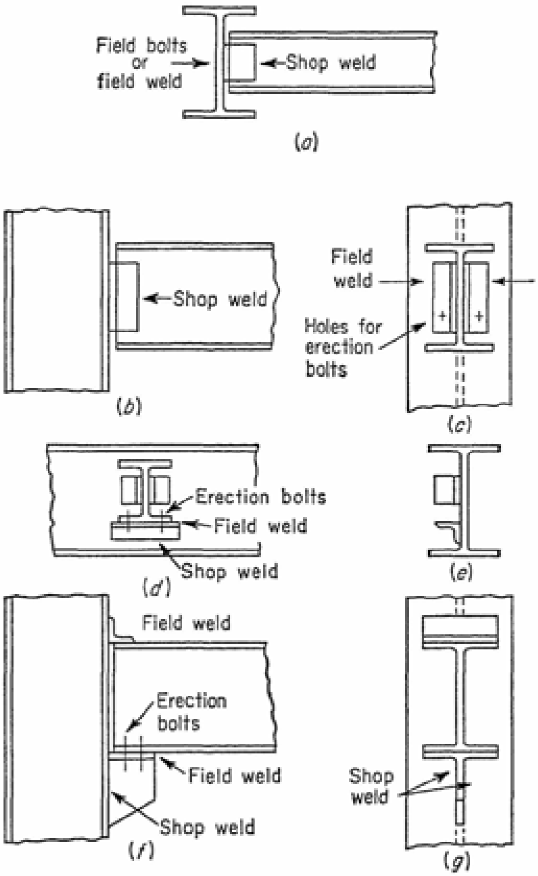


FIG. 6-6. Welded connections.

with the connection angle shop-welded to the web of the beam. The connection in the field may be accomplished with the use of bolts or may be welded. The treatment in the field is determined by the job specifications. Figure 6-6*b* gives a framed connection which joins a beam to a column flange. The clip angles are shown shop-welded to the beams, and erection bolts are provided for connecting to the column. These bolts will secure the beam until the structure is plumbed and welding completed. Under certain conditions this arrangement of connections may

present some difficulty in erection because of clearances. However, this is a problem for the draftsman to solve.

The clip angles may be welded to the column flange, in which case more beam work would be necessary. Holes would be punched in the beam webs, and also it might be necessary to cut the bottom flanges of the beams to permit passage down through the opening between the two clip angles. Figure 6-6*c* is another view of the connection shown in Fig. 6-6*b*.

Figure 6-6*d* and *e* shows a type of connection which is made up of a seat angle and clip angles. The seat angle is welded in the shop to the web of the beam as shown and is provided with holes for erection bolts, or there may be the final bolts if the specification so states. One or two clip angles may be provided.

6-11. Built-up Seats. Figure 6-6*f* shows a seat bracket and a top angle. The top angle will be fillet-welded at both the top flange of the beam and the flange of the column after the beam has been erected and bolted to the seat bracket. The seat bracket consists of two plates which are shop-welded to each other and also welded to the column flange.

The use of two plates, instead of angles (which could have been used), requires less material for the connection. A saving of material will often occur with welded connections as well as with other units of the structure.

A plate may be used in place of the top angle. Also, if preferred, a structural tee section may be used instead of the two plates. This will reduce the number of pieces to be handled in the shop to one instead of two.

This description of detailing should enable the estimator to envision differences which might occur in final detailing of connections.

Figure 6-6*g* is another view of Fig. 6-6*f* and shows how the plates are assembled. Note that these figures do not show the welding symbols. A complete description of welding symbols will be included in Chap. 8, Welding.

6-12. Wind-bracing Connections.[1] Wind-bracing connections, perhaps preferably identified as moment-resistant connections, are usually shown

[1] Many of the details for connections, including wind-bracing details, included in this book, are similar to some of the details for connections found in the book published by the McGraw-Hill Book Company, Inc., 1957, entitled "Design of Steel Structures." The authors are E. H. Gaylord, Jr., Professor of Civil Engineering, University of Illinois, and C. N. Gaylord, Chairman, Department of Civil Engineering, University of Virginia.

This book is one of the McGraw-Hill Civil Engineering Series, H. E. Davis, Consulting Editor. Considerable design and detail data are included in the work, and suggestion is made to the more experienced estimator that much valuable information may be obtained from a study of at least parts of this book. Thereby the estimator will see many details of construction.

in detail on the design drawing of a structural frame. The addition of wind-bracing connections or other framing used in this way considerably increases the quantity of material required for a structure and also materially raises the fabrication costs. A most careful study of all the plans of a structure, particularly in the case of a tall, narrow building, must be made by the estimator to be sure that all material shown on the plans has been included in the estimate.

For the purposes of this book all such connections will be designated wind-bracing connections.

6-13. Plan Identification of Wind-bracing Symbols. Figure 6-7 shows a section of a floor plan, including part of the information which may appear on the plan for a wind-braced structure. The identification marking WB1, WB2, WB3, WB4 may be the total information given on a floor plan. The designation WB1, etc., indicates the specific type of wind-bracing material required at a point or column. A detail of each type of connection is usually included on one of the drawings, or if not, then some other form of tabulation will be followed.

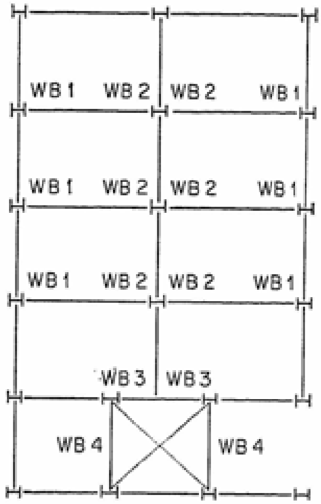


FIG. 6-7. Plan of wind-braced beams.

At the points in this sketch indicated as WB4, cross bracing may be used in place of connections. There are certain areas in the framing where cross frames may be used. This type of framing is a more economical method of wind bracing but usually is not desired except around shaft areas because of interference with certain architectural features, including, for instance, spaces where there are large room areas. The diagonal bracing obviously will break up the room finish and appearance.

6-14. Wind-bracing Details. In Fig. 6-8 examples of two types of wind-bracing connections are shown. Figure 6-8*a* gives a detail of quite a simple connection consisting of two angles connected to the web of the beam. This, of course, is the normal standard connection. The thickness of the top and seat angles will be quite large as compared with the standard connection angles, or in this case ⅞ in. for the top and seat angles and ¾ in. for the web-connected angles.

Note that it is not unusual for the diameter of rivets through the top and seat angles to be considerably increased over the size of rivets used in the web connections.

Figure 6-8*b* is an end view of Fig. 6-8*a*. Figure 6-8*c* shows a very interesting connection made up of a pair of angles which connect to the

column flange, to the brackets on top of and below the beam, and to the web of the beam. The two brackets are composed of beam sections with one flange removed and also bevel-cut. Sometimes the distance from the flange of the bracket section to the horizontal cut is such that half

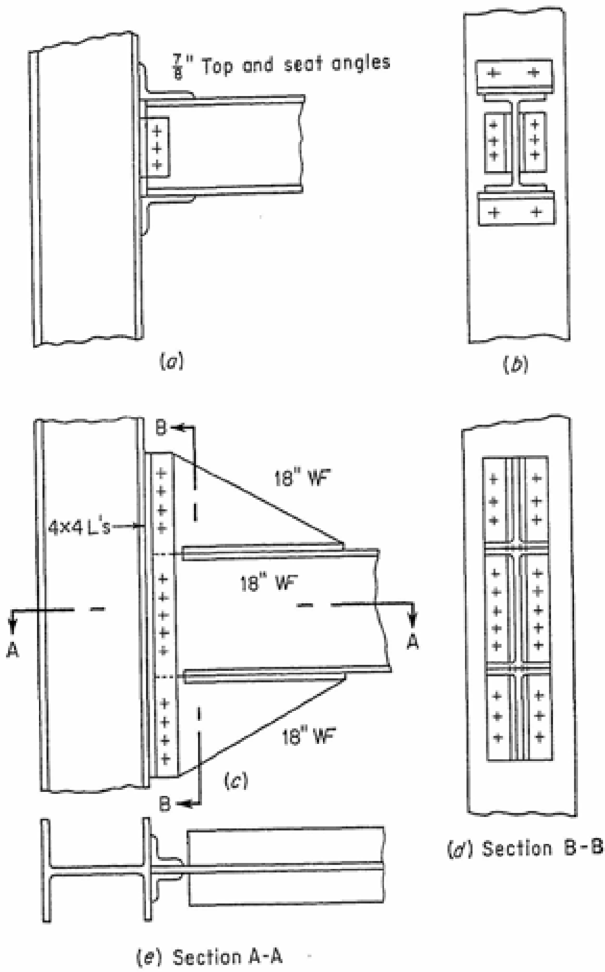


FIG. 6-8. Wind-bracing connections.

of the beam section can be used at the top and the other half at the bottom. Otherwise it will be necessary to cut off and scrap part of the bracket section.

The estimator must include the proper quantity of material depending on the requirements of the connection. If a beam can be split in half, this will be more economical than when a small part must be scrapped;

in this latter case an entire section must be estimated for both top and bottom. Note that the remaining flanges of all the beam sections must be cut to allow the angle to pass by.

6-15. Additional Wind-bracing Details. Figure 6-9 shows three types of wind connections. All have the standard angles connecting the webs of the beams to the column flanges.

The detail shown in Fig. 6-9*a* has a tee section connected to the top and bottom flanges of the framing beam.

Figure 6-9*b* shows a fairly heavy type of connection consisting of a beam section on the top of the floor beam. One of the flanges has been cut off as seen, and most of the remainder of the section will be used so that the required number of rivets may be accommodated through the remaining portion of the web. At the bottom of the floor beam the first section seen is a WF or H section. This section may be several feet long. Beneath this will be a tee section, similar to the one at the top, which will be made from a deep beam with one flange removed.

Angles and plates are used in the connection shown in the detail of Fig. 6-9*c*. The standard framed angles are used at the connection of the beam web and the column flange. The two brackets shown at the top and bottom of the beam are each composed of a gusset plate which has been cut as shown, together with a pair of angles connecting between the gusset plates and the top flange of the beam. Another pair of angles connect between the gusset plates and the flange of the column.

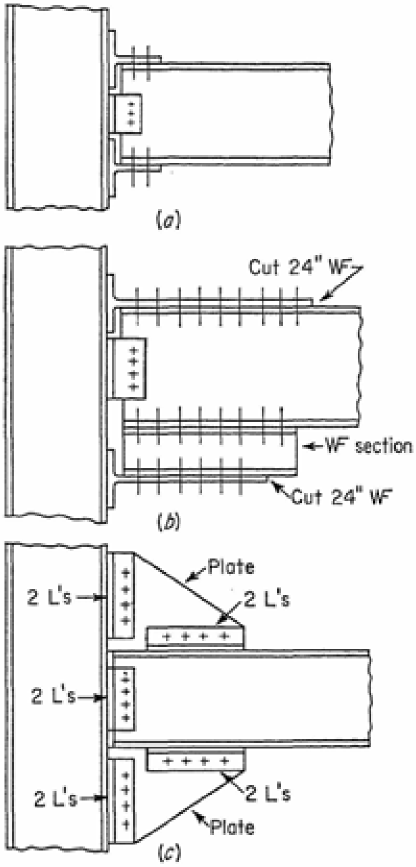


Fig. 6-9. Wind-bracing connections.

The selection of rivets to be driven in the field and of those to be driven in the shop will be determined by the designing engineer or by the draftsman after consideration of certain clearances for erection.

6-16. Floor Framing at Different Elevations. Certain architectural requirements may be such that some portions of a floor are at an elevation different from that in the adjacent area. As shown in Fig. 6-10*a*, the ele-

vation of several beams is at +11 in. above the balance of the framing. In Fig. 6-10*b* to *e* are shown two methods of the end arrangement where beams *C* meet beam *D*. The connections to the columns are not under discussion at this time except to note that connections will be located so that the elevation of the beams at +11 in. is maintained.

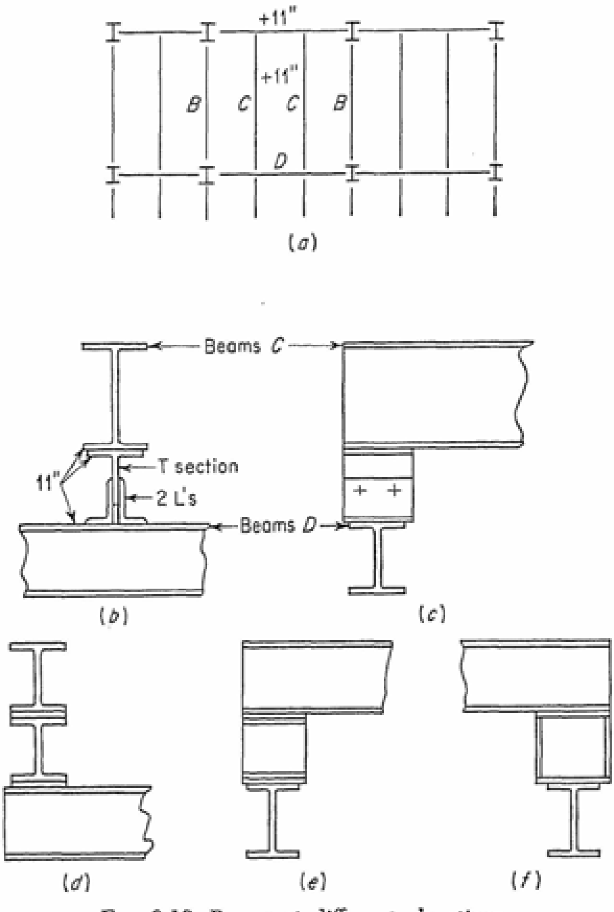


FIG. 6-10. Beams at different elevations.

An arrangement of a tee section and two angles is shown in Fig. 6-10*b*. Material of the proper sizes must be selected to equal the required distance of 11 in. Figure 6-10*c* is another view of Fig. 6-10*b*. Figure 6-10*d* is a different treatment of the same situation, but instead of the tee and angle arrangement the connection is accomplished by the use of a 10-in. beam section with ½-in. plates at the top and bottom to make up the required 11 in. Figure 6-10*e* is a side view of Fig. 6-10*d*.

Another method could be as shown in Fig. 6-10*f*. A column stub sec-

tion is placed upright, and plates are welded top and bottom. The plates will be provided with holes for field bolts or field rivets. This arrangement is often used where the distance between the elevations is, say, several feet instead of a few inches.

There are many times when the estimator is required to use especially sound judgment as to the material and work to be included in the estimate. These drawings and sketches point out some of the various conditions which occur with respect to steel framing. When a detail is not shown on the estimating plans, it is up to the estimator to assume and include in the take-off sufficient cost and quantity of material. As previously stated, the engineers and draftsmen may use other methods than those assumed by the estimator, but meanwhile costs and a quantity of material have been included in the bid figure.

6-17. Table of Beam Connections. Table 6-1 has been prepared for estimating use from the standard-beam-connection information contained in the AISC Manual. The information from the Manual has been condensed for estimating use and therefore may not be sufficient for the preparation of the final job details.

The sizes of connection angles and also other data which have been included in the table will be used without change by many steel fabricators. Others may prefer connection details which are different from those in the table, details, for instance, which are more suited to certain drafting standards adopted by these companies.

However, the weights and sizes indicated in the table are suitable for all practical purposes in connection with this work on estimating.

6-18. Seated Connections. The average weight of seated connections is approximately 1½ times to twice the weight of the equivalent framed connection. In cases where the seated connection is only on one side of the web of the column, it is usually necessary to provide six field rivets or bolts, four of which will be required for the top angle, assuming it is shipped loose, and two for the seat angle through the bottom flange of the beam.

Where there is an equivalent seat angle on each side of the web of the column, there will be 10 field rivets or bolts. The two holes in the vertical leg of the top angle will use a common bolt or rivet, assuming that the beams are exactly opposite and this is frequently the condition. The remaining holes to be filled are two in each top angle and two in the seat angle.

These conditions will have been observed on the plans for the beam and column framing.

The weight of shop rivets for seated connections will be about 10 or 20 per cent of the weight of the material in the connections.

Most fabricators provide their estimators with standard tables of con-

Table 6-1. Framed Beam Connections

AISC Series A

Beam section	Length of angles, and detail	No. rivets or bolts, outstanding legs	No. rivets, web legs	Wt angles, lb	Wt shop rivets, lb
36 WF	2′-5½″, A	20	10	52.1	10
33 WF	2′-2½″, A	18	9	46.8	9
30 WF	1′11½″, A	16	8	41.5	8
27 WF	1′-8½″, A	14	7	36.2	7
24 WF	1′-5½″, A	12	6	30.9	6
24 I	1′-5½″, A	12	6	30.9	6
21 WF	1′-2½″, A	10	5	25.6	5
20 I	1′-2½″, A	10	5	25.6	5
18 WF	0′-11½″, B	8	4	17.4	4
16 WF	0′-11½″, B	8	4	17.4	4
18 I	0′-11½″, B	8	4	17.4	4
15 I	0′-11½″, B	8	4	17.4	4
14 WF	0′-8½″, B	6	3	12.9	3
12 WF	0′-8½″, B	6	3	12.9	3
12 I	0′-8½″, B	6	3	12.9	3
10 WF	0′-6″, C	4	4	12.3	4
8 WF	0′-6″, C	4	4	12.3	4
10 I	0′-6″, C	4	4	12.3	4
8 I	0′-6″, C	4	4	12.3	4
7 I	0′-3″, C	2	2	6.2	2
6 I	0′-3″, C	2	2	6.2	2
5 I	0′-3″, C	2	2	6.2	2

Detail A, 2 L 4 × 3½ × 7/16
Detail B, 2 L 4 × 3½ × ⅜
Detail C, 2 L 6 × 4 × ⅜
Shop rivets, ⅞″
Field rivets, ⅞″

AISC Series B

All information and details the same as Series A, with the following exceptions:
Shop and field rivets all ¾″
Length of L 10″ and 8″, sections 5½″
Weight of L 10″ and 8″, sections 11.3″
Weight of shop rivets for each connection one-half of Series A

nections used by the shop and drawing room. Many also provide tables containing information for estimating use. In other cases the fabricator may elect to have the estimating department make complete use of the AISC Manual to obtain any necessary data and information.

Table 6-2. Reaction Values

AISC Series A ⅞″ rivets, AISC Series B ¾″ rivets

Beam	Max. value Series A, kips	Max. value Series B, kips	Beam	Max. value Series A, kips	Max. value Series B, kips
36 WF	180	132	15 I	72	53
33 WF	162	119	14 WF	32	28
30 WF	144	106	12 WF	32	27
27 WF	126	92	12 I	54	39
24 WF	108	79	10 WF	36	26
24 I	108	79	8 WF	26	26
21 WF	90	66	10 I	36	26
20 I	90	66	8 I	36	26
18 WF	72	53	7 I	18	13
16 WF	72	53	6 I	18	13
18 I	72	53	5 I	18	13

Note. Reaction values include the heaviest beam of each section.

Table 6-3. Approximate Minimum Spans

AISC Series A ⅞″ rivets, AISC Series B ¾″ rivets

Beam	A connections	B connections	Beam	A connections	B connections
36 WF 300	41′	56′	20 I 65.4	9′	12′
36 WF 230	31′	43′	18 WF 96	18′	24′
36 WF 150	19′	26′	18 I 54.7	10′	12′
33 WF 200	28′	38′	18 WF 50	12′	14′
33 WF 130	17′	23′	16 WF 88	15′	19′
30 WF 172	25′	34′	16 WF 36	9′	11′
30 WF 108	14′	19′	15 I 42.9	7′	8′
27 WF 145	22′	29′	14 WF 30	10′	12′
27 WF 94	14′	18′	12 I 31.8	7′	8′
24 WF 130	21′	28′	12 WF 27	9′	11′
24 I 79.9	11′	15′	10 WF 21	5′	6′
24 WF 76	13′	15′	10 I 25.4	5′	7′
21 WF 112	18′	26′	8 WF 17	4′	4′
21 WF 62	12′	14′			

Table 6-4. Framed Beam Connections

AISC Series HH and AISC Series H

Beam section	Length angles	No. rivets or bolts, outstanding legs		No. rivets, web legs	Wt angles, lb		Wt shop rivets, lb, HH and H
		HH	H		HH	H	
36 WF	2′-5½″	40	..	16	85	..	16
33 WF	2′-2½″	36	..	14	76	..	14
30 WF	1′-11½″	32	..	12	67	..	12
27 WF	1′-8½″	28	14	11	59	49	11
24 WF	1′-5½″	24	12	10	50	42	10
24 I	1′-5½″	24	12	10	50	42	10
21 WF	1′-2½″	20	10	8	42	35	8
20 I	1′-2½″	20	10	8	42	35	8
18 WF	0′-11½″	16	8	8	29	24	8
16 WF	0′-11½″	16	8	8	29	24	8
18 I	0′-11½″	16	8	8	29	24	8
15 I	0′-11½″	16	8	8	29	24	8
14 WF	0′-8½″	12	6	6	21	18	6
12 WF	0′-8½″	12	6	6	21	18	6
12 I	0′-8½″	12	6	6	21	18	6

20 I and 21 WF to 36 WF:
HH, 2 L 6 × 6 × 7/16
H , 2 L 6 × 4 × 7/16
12 WF, 14 WF, 16 WF, 18 WF, 15 I, 18 I:
HH, 2 L 6 × 6 × ⅜
H , 2 L 6 × 4 × ⅜
All shop and field rivets, ⅞″

AISC Series KK and K

All information and details the same as Series HH and H, with the following exceptions:
Shop and field rivets ¾″
Weight of shop rivets for each connection one-half of Series HH or one-half of Series H.

6-19. Reaction Values. Reaction values are not usually indicated on estimating drawings, but there will be cases when they are shown and when they should be considered in selecting the proper connections.

Standard framed connections, AISC Series A and B, are satisfactory up to certain maximum reaction values. When these quantities are exceeded, a heavier connection must be estimated. Table 6-2 gives maximum values for reactions of the connections, Series A and B.

Certain structures have very short spans. In many cases these beams

require heavier connections. Details of these connections may be shown on the estimating drawings.

Complete tables of minimum spans for beams with standard Series A or B framed connections will be found in the AISC Manual. Also, Table 6-3 tabulates the minimum spans for beams frequently used in structural framing.

6-20. Heavy Connections. Table 6-4 is a condensation of AISC Series HH, H and KK, K connections. These are the heavier kinds of connections. Many fabricators will use angles of the size and detail shown in the tables. Others will prefer to detail heavy types of their own design.

Many engineers make use of heavy 12 and 14 WF sections. A special connection is required whenever one of the heavy WF sections appears on the floor plan.

Much space has been devoted here to connections because they are among the most important units of fabrication and a thorough understanding is considered very necessary.

CHAPTER 7

Columns—Built-up Sections—Girders

7-1. Introduction. A considerable portion of structural estimating is concerned with columns. Detailed description and explanations of column footings, column bases, splices, and built-up column assemblies will be included in this chapter.

7-2. Base Plates. Figure 7-1*a* shows a simple rectangular plate or section of flat steel. It may be used either as a base plate under a column or a wall-bearing plate placed under the end of a beam at the place of bearing on the masonry.

Figure 7-1*b* shows a section similar to Fig. 7-1*a*, but with the addition of two holes. These holes are for the anchor bolts. The thickness of the base plates may be up to and including 2 in., and usual practice is to designate plates over 2 in. as slabs. Shopwork on base plates consists in shearing or cutting to the proper size and punching or drilling holes for anchors.

7-3. Slabs. Slabs are medium to extremely heavy plate or billet sections. The heavier slabs will weigh several tons each. As received from the rolling mills, these heavier sections may not be perfectly flat, and because most specifications require the bearing surfaces to be absolutely smooth, either planing or pressing will be required at the fabricating shop.

Plates between 2 and 4 in. thick may be straightened by pressing and above 4 in. by planing. Most fabricators will plane or mill the slabs. The addition of ¼ in. to the thickness of all slabs is good practice. Slabs bearing on masonry and which will be grouted are not required to be planed on the bottom surface.

Figure 7-1*c* shows a slab marked M1S, which signifies that milling is required on one side or, to be completely specific, that it is required on top. Anchor-bolt holes will be provided as indicated. Figure 7-1*d* is similar, except that it will have four anchor-bolt holes, and is milled on one side.

All these shop operations, milling, drilling, or burning anchor-bolt holes and, sometimes, additional holes for pouring grout, require expenditures of shop labor and must be included in the estimate.

In Fig. 7-1*e* the section indicates that the slab shall be milled both top and bottom (M2S, "mill two sides"). An additional ¼ in. will be needed for milling the top and ¼ in. for the bottom, a total of ½ in. added to the thickness. In all cases where thickness has been referred to,

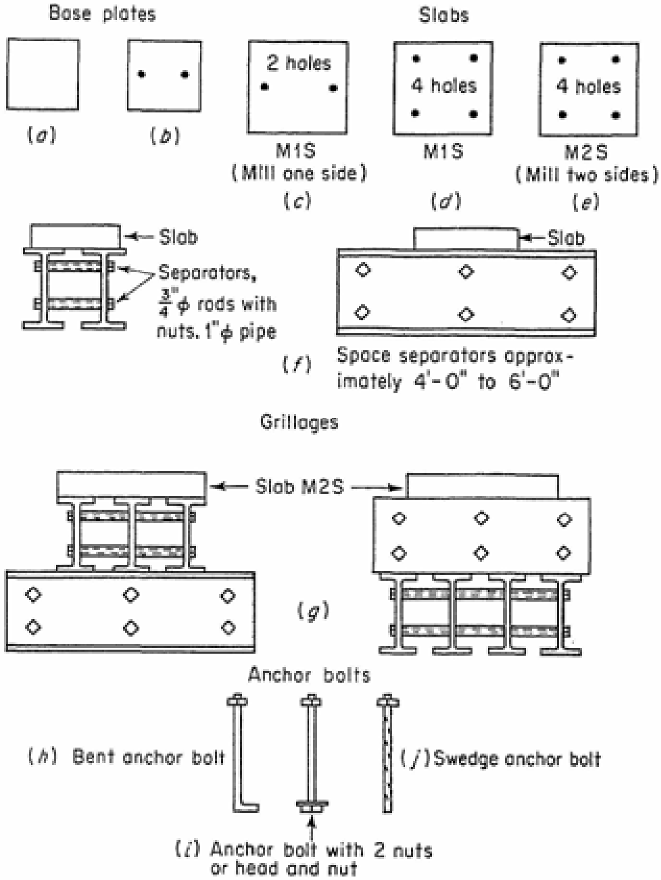


FIG. 7-1. Foundation material.

the thickness as shown or indicated on the foundation or footing plan is meant.

7-4. Grillages. Figure 7-1*f* shows an end view and a side view of a "grillage." Beams or girders which distribute the loading received from a column to the foundation masonry or other material are called grillages. The slab in the sketch will require milling top and bottom. It may also be necessary to mill the surface of the beam which is in contact with the slab. Beams will be held at a fixed relationship to each other by the use of separators. A separator consists of a rod or bolt which is passed through

holes in the webs of the beams as shown. The rods will have a head on one end and a nut on the other or may have a nut on each end. A section of pipe of the proper diameter to fit the rod or bolt is cut to the length necessary to separate the beam sections and will hold the beams at the proper distance apart.

Figure 7-1g shows a grillage consisting of a slab and two layers of beams. All details are similar to the grillage which has been previously described. All contact surfaces will be required to have complete bearing, and the proper charge must be included in the estimate.

7-5. Anchor Bolts. Three types of anchor bolts are shown in Fig. 7-1*h* to *j*. The bent anchor bolt will require bending or blacksmithing and threading on one end to receive the nut. The bolt of Fig. 7-1*i* is actually a bolt of the proper length or a rod with each end threaded and supplied with two nuts and washers. In the final sketch (Fig. 7-1*j*) what is called a "swage bolt" is shown. This is made from a round rod threaded on one end and provided with a nut. The rod has nicks, or indentations, which are intended to provide improved binding with the concrete or grout in the pier or footing.

These are the most common kinds of anchor bolts. However, it is not unusual to encounter very long and heavy anchors on many structures. Bearings and bases for the ends of bridge girders and stringers are often quite complex. The details and descriptions will be included in Chap. 9, Typical Structures.

7-6. Column Footings. Many different types of column footings will be needed depending upon the wishes of the designing engineers and the different requirements of the structure. Figure 7-2*a* shows a very simple column footing of a type often required. The shopwork consists in milling the column shaft and welding the base plate to the shaft. Usually anchor-bolt holes will be drilled in the base plate before welding is done.

The size of the angles shown in Fig. 7-2*b* will serve as an approximate size which may be estimated when sizes are not indicated on the drawings or when the fabricator's shop standards are not available. The angles will be punched for rivets and also for anchor bolts, after which they will be attached to the column shaft. The column shaft and the angles will then usually be milled or faced.

Figure 7-2*c* shows a column section with both angles and the base plate. The angles may be riveted to the shaft of the column, which may then be machined before attachment of the base plate. The base plate may be attached with rivets, which will be countersunk on the underside of the base plate.

In Fig. 7-2*d* are shown the two angles secured to the column flanges. The size of angles is a suggested size; as previously noted, size of angles may be determined by the fabricator's standards. The usual arrangement

is to provide four rivets in each of the angles. After the angles are attached, the end may be machined or milled.

Figure 7-2*e* is a front and side view of a slightly heavier column foot-

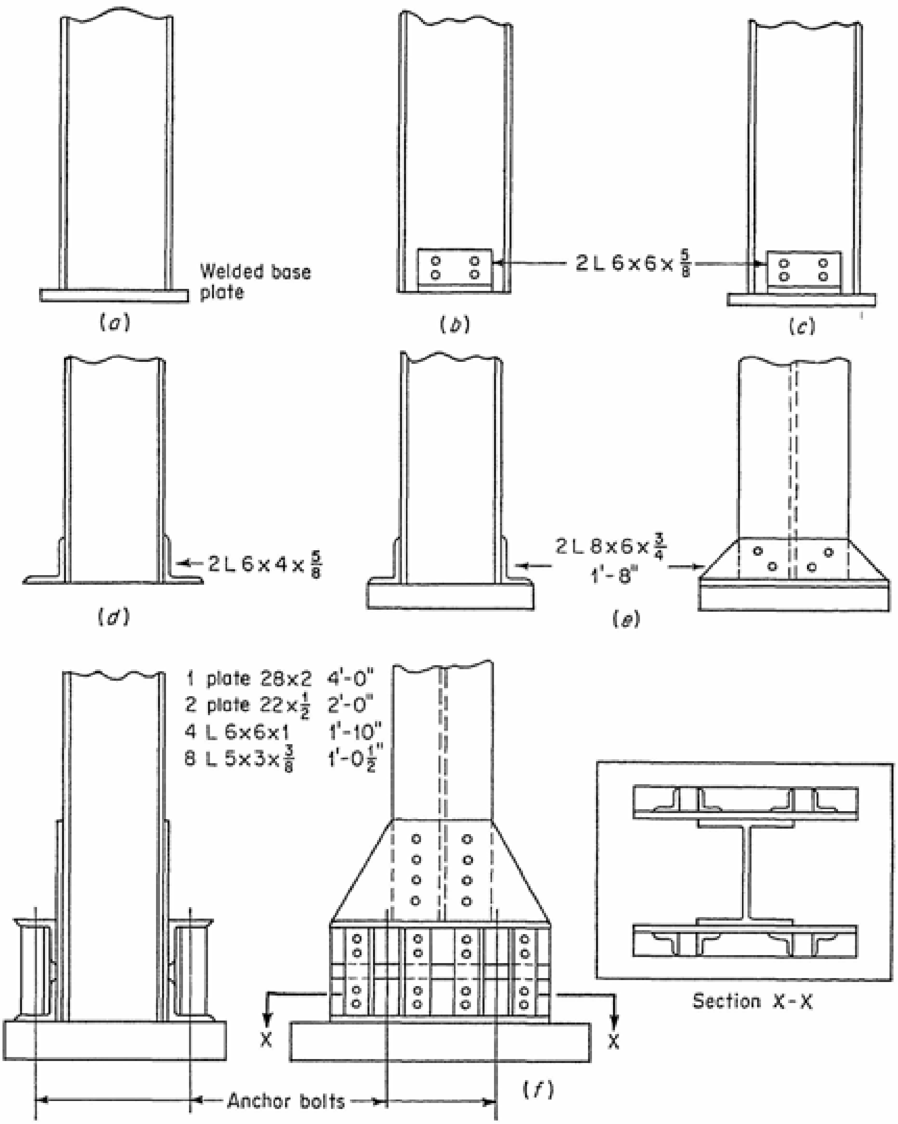


FIG. 7-2. Column bases.

ing. The sizes of the angles are, again, suggested sizes and will be satisfactory to use in the event complete sizes of the detail are not available.

In Fig. 7-2*f* is given a detail of a very heavy column footing which

will often be seen on mill-building construction, particularly where there are crane runways. The views are front view, side view, and section through the base, as indicated. Here, again, several sizes of material have been shown, representative of sizes of material which may be used on this style of base. The eight angles $5 \times 3 \times \frac{3}{8}$ in., which are stiffeners, will be milled to provide a full bearing on each of the 6×6-in. angles. The $22 \times \frac{1}{2}$-in. plates are the side plates, and the 28×2-in. plates are the base plates.

The estimator should study the detail very carefully, as this would be a column base having a considerable shop cost. The very heavy and long anchor bolts which would be expected with this footing would be carried up through the outstanding legs of the upper horizontal angles.

7-7. Column Splices. At places where the upper and lower lengths of columns join, some form of splice must be provided. Many different designs of splices are used on structural framing. A few basic examples will now be described.

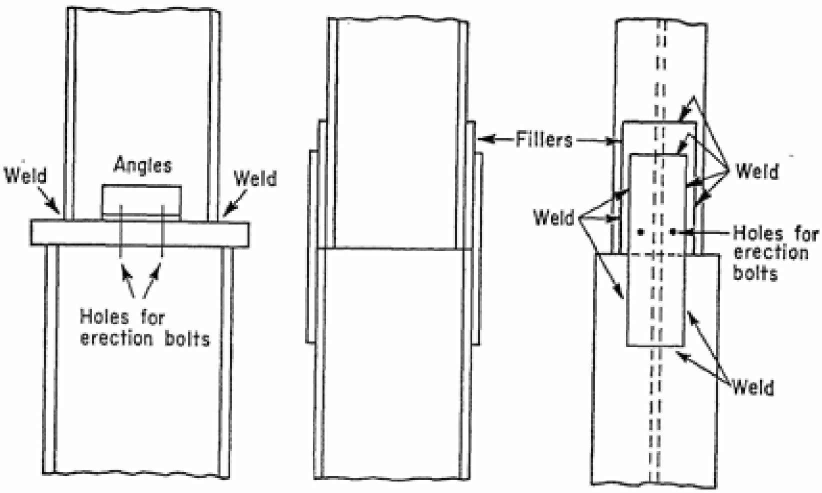
Figure 7-3*a* shows a simple welded splice. The cap plate is usually welded to the lower section of the column, and a pair of angles are welded to the upper section. Both the cap plates and the outstanding legs of the angles are provided with holes through which bolts will be placed to secure the column until the indicated welds are completed in the field.

Figure 7-3*b* is drawn with a front and side view. Where the adjacent columns are of different depths, it will be necessary to include filler plates, which have been shown in the sketch. This is a very common condition. Suppose, for example, that this lower column section is 14 WF 78 with a depth of section of 14 in. Assuming the upper section of columns to be 12 WF 53 with a depth of 12 in., there would then be a space of 2 in. to be filled, which would require a plate 1 in. thick on each side. These fillers would be attached in the shop and the column shaft and fillers milled after the fillers are on the column. The outside plates may be attached in the shop to either the top or the bottom column section, depending upon shop or erection practice. In the sketch shown, they are indicated in the bottom section, with holes provided for erection bolts. The proper welding symbols are not indicated here, as this will be a special subject.

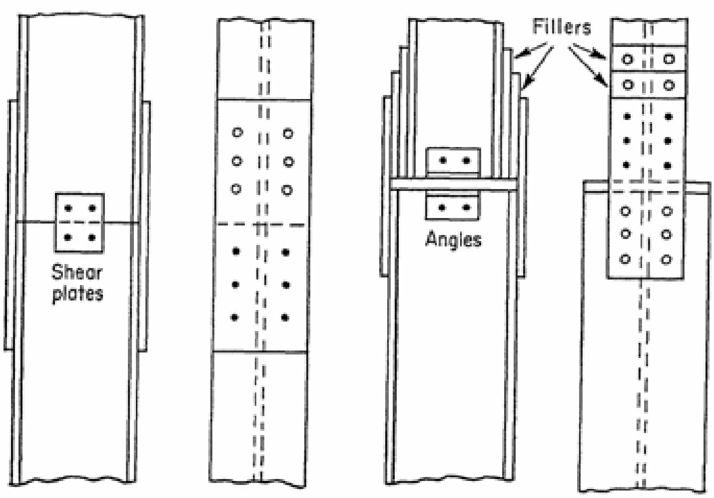
Figure 7-3*c* is a front and side view of a riveted splice. The adjacent sections do not require fillers. The shear plates are not standard with some fabricators or engineers and may or may not be used. The shop rivets may be on the upper or lower column section. Common practice is to shop-rivet the plates to the lower section. Some erectors may require the two rivets next to the end of the section to be field rivets. This will

have to be considered by the estimator in making the count of the required field rivets.

Figure 7-3*d* shows a riveted splice which will require the addition of



(*a*) Welded splice (*b*) Welded splice with fillers



(*c*) Riveted splice (*d*) Riveted splice with fillers

FIG. 7-3. Column splices.

splice plates and also a cap plate on the lower column section. The four filler plates, two on each column flange, have been shown with two shop rivets each.

Many other methods of column splicing will be encountered, but these few basic examples should provide an estimator with some suggestions for use in preparing the estimate weight and cost. Note that in almost every case it will be specified that columns have full bearing at all splices.

Many fabricators provide the estimator with a set of standard tables

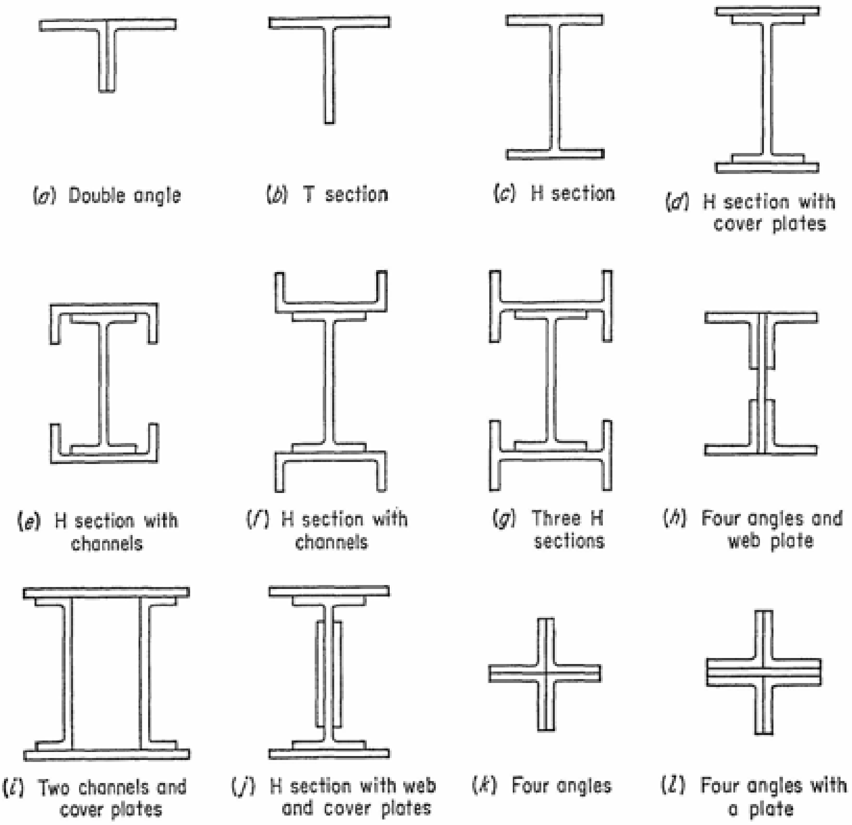


Fig. 7-4. Built-up column sections.

which indicate the weight of splices and the number of shop and field rivets or the quantity of weld. It should be noted in using a table that the figures will be average, as it is impractical to estimate a different weight for the fillers with each change of column section. For example, a 14 WF 53 section is 14 in. deep, a 14 WF 158 is 15 in. deep, a 14 WF 228 section is 16 in. deep, and so on.

7-8. Built-up Column Sections. Many combinations of shapes and plates are made use of in various column assemblies. Some of the combinations are shown here, but many others are possible.

Figure 7-4*a* shows two angles which may have one or two lines of rivet,

depending upon the size of the angle. The T section (Fig. 7-4*b*) is actually one-half of a WF or an H section and is made by splitting the WF or H. Many T sections are equivalent to a pair of angles and do not require the additional shopwork.

In Fig. 7-4*c* the H or WF sections are rolled in so many sizes and weights that they are used in many structures. The addition of cover plates (Fig. 7-4*d*) will, of course, provide a very strong column section. The cover plates may be attached by rivets or may be welded to the shaft. The flanges of many of the heavier 10-, 12-, and 14-in. sections cannot be readily punched and must therefore be drilled. Drilling is usually a much more expensive operation than punching. Welding cover plates may be a more economical method, depending on the size of the material and the equipment of the fabricating shop.

Figure 7-4*e* and *f* shows sections made up with channels and a WF section. Figure 7-4*g* shows three WF sections. These assemblies will occur on certain work, and when they are to be included in an estimate, the estimator must add the necessary number of shop rivets or the amount of weldment.

The section of Fig. 7-4*h* consists of four angles and a web plate. Also, cover plates may be added if required by the design. This section has very largely been replaced by the single WF or H section. Another section, shown in Fig. 7-4*i*, is composed of two channels and two cover plates. Sections of this kind may be seen on some of bridge work.

Figure 7-4*j* shows an assembly consisting of an H section with both flange and web plates. When a section such as this appears on the column schedule, the estimator must be sure to include all the fastening material.

The assembly of four angles of Fig. 7-4*k* is sometimes referred to as a "star strut." This section will require four lines of shop rivets or more, depending upon the size of the angles. Finally, a section of four angles and a plate is shown in Fig. 7-4*l*. This section is a further development of the star strut and will sometimes have plates between the vertical legs of the angles.

7-9. Offset Columns. Many times a condition such as that seen in Fig. 7-5 will occur. Referring to the partial column schedule shown here, it is indicated that column 5 will frame underneath a beam or girder at the sixth floor. It is further seen that column 5*a* will begin at the sixth floor. This information may be indicated by symbols on the section of floor plan. A dash drawn above the number 5 would mean that column 5 ends under the 33 WF beam; also, the opposite condition obtains at column 5*a*. A dash line under the column number would mean that the column starts above or on the top of the 33 WF beam.

All designing engineers do not use these or similar symbols, but many do.

7-10. Stiffeners. When there is a condition such as that of Fig. 7-5 or in many other cases where a beam or girder receives a concentrated load, it will be necessary to provide additional material to support or stiffen

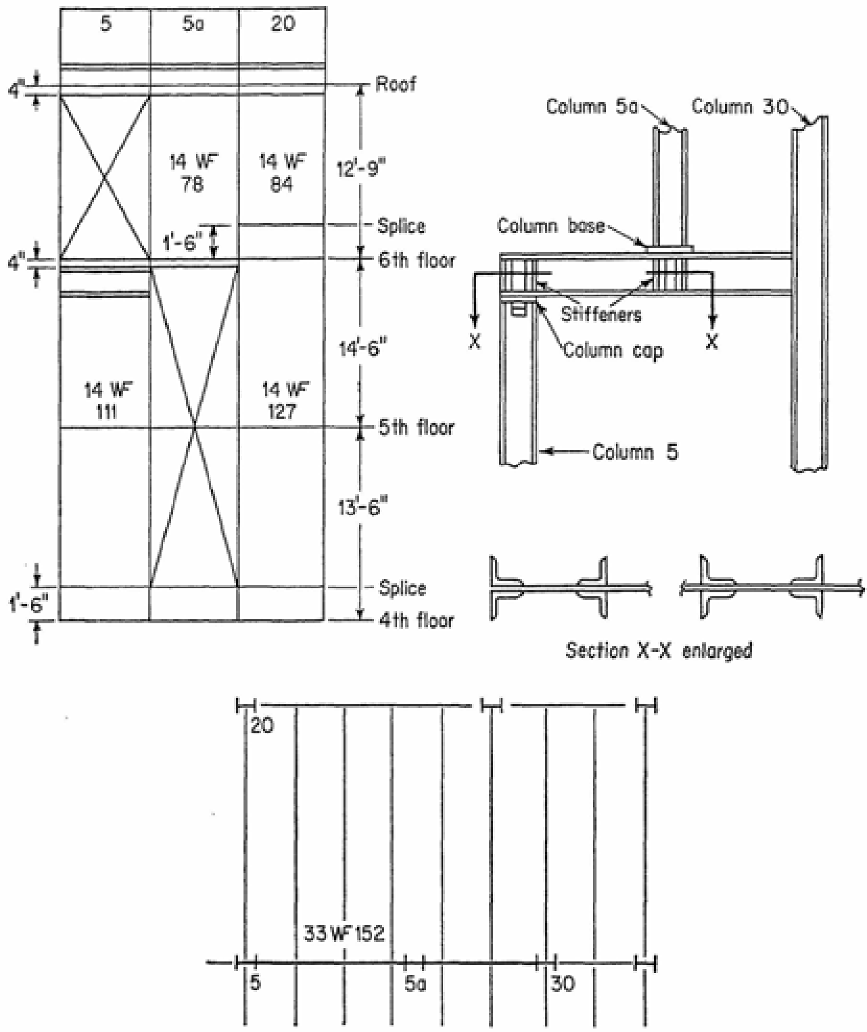


FIG. 7-5. Offset column framing.

that section of the beam. This will usually take the form of angles placed in such manner that the outstanding legs will come under or over the column flanges. Note that in the case of welded construction a section of plate or flat bar may be welded perpendicular to the web of the beam. It may be noted that with the use of the plate there will be a saving in the quantity of stiffener material. The stiffener angles will be riveted to

the beam under the upper column and also above the lower column, all as indicated in Fig. 7-5.

The flanges of the 33 WF 152 beam are 11⅝ in. wide. In that case an angle with a 5-in. outstanding leg can be used. This size of angle has been selected as it is usual practice to keep the outstanding toe on the leg of the angle inside the flange of the beam. The thickness of the stiffener

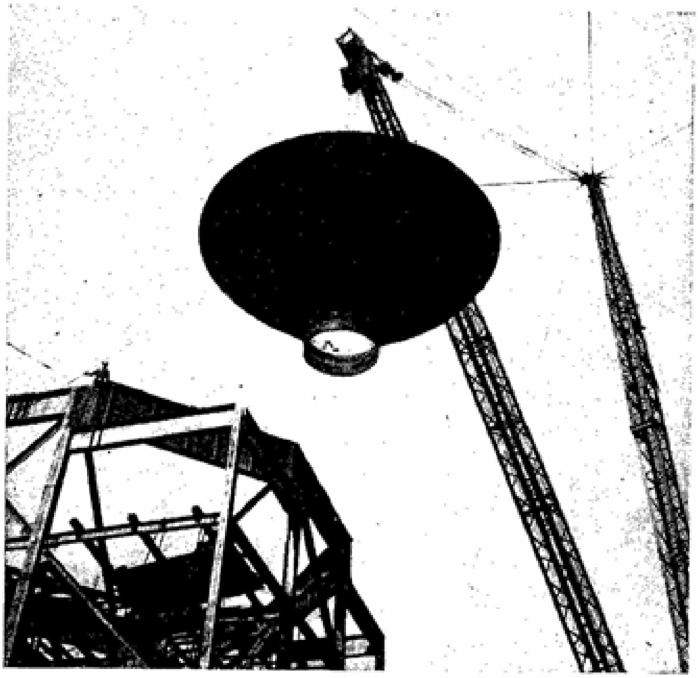


Fig. 7-6. Field picture of stiffeners. (*Standard Oil Co. N.J.*)

angles should be made about equal to the flange thickness of the supported and of the supporting columns.

The column-flange thickness for the 14 WF 78 is $^{11}/_{16}$ in., and the flange of the 14 WF 111 is ⅞ in. thick. Consequently the sizes of the angles used here may be as follows: Above column 5, there will be four angles $5 \times 3\frac{1}{2} \times \frac{3}{4}$ in.; under column 5*a*, four angles $5 \times 3\frac{1}{2} \times \frac{5}{8}$ in. In the take-off an allowance must be included in the length of angles for milling. Stiffener angles will be milled or ground smooth on the ends to obtain full bearing on the flange of the beam. Section *XX* is an enlarged detail of the stiffener angles and indicates the direction in which the angles are placed on the beam. Each pair of angles will require about five shop rivets.

To show the difference in the quantity of material between riveted

and welded work, the weight per foot of 5 × 3½ × ¾-in. angles is 19.8 lb, and that of a 5 × ¾-in. bar is 12.8 lb, a difference of 7 lb per ft in the quantity of material. There will be a variation in shop cost accounted for by shop's practice and experience. Each pair of angles will require shop labor for punching 15 holes, namely, 5 in each angle and 5 in the web of the beam. A pair of bars of the size required in this example will use about 6 or 7 ft of weldment. Both the angles and bars must be ground or milled to bear on the beam flanges.

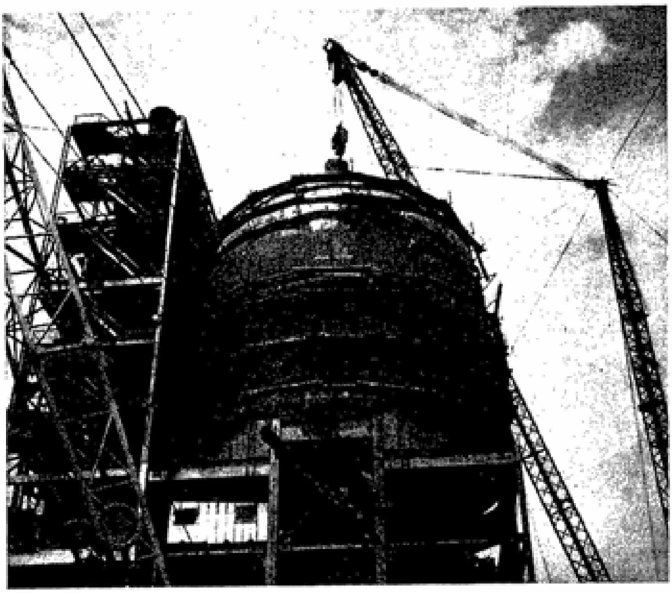


FIG. 7-7. Stiffeners. (*Standard Oil Co. N.J.*)

7-11. Illustration of Stiffeners. Figure 7-6 shows part of a structural frame. Several sets of stiffener angles can be seen, and also a pair of bars used as stiffeners. The structure is a support for a fluid catalytic cracking unit located at an oil refinery, and as will be seen in another figure, several concentrated loads are imposed on the structure. Several sets of stiffeners are seen at the centers of the beams and girders at the top of the framing. The intermediate stiffeners on the plate girders will be described in connection with plate girders and will be included in another chapter.

Near the left end of the beam, below the girder on which the ironworker is sitting, are two stiffeners which are bars welded to the web and flange of the beam. Therefore in this figure both angle stiffeners and bar stiffeners can be seen.

Figure 7-7, which is of a later date, shows the main section of the catalytic cracking unit. By a study of this figure, the point of contact be-

tween the curved cracking unit and the structural frame will be noted.

Considerable detailed description of stiffeners has been given in this chapter. On many estimating plans, stiffeners will not be indicated, and it is the responsibility of the estimator to include sufficient of this material and the cost thereof. On a structure such as has been seen in these figures and also on one with many offset columns the number of stiffeners will be large.

BUILT-UP SECTIONS

7-12. Built-up Riveted Sections. A built-up section can range from the most elementary combinations of structural shapes to others that are extremely complex. One of the minor assemblies is the angle group shown in Fig. 7-8*f*. This group of three angles will be found to occur on many structures as a lintel supporting brick or masonry.

The shopwork on the single angle will usually consist of cutting to the required length and painting. Because of mill extra charges for cutting to the shorter lengths, it is general practice for the fabricator to purchase angles used for lintels in long lengths.

The pair of angles will be riveted, welded, or bolted together. Spacing of the rivets or bolts will be 12 to 18 in. The estimator must include the proper number of fastenings and the cost of the shop labor to punch, rivet, and paint.

Figure 7-8*a* shows a type of lintel consisting of a pair of channels and an angle. The angle may be bolted or riveted to the channel as indicated and the separators provided as shown. These separators consist of rods with a head or nut or threaded on each end and provided with two nuts. Separators such as these were also described in connection with grillages.

The lintel of Fig. 7-8*b* would be used where the opening is not too wide. It is approximately the same as the longer section shown in Fig. 7-8*a* except that one set of separators will be necessary.

Figure 7-8*c* represents a built-up section composed of a web plate and four angles. A section such as this may be required to support a canopy or for any other purpose selected by the designing engineers. It is unusual only in that an additional shop operation will be necessary. That operation is the cutting of the web plate. In estimating this assembly, either the plate will be taken off at the maximum width and the discarded portion of the plate scrapped, or when there are a number of sections, a combination may be considered where material is taken off sufficient to cut pairs of plates and without waste.

7-13. Separators and Diaphragms. When a more rugged separator is required, a type such as that seen in Fig. 7-8*d* or *e* may be selected. As can be noted from the two sections *XX* and *YY*, the separator or diaphragms may be made from a single channel section or of a plate and two

angles. Other variations may be the use of a beam section and also four angles and a plate. If it is desired to use a channel or beam section and the distance between the main numbers is a little greater than the depth

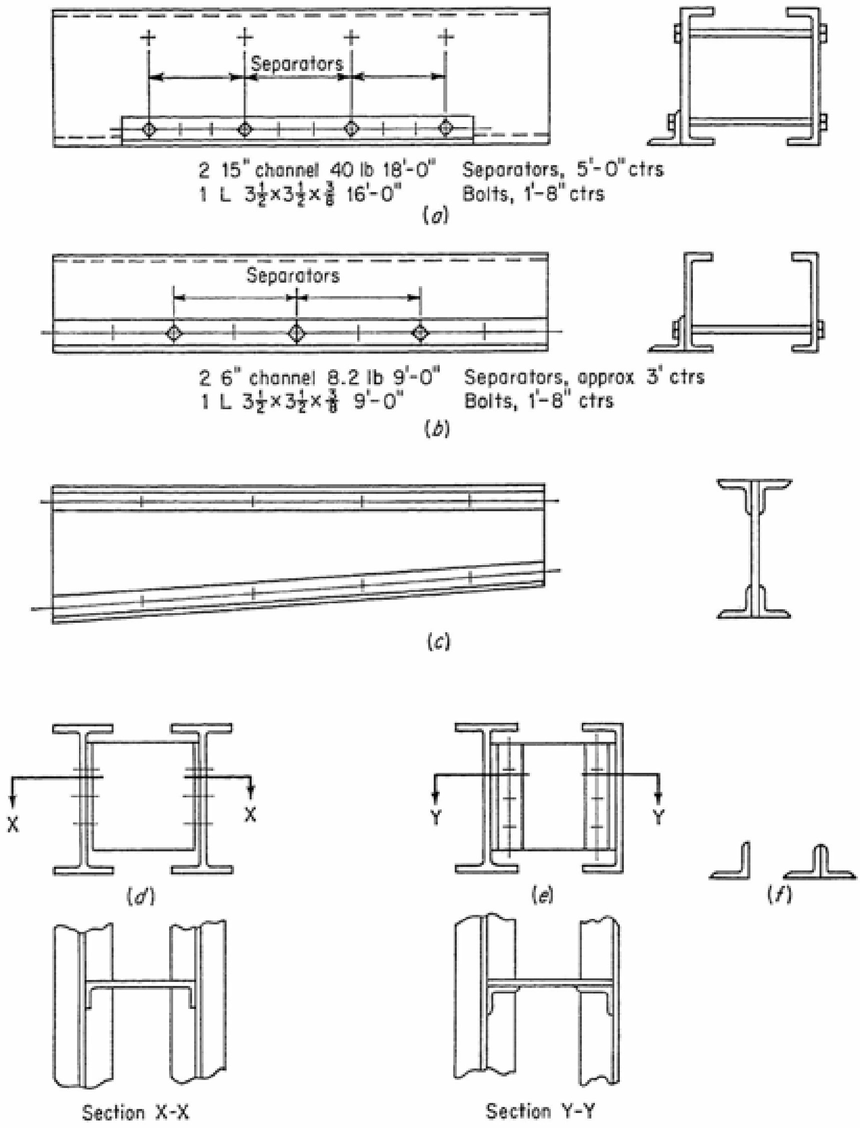


FIG. 7-8. Lintels and separators.

of the channel or beam, a narrow plate or bar may be placed between the flanges and the webs of the beams. Specifications often indicate that diaphragms or separators are to be supplied where necessary, but nothing

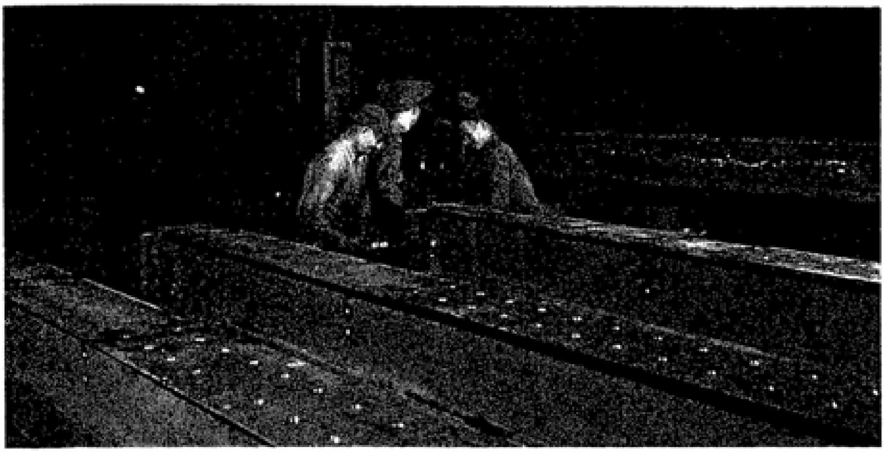


FIG. 7-9. Cover-plated sections. (*Bethlehem Steel Co.*)

further may be indicated on the plans. Therefore, the estimator may provide diaphragms similar to those which have been detailed in Fig. 7-8*d* or *e*. Separators will be spaced about 5 ft apart.

Figure 7-9 shows WF sections which have been built up with cover plates. Each of these plates has been attached to the WF section by two lines of rivets. The spacing lengthwise of the rivets is apparently about 6 in.

7-14. The Use of Lacing Bars and Tie Plates. The section shown in Fig. 7-10*a* represents a pair of channels connected top and bottom with tie plates at the ends and with lacing bars. Sections such as are indicated in all three of the sketches are used for many different purposes and various structures. The sections are typical of certain bridge members and also may be bracing struts in a mill building.

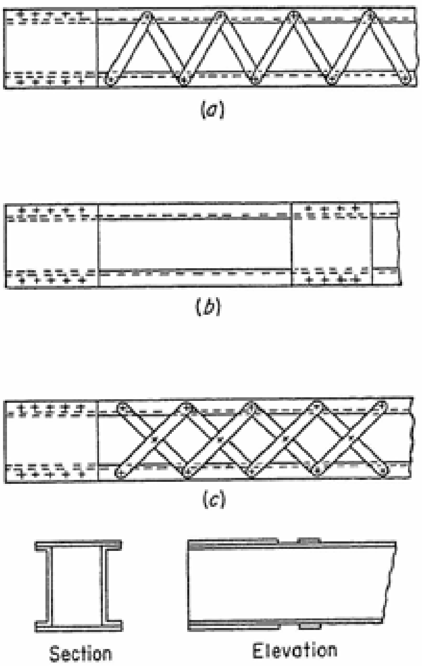


FIG. 7-10. Struts and latticed sections.

An end view is shown at the lower left corner of Fig. 7-10. Struts may be built up in many other forms, such as a pair of angles and lacing bars.

The lacing bars in Fig. 7-10*a* are described as single lacing. These

bars are placed at an angle of 60° with the channels. They may be fastened with a single rivet connecting two overlapping bars and the channel. In the average strut, if sizes have not been indicated on the erection plans, the bars may be estimated to be about $2\frac{1}{2} \times \frac{3}{8}$ in. With sections such as have been shown the lacing bars will, of course, be estimated both top and bottom.

Figure 7-10*b* shows a section composed of two channels and tie or bottom plates with no lacing bars. In the event that distances are not shown on the estimating drawings, the pairs of plates will be 3- to 5-ft centers.

The section in Fig. 7-10*c* is also a laced section. This section employs double lacing for greater strength. The lacing bars are at an angle of 45°. More than one rivet may be used if required by the design. When this is the case, the proper design of members will provide the necessary clearances for the several rivets.

7-15. Plate Girders. Plate girders are, of course, assemblies of various sections. While the designation is "plate girders," material other than or in addition to plates will be included in the assembly.

End views of nine types of girders have been drawn (Fig. 7-11). Figure 7-11*a* represents a section made of three plates, the web and top and bottom flanges. This is a design adapted for welding. It is a section which is very popular because of both its simplicity and its flexibility. It is quite usual on a long bridge girder, for instance, to have several thicknesses of cover plates comprising a flange section. The estimator must be alert to the arrangement of design. The several cover plates are usually joined to each other with butt welds. A butt weld requires much more weld material and labor than the mere simple fillet weld and must be estimated accordingly. When the girder is long, it may be necessary to splice the web plates and the splices of adjacent sections of web plates will also require butt welds.

Figure 7-11*b* shows a welded design consisting of a web plate with a channel section as a top flange and a plate for the bottom flange. Figure 7-11*c* might be described as the basic girder design, consisting of the four angles and the web plate. Many combinations of angles and a wide range in the size of the web plate are possible here. A modification of this design is one made up with two angles, one at the top and the other at the bottom, and the web plate. Figure 7-11*d* is a development of Fig. 7-11*c* by the addition of cover plates. One cover plate may be added to the top and one to the bottom of the section, or several plates may be added to both top and bottom. The lengths of these plates will be as required to support the loading.

In Fig. 7-11*e*, the section consists of a web plate, four angles, and a channel, and Fig. 7-11*f* is similar except for the replacement of the channel with a plate and two angles. Each of these sections may be consid-

ered special-purpose designs and may be encountered in crane-runway framing.

The box girder in Fig. 7-11g is built with the two web plates, four angles, and the necessary cover or flange plates. Variations of this assem-

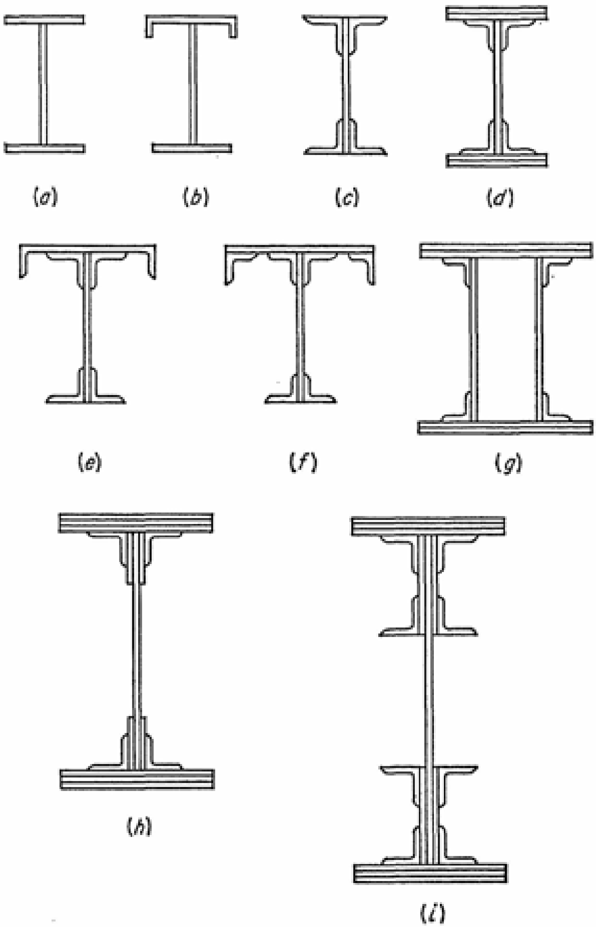


Fig. 7-11. Built-up sections.

bly will be found in many bridge structures, and it is suggested that this basic design be carefully studied.

Figure 7-11*h* is a heavier development of the girder of Fig. 7-11*d*. The major difference is the addition of four quite narrow plates under the four flange angles. The drawing also indicates additional cover plates. The number and length of cover plates are determined by the designing engineers, and the material will be listed on the estimate take-off as indicated on the estimating drawings.

Finally, Fig. 7-11*i* is an end view of a very heavy type of girder. Girders similar to this will be found on some of the heavy railroad bridges. As can be seen in the sketch, there will be a web plate, eight angles, and an additional plate parallel to the web, placed under each pair of flange angles. The cover plates will be as required by the design.

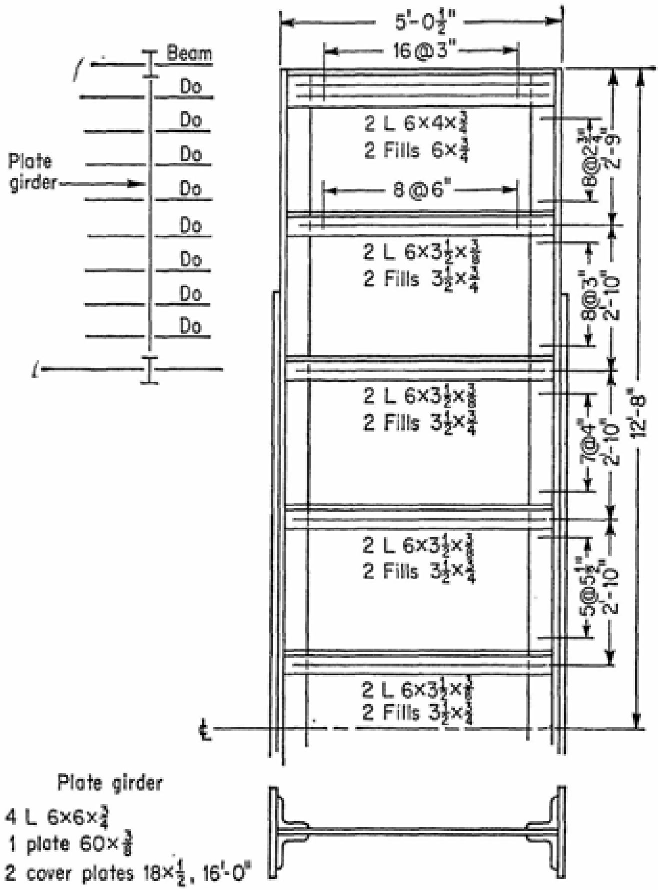


FIG. 7-12. Detail of plate girder.

7-16. Details of a Plate Girder. Figure 7-12 gives a partial detail of a plate girder. The small plan indicates a number of beams framing to the girder, but the detail of the girder does not show the connection material for the beams because the example is intended to describe only the assembly of the girder.

The girder consists of four flange angles, a web plate, and two cover plates which do not extend the full length of the girder. The end connection angles are heavier than the intermediate angles, as shown in the

detail. The width of the fillers will be as indicated. Note that the end connection angles and also the other stiffener angles rest on top of the main flange angles. This will leave an open space from the back of the stiffeners and connection angles to the web plate. The flange angles are ¾ in. thick, and therefore the open area will be ¾ in. Filler plates or bars, the widths as shown, will be provided.

The reference to two angles and two filler plates is intended to include the same material on each side of the girder. The web plate is 60 in., or 5 ft, and the distance noted on the drawing of 5′-0½″ back to back of the flange angles will be to indicate that the angles are offset ¼ in. on either edge of the web plate. This is generally normal practice and will not particularly concern the estimator in preparing the estimate. The next two sets of figures have to do with the number of rivets between the two arrowheads and the number of rivets required in that area. The several other figures—8 at 2¾ in., 8 at 3 in., 7 at 4 in., and 5 at 5½ in.—also designate the number of rivets in the several areas as shown.

Some design drawings indicate the complete number of rivets required for the entire girder, but many estimating plans are not provided with this information. Therefore, it is incumbent upon the estimator to make an approximate estimate of the number of rivets needed. It is general practice to include 5 per cent of the weight of all material to obtain the weight to be added for rivets.

The estimating drawing may indicate the girder only as shown by the small sketch, upper left, in Fig. 7-12 and a listing only of the main material. The estimator will then be obliged to supply the balance of the items to complete the work.

7-17. Plate-girder Stiffeners. Stiffener angles have been explained in considerable detail in the sections on columns. A few suggestions can be set down to serve as a guide for the estimator when the girders are not shown in detail on the plans. This information will not be completely adequate for all girders but may be used as a basis for much girder work.

End stiffeners or connection angles will generally provide for two lines of rivets through the legs connecting to the girder web. The filler plate will be as wide as this angle leg or may be of sufficient additional width to add one extra line of rivets through the web and beyond the leg of the angle. The thickness of the end angles may be assumed to be the same as the thickness of the flange angles.

Stiffeners should be provided under all concentrated loads. There is a definite design specification for the spacing of intermediate stiffeners, but it is suggested that the estimator space these intermediate stiffeners at about the depth of the girder unless otherwise advised, that is, 5 ft apart where there is a 60-in. web plate.

The thickness of intermediate stiffeners may be about the same as that

of the web plate. The outstanding leg may be about wide enough nearly to reach the edge of the flange angles and the other leg about sufficient in width to accommodate one line of rivets.

Some fabricators have shop equipment which crimps stiffeners and thereby saves the expense of providing filler plates and the shopwork of cutting and punching the filler-plate material. A crimped stiffener is an angle which has been sufficiently offset at each end to make it fit closely to both the flange angle and the web of the girder.

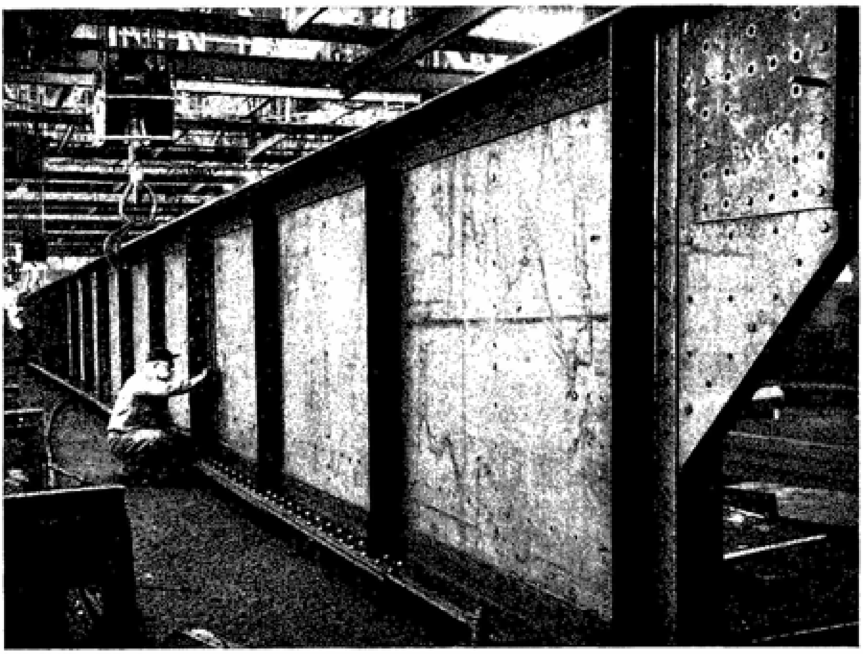


FIG. 7-13. Plate-girder fabrication. (*Bethlehem Steel Co.*)

Figure 7-13 shows a plate girder in the process of fabrication. The stiffener angles, except those at the ends or under concentrated loads, are crimped as seen. The girder has two lines of rivets in each leg of the flange angles. It may also be noted that the rivets connecting the web to the flanges have not been driven at this point. In connection with erection, the expression "girder dogs" may be used. Shown very clearly in this figure, the girder dogs are the two sets of hook arrangements connected to the hook of the bridge crane and to the top flange of the girder.

7-18. Plate Girder and Column. Figure 7-14 is a very good picture of a stiffener arrangement on a plate girder. One set of stiffeners can be seen above a column, and the other set is below the upper column section.

Another condition which is apparent here is web reinforcement. When

a situation such as is seen here occurs, the design may include additional web plates for a short section of the girder. These plates will be attached to each side of the web plate with the rivets, as shown in the figure.

Also shown is part of a truss. This truss seems to have been shipped to the site in sections and the sections assembled after arriving at the job. It is not practical and often not possible to ship a section more than 12 or 13 ft deep either by truck or by rail. High-strength bolts are now being

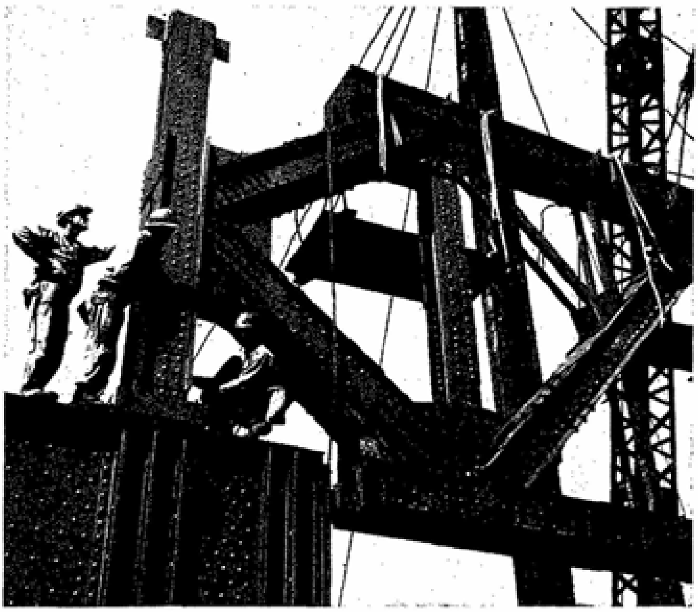


FIG. 7-14. Field view of girder and truss. (*Bethlehem Steel Co.*)

used for field connections, and these can be seen connecting the several members to the gusset plates. A gusset plate is the designation for a flat plate used to connect several members together at the junction of the sections. Further clarification of gusset plates was made in connection with trusses.

Figures 7-15 and 7-16 show very complex assemblies. These sections will form members of a bridge. Figure 7-15 shows a section still in the process of assembly. This kind of construction is usually found only on major bridge work. Most estimators will not be required to produce an estimate for this type of assembly. It is usual for design drawings of complex structures to show many details of the various sections, and the more experienced estimator can readily follow these details.

Two methods of reinforcing openings are seen in Fig. 7-15. At the left of the assembly a plate reinforcement may be seen, and in the foreground

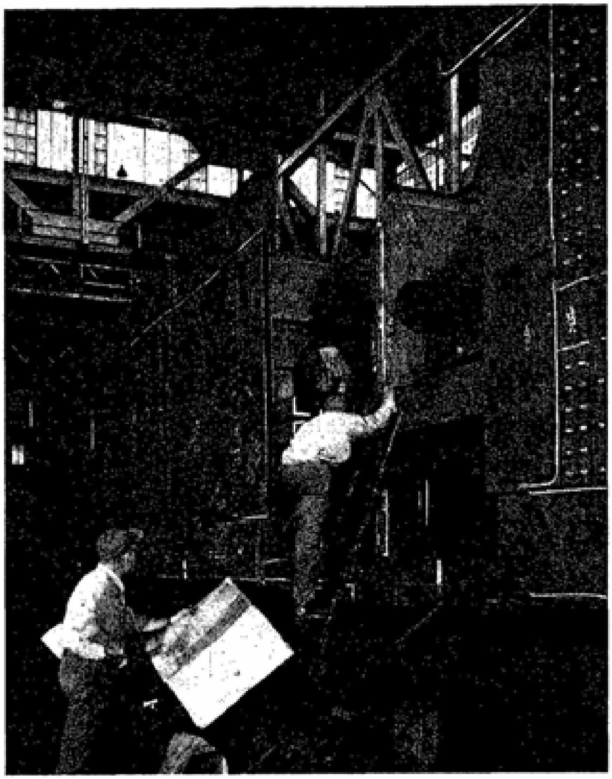


Fig. 7-15. Shopwork on complex assemblies. (*Bethlehem Steel Co.*)

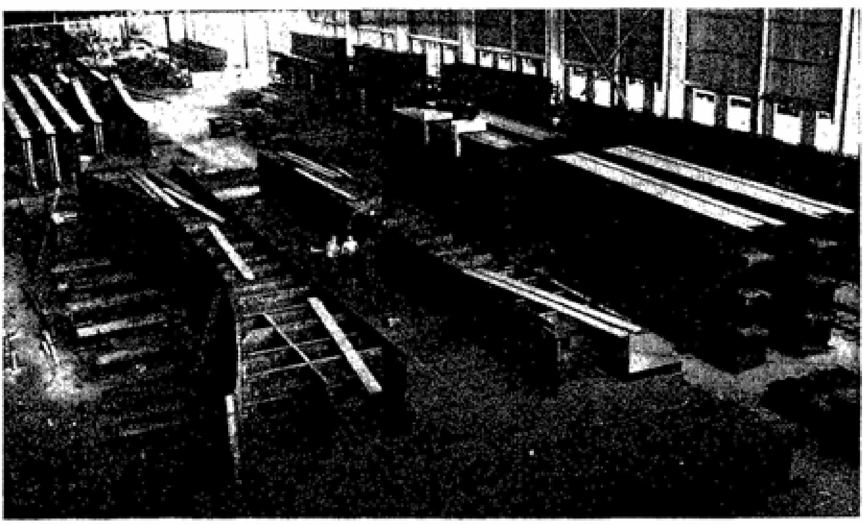


Fig. 7-16. Bridge assemblies. (*Bethlehem Steel Co.*)

angles are seen above and below the oval openings. The angles at the upper opening apparently have been located at the far side.

Figure 7-16 is a general view of a part of the fabricating shop. Many different assemblies are seen here, many of which are ready for shipment. Railroad cars are in the process of being loaded, and workmen may be observed securing the load in one of the cars.

It is generally specified and usually required on work of this kind to match and mark the adjacent sections before shipment so that little difficulty will develop in the field in matching the holes for connecting.

CHAPTER 8

Welding

8-1. Welded Fabrication. A large percentage of structural fabricators have equipment and facilities for producing welded work. Therefore it is advisable that estimators become familiar with the average types of welded work. Some welded details have been included in Chap. 6, Connections.

8-2. Welding Symbols. The American Welding Society has developed standard welding symbols. Full details may be obtained from the Society. The symbols may also be found in books on welding such as the "Procedure Handbook of Arc Welding Design and Practice," published by the Lincoln Electric Company, Inc., Cleveland, Ohio, the AISC "Steel Construction Manual," and "Modern Arc Welding Procedure and Practice," Hobart Trade School, Inc., Troy, Ohio, and in many other publications.

8-3. Types of Structural Welds. The structural estimator will be mainly concerned with two types of weld, fillet and butt. A very brief description of these two types of weld will be given here, but it should be emphasized that the estimator must carefully read the information shown or noted on the drawings and include exactly the material and the welding which is indicated.

The fillet weld may be used to connect the web plate of a girder to the flange plates, and the butt weld may be used to join two adjacent sections of web plates or two adjacent sections of flange plates. The butt weld may also be employed in connection with the joining of several members of a truss.

Fillet welds will be used to connect connection angles or connection plates to beams and/or columns. It must be noted that the amount of welding necessary to produce a butt weld is usually many times that required to produce a fillet weld. The estimator should recognize this condition so as to include the proper quantities in the estimate.

8-4. Reading Weld Symbols and Sizes. A sketch of a simple framed beam connection is seen in Fig. 8-1*a*. The framing angles are a pair of L 3×3, and they are $10\frac{1}{2}$ in. long. As indicated on the drawing, there

are two welding symbols which apply to this particular connection. A circle in which the center portion is not filled in indicates that welding will be done in the shop all round the edge of the angle and within the dimensions shown. The second symbol, a triangle connected to a line,

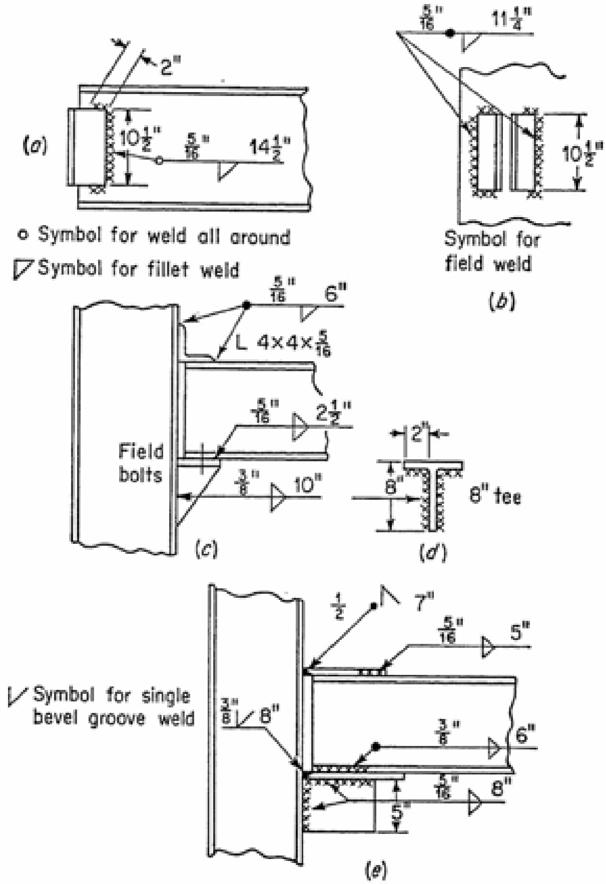


FIG. 8-1. Details of welded connections.

shows that a fillet weld is required. Then the dimension of 5/16 in. to the left is the size of the weld, and the remaining figure of 14½ in. is the total length of the weld on this side of the connection.

In listing the quantity of weld on the estimate, take twice the length of 14½ in., or a total of 29 in., for the amount of shop weld required.

The field connection is shown in Fig. 8-1*b*. The length of weld is 11¼ in. for each angle, the size of weld in this detail is 5/16 in., and the type of weld is a fillet weld. It is common practice to turn the weld at the top of the angle for a distance of twice the weld size. The figure of 11¼ in.

is therefore obtained from the total of the 10½-in. dimension plus twice ⅜ in. equals 11¼ in., so the field weld required is a total of 22½ in. for two angles.

Note that two holes will be provided in the angles and in the connecting member for field bolts. These bolts are used to secure the beam during erection and before welding. The specifications may require the

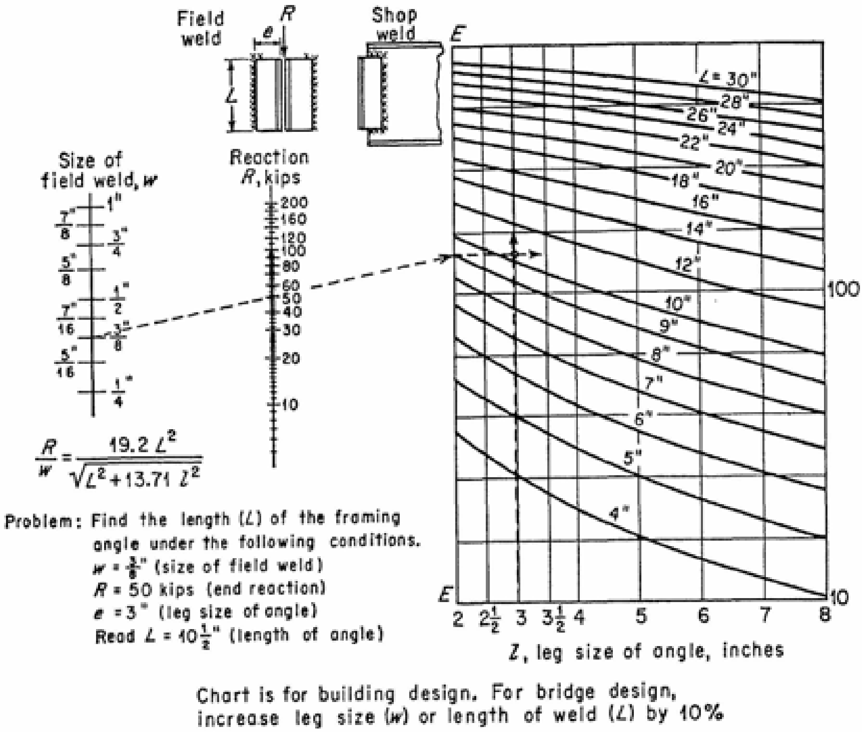


Fig. 8-2. Framing angles and size of field weld. (*Lincoln Electric Co., Inc., copyright* 1956.)

bolts to be spot-welded in place. The estimate should include bolts in the take-off unless it is company policy to do otherwise. For instance, the erector may be expected to supply these bolts, and he will then add the costs to his price.

Some specifications require that the erection bolts be removed and the holes be plug-welded, that is, be completely filled with weldment. This operation will add considerably to the cost of the erection.

8-5. Connections with Stiffened Seats. A column connection with a welded stiffened seat is shown in Fig. 8-1*c*. This consists of a top angle which is shipped loose and is completely welded in the field, with $\frac{5}{16}$-in. fillet welds as indicated.

The seat bracket is a tee section and is connected to the column flange in the shop, as shown in Fig. 8-1*d*. The welding symbol seen here indicates that welding will be ⅜ × 10 in. on each side of the tee. A double symbol of this kind means that both sides are to be welded alike.

Both the bottom flange of the beam and the top of the tee are provided

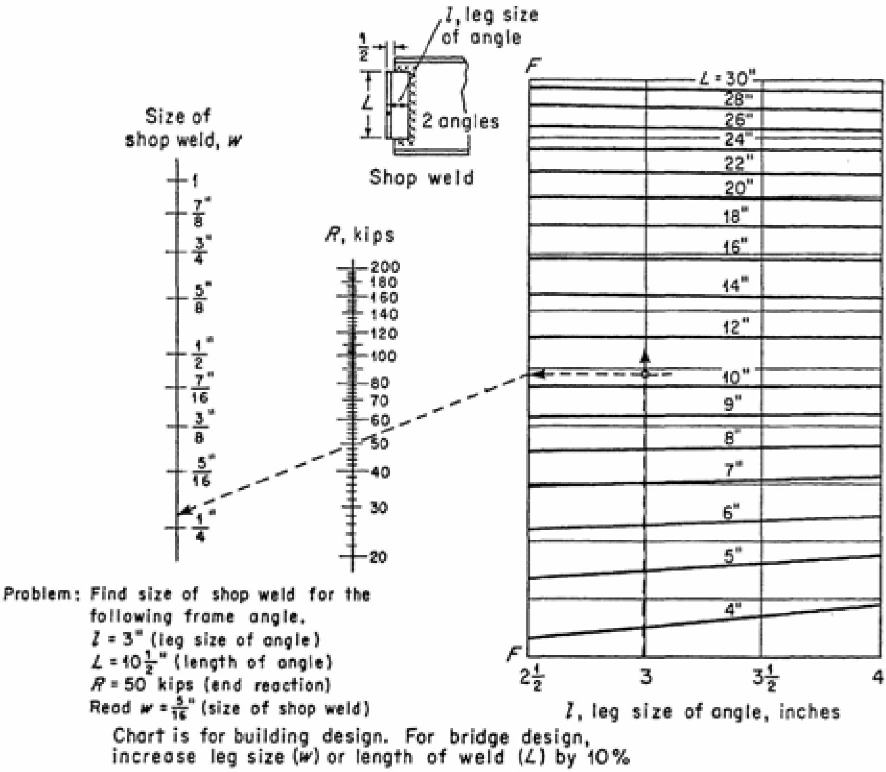


FIG. 8-3. Size of shop weld for framing angles. (*Lincoln Electric Co., Inc., copyright* 1956.)

with two holes for erection bolts. After erection the weld, as indicated, will be applied between the flange of the beam and the top of the seat bracket.

8-6. Moment-resistant Column Connection. The connection shown in Fig. 8-1*e* is a moment-resistant connection, a type which is frequently seen. The fillet welds may be identified by the symbol, which has previously been described. The symbol for the two butt welds is given in Fig. 8-1*e*. The material for connections such as these may have to be completely listed: in most cases the details will be specifically designed, as the fabricator's standard connections will not apply.

8-7. Nomographs. The Lincoln Electric Co., Inc., has prepared a set of nomographs which may be of considerable assistance to the estimator in obtaining sizes of material and the quantity and size of weld for many connection conditions. Several of the nomographs are included here (Figs. 8-2 to 8-7).

8-8. Other Conditions. Naturally, there are so many different conditions in respect to welded connections, including column bases and splices,

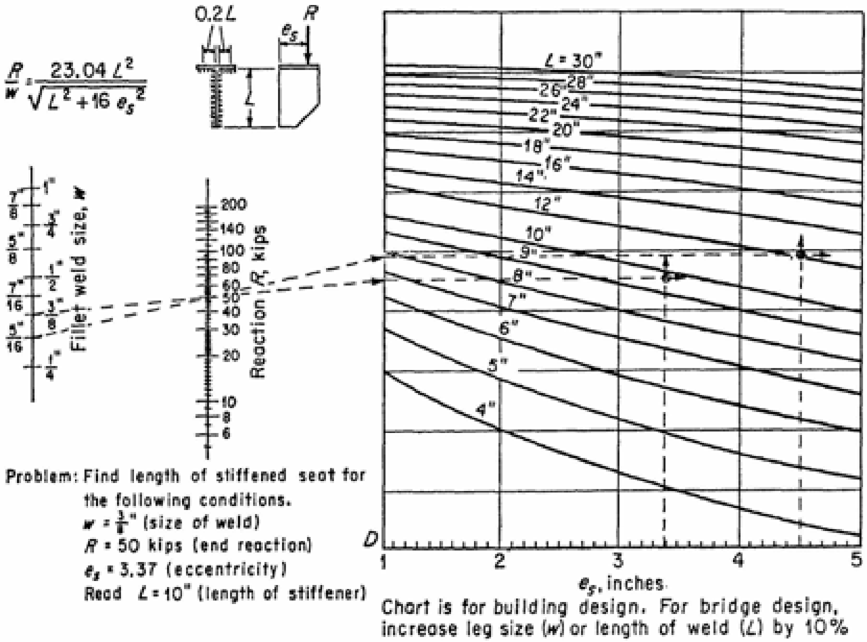


FIG. 8-4. Length of stiffeners and size of weld for stiffened seat. (*Lincoln Electric Co., Inc., copyright* 1956.)

that it would not be feasible to include them all. However, it should be noted that many cases require the use of stiffening or tie plates; a single case is shown in Fig. 8-8*a*. Also, another arrangement of a beam-to-beam connection is shown in Fig. 8-8*b*. Welding symbols have been marked on these drawings.

8-9. Economy of Welded Design. Many structures may be designed to afford considerable savings in the quantity of structural material required. However, it should be noted that the saving in material is sometimes partly offset by the additional shop labor necessary.

The Lincoln Electric Co., Inc., has furnished data indicating a saving in material by the use of rigid framed beams as opposed to simple beam framing. The two conditions are shown in Fig. 8-8*c*. The saving in material is 70 lb per ft less 48 lb per ft, or 22 lb for each foot of span. This,

of course, does represent a considerable saving. However, the estimator should note the difference in shopwork. It will be required to prepare the four stiffener plates between the flanges of the column, and these must be welded in place. The balance of the connection will probably be the same for each of the beams. These data are presented here, not with a view to criticizing the savings in welded design, but rather to caution the estimator to be prepared for a moderate increase in the shopwork.

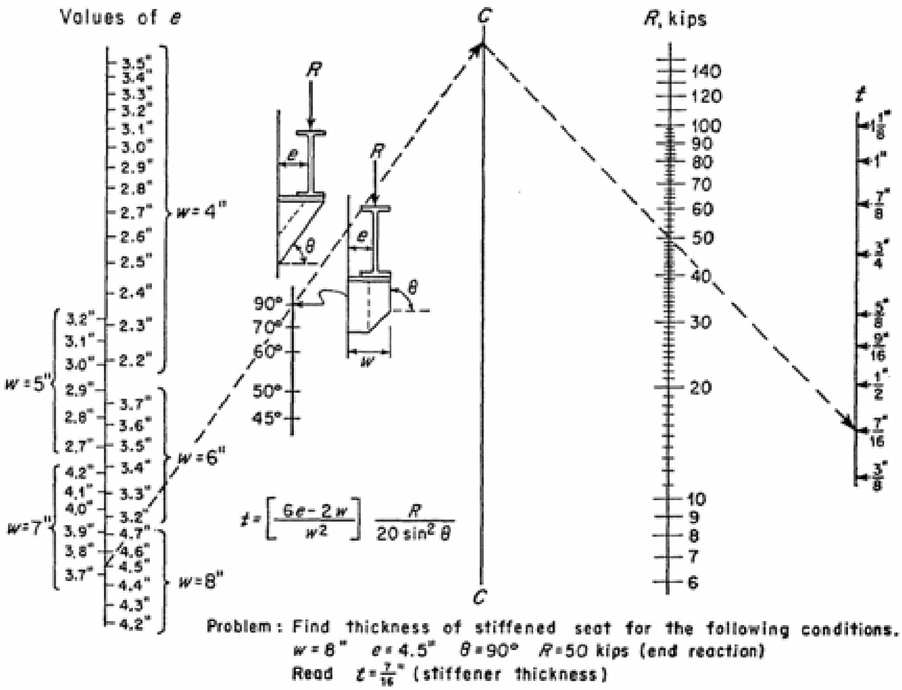


FIG. 8-5. Thickness of stiffened seat. (*Lincoln Electric Co., Inc., copyright* 1956.)

8-10. Welded Column Splices. Some details of welded column splices were given in Chap. 6, Connections. However, it is deemed advisable to expand the data in this chapter. A group of column splices are shown in Fig. 8-9. These sketches indicate several methods of splicing columns.

With the application of welding it is often possible to avoid drilling or punching the main sections of material. Figure 8-9*a* is a splice of two column sections each of which is a different size. The clip angles are attached to the column webs as indicated, and four holes are drilled in the cap plate to connect the two angles with field bolts. The field welding for the splice will be deposited as shown.

The splice (Fig. 8-9*b*) is made without the use of a cap plate. The connecting plates are all shop-welded, and the holes for the erection bolts

are punched or drilled in the positions as shown. In a splice such as this the upper section will have full bearing on the lower column section, and here again the field weld will be applied as indicated.

A quite similar condition obtains for the splices of Fig. 8-9*c* and *d*. The difference is in the use of four angles in each case to provide the

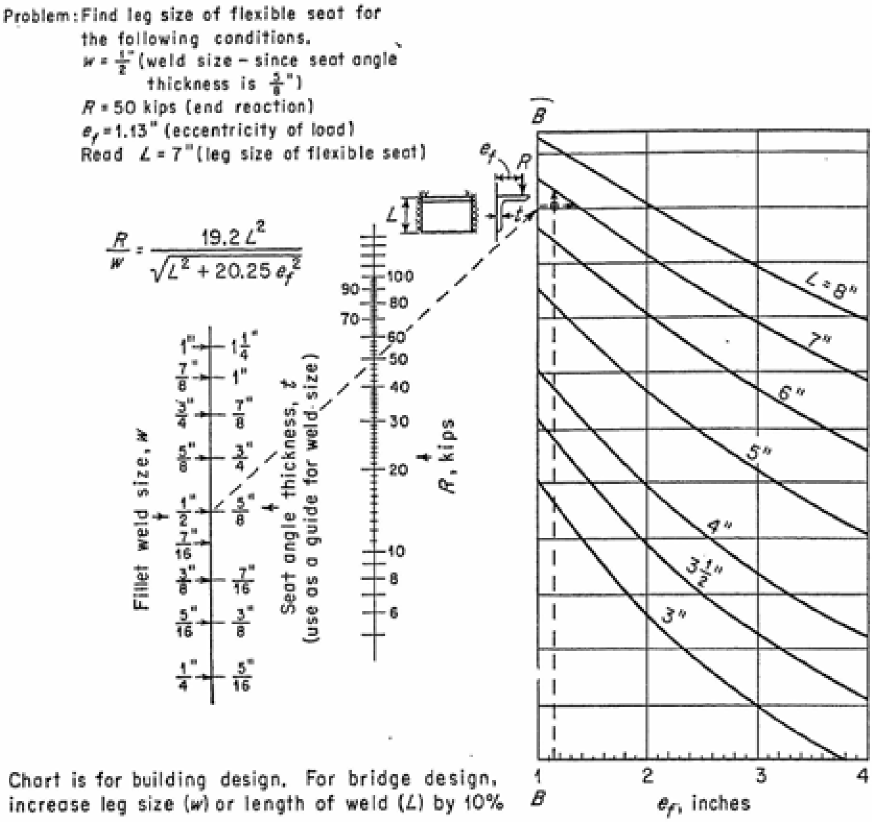


FIG. 8-6. Leg size of flexible seat and weld size. (*Lincoln Electric Co., Inc., copyright 1956.*)

temporary field connections. Here again all holes are through the outstanding legs of the angles, and none have been made in the main material.

Finally, Fig. 8-9*e* shows a connection in which there is considerable difference between the sizes of the upper and lower column sections. Splice and filler plates are used in this design. The splice and filler plates are shop-welded to the upper column section. This is done because of the higher welding speeds possible in the shop, where the column can be welded in a flat position instead of upright. Drilling or punching of

the holes for erection will be done in this case through the flanges and web of the column.

8-11. Examples of Connections with Stiffener Plates. The group of sketches of Fig. 8-10 show the cover plates which are added at the ends of the beams to carry the extra negative moment and which must be welded to the column for continuity. A detail of this section is shown in Fig. 8-10*a* and *c*.

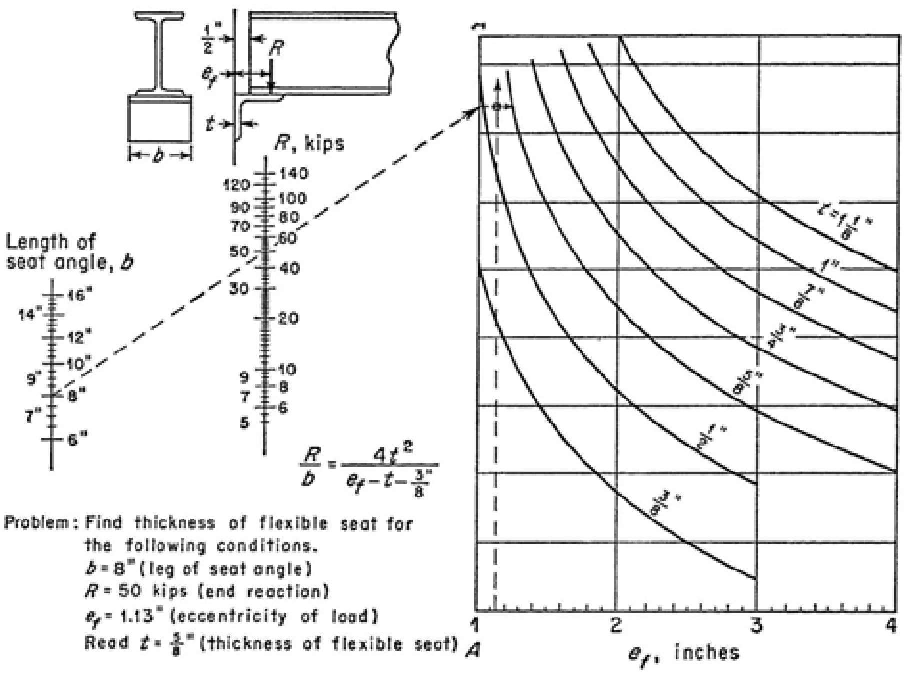


FIG. 8-7. Thickness of flexible seat. (*Lincoln Electric Co., Inc., copyright* 1956.)

In the detail of Fig. 8-10*d* the heavy stiffener plates are replaced by two lighter plates, each having half the thickness of the corresponding heavier plate. This permits working with lighter connecting material and using two butt welds half the size of the single butt weld. An estimator will not be particularly concerned with the difference in these two designs but must be sure to include the amount of weldment and fabrication costs.

8-12. Welded Plate Girder. A welded plate girder is shown in Fig. 8-11. This girder consists of a web plate 50 in. deep and two 16-in. flange plates. The length of 30 ft 0 in. normally will not require splicing in either the web or the flange plates. The only remaining material will be the stiffener plates. Unless otherwise indicated, the stiffener plates will be in pairs, that is, on either side of the web.

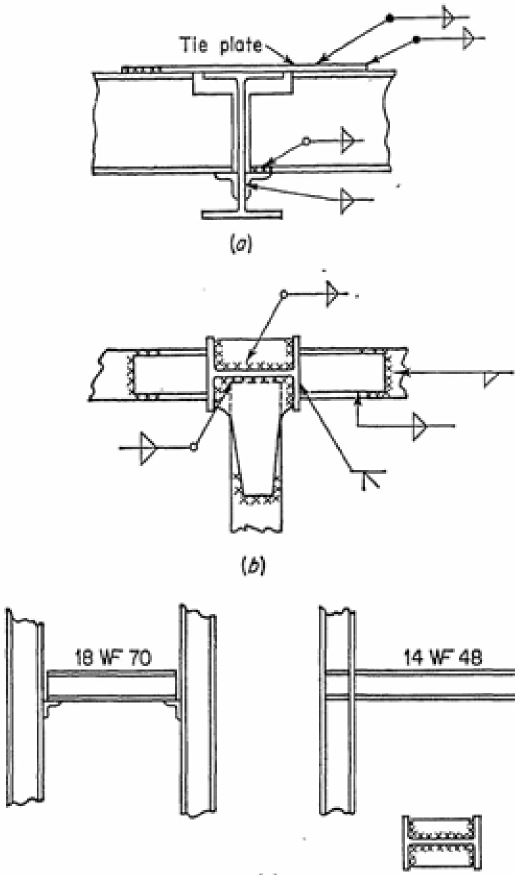


Fig. 8-8. Welded-connection details and design comparison.

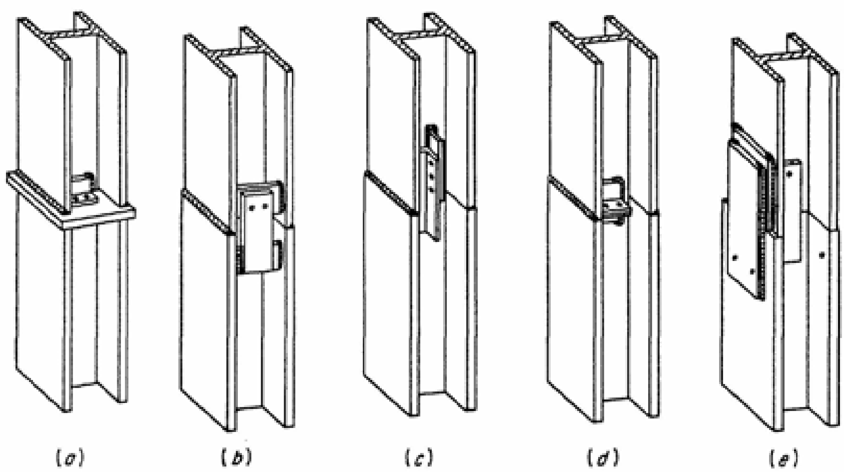


Fig. 8-9. Examples of column splices. (*Lincoln Electric Co., Inc., Studies in Structural Arc Welding* 143, *AIA File* 13 C-2.)

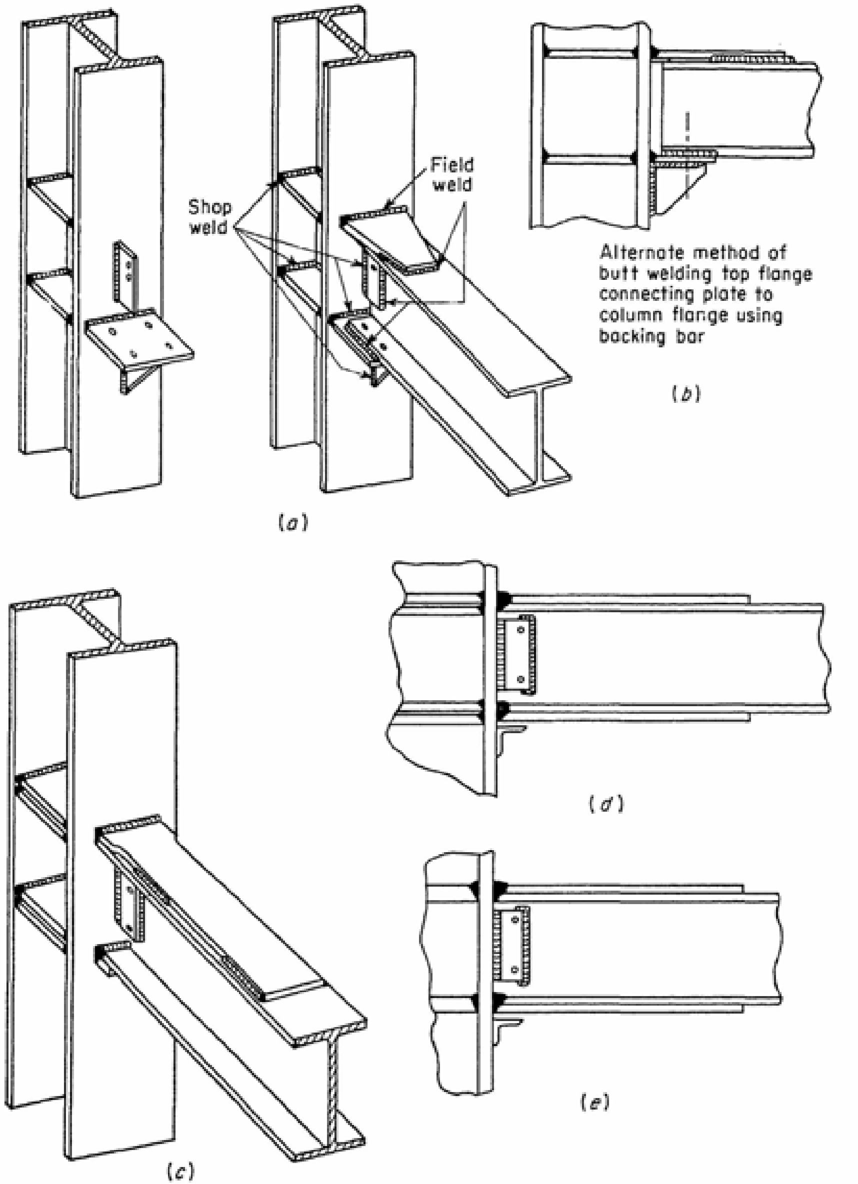
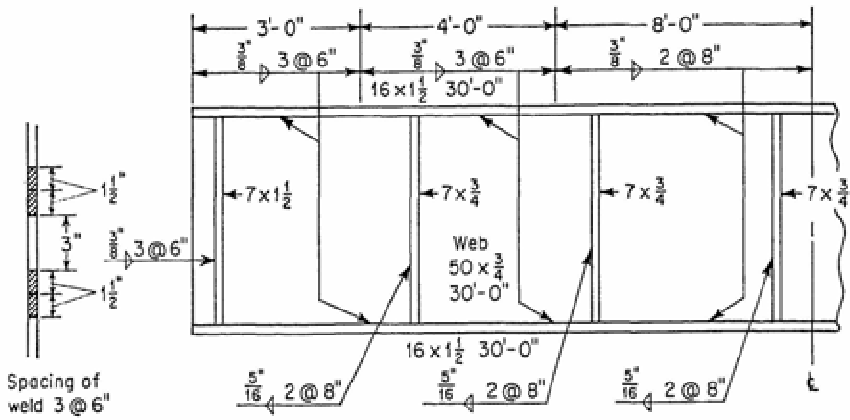


FIG. 8-10. Examples of stiffened connections. (*Lincoln Electric Co., Inc., Studies in Structural Arc Welding* 143, *AIA File* 13 *C*-2.)

A take-off of this plate girder is shown in Fig. 8-11. The listing of material follows normal procedure. The main material is listed first, followed by the minor or detail material. The length of end stiffeners is sufficient to permit a tight bearing fit with the flanges, but the length of the

intermediate stiffeners does not provide for bearing, hence the different lengths. It is usual for the estimating drawings to indicate the difference between the requirements of stiffeners, and the estimator should observe this and enter the information on the take-off as required.



No.	Material	Weight	Length		
Estimate No.			By Date	Sheet	
1	50 × ¾		30′-0″		
2	16 × 1½		30′-0″		
4	7 × 1½		4′-0″		
12	7 × ¾		3′-10″		
	shop weld				
	48′-⅜″				
	12′-⅜″				
	30′-5/16″				

Fig. 8-11. Take-off of welded plate girder.

Fitting of the bearing stiffeners will be required and will be an additional shop cost. The quantity of shop weld is indicated in the schedule in Fig. 8-11.

8-13. Welding Symbols on a Plate-girder Detail. The welding shown in the detail of Fig. 8-11 is intermittent. As indicated in the small detail to the left of the drawing of the girder, a weld spacing as shown of 3 at 6 will be a series of welds, each 3 in. in length and at a spacing of

6 in. center to center of welds. The figures of ⅜ in. and $\frac{5}{16}$ in. refer, of course, to the thicknesses of weld, and the symbol indicates welding on each side.

The reader may have noted the difference in material requirements between the riveted and the welded plate girders. In the design of the flanges the material will be one section of plate in place of two or more angles and the cover plates, as required. In regard to the flange plates of welded girders, where the loading conditions require it, the thickness will be increased and also the width if necessary. The stiffeners will be plates instead of angles and the quantity of this material proportionately reduced.

8-14. Heavy, Long Girders. There are many factors involved in estimating a long, heavy welded plate girder, and considerable costs will be involved in many of the shop operations, particularly on bridge work. It is not practical to include drawings of the many possible designs of welded girder work—it might even tend to be confusing to do so. Instead, several of the major points will be described in this text.

Perhaps it may be necessary first to consider the maximum size of section that can be handled in the shop or in the field. The matter of room in the shop, the lifting equipment, and the maximum reach of tools such as punches or drills must be considered. Conditions at the site, transportation, clearance, limits of reach and lift of the erection equipment are other factors involved after the shop considerations.

When the maximum size to be fabricated or shipped is determined, the estimator will know where splices should occur and will provide the necessary information to the erector or will indicate the shopwork on the take-off. There are size limits on all plates as shipped from the mills. Some of the plates may be supplied in very long lengths, but as certain dimensions increase, the lengths may conversely decrease.

The estimator employed by the fabricator who has an average-capacity shop may be obliged to consider a maximum section of 100 ft or under, whereas, in some of the major shops, pieces much larger may be fabricated. It will be presumed that all estimators will know or be informed of the maximum sizes possible at the plants where they are employed.

In proceeding with the take-off of a welded girder it is suggested that the web plates and cover plates be the first items listed. Many designs, particularly those of bridge work, may indicate continuous welding to connect the web to the flanges.

Some designing engineers will require and will indicate groove welding for the connection between the web and flange plates. Note this carefully, for groove welding will usually require much more deposited weld metal and cost more than the simpler fillet welding.

The next consideration may be the splices in the web and flange ma-

terial. These will be, in practically all cases, butt splices. Look for quite large splice weld areas on the flanges, as it is not unusual to see material in the flanges changing from, for instance, 3 in. thick to 2 in. thick, and so on. The amount of welding necessary for a condition such as this will naturally be quite high and will be estimated accordingly.

On bridge work the welding indicated for stiffeners or diaphragm con-

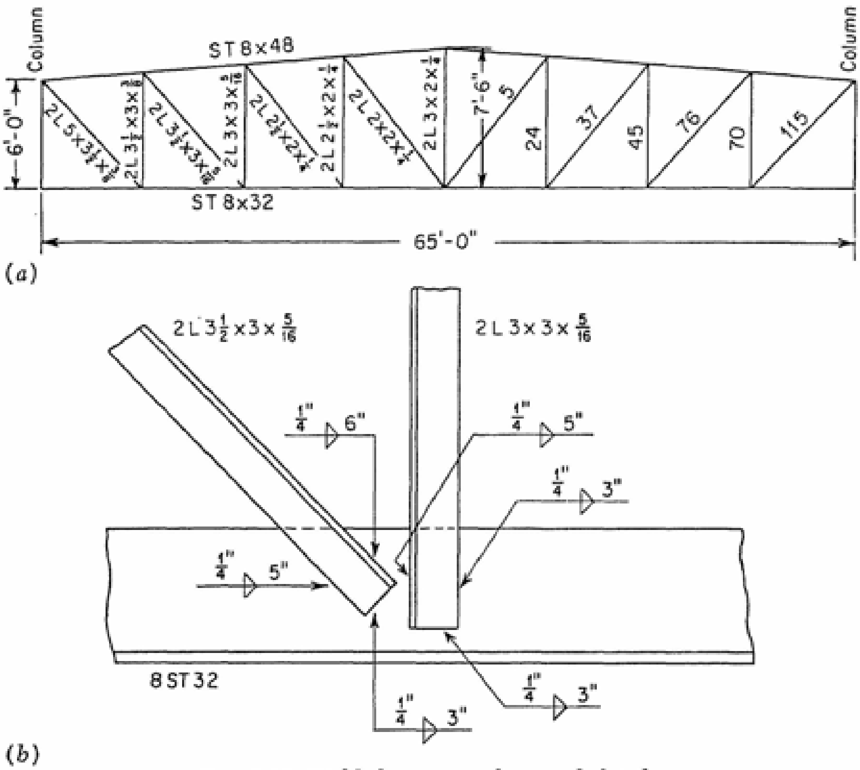


FIG. 8-12. Welded-truss members and detail.

nections may be continuous welding. A type of bridge stringer is known as a composite I-beam bridge. The design of this type of structure combines the value of part of the concrete slab with the value of the steel and provides a saving in weight of the steel.

In most cases the steel beam will be a very heavy WF section, perhaps 27 to 36 in. deep. Cover plates may be required; if so, they will be placed on the bottom flange of the beam. The welding of cover plates to the beams will in most cases be continuous.

8-15. Welded Trusses. Types of welded trusses are shown in Figs. 8-12 and 8-13. Often there are considerable savings in material on a welded design. Many welded trusses will be so designed as not to require gusset plates, a very considerable saving in material.

The truss of Fig. 8-12*a* has the top and bottom chords made from tee sections, and the web members are angles. This makes for a very practical design for a truss of average span and with average loading. The development of the welding required at one of the points of a truss is

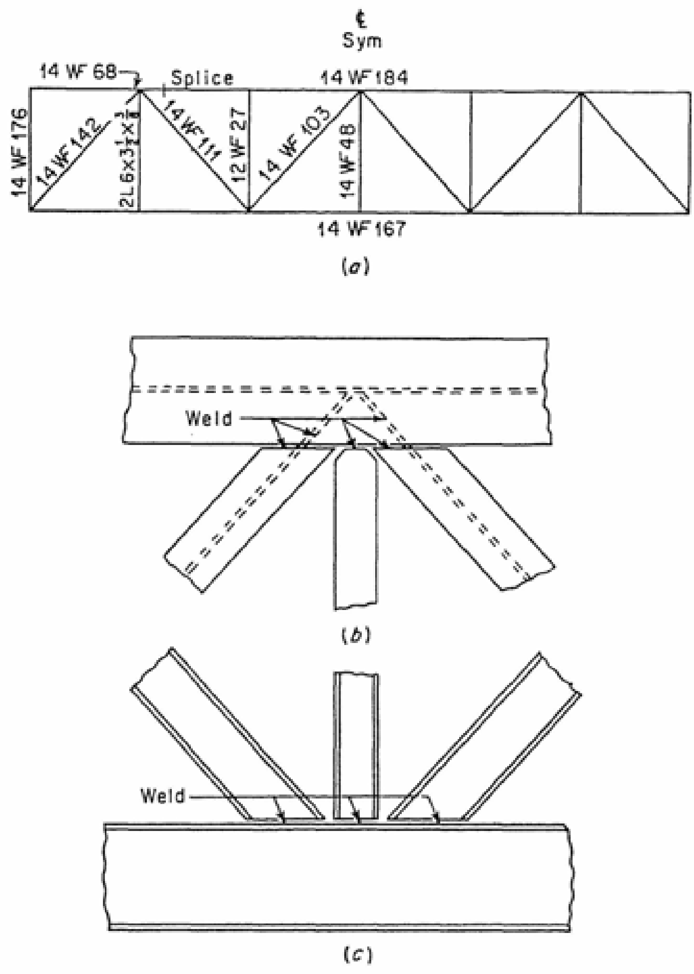


FIG. 8-13. Heavy welded-truss members and details.

shown in Fig. 8-12*b*. The take-off of the truss of Fig. 8-12*a* should not be difficult as far as the material is concerned. Some small number of gusset plates may be required to provide sufficient room for the amount of welding necessary for connecting the larger web members. Some estimators prefer to include an item of weight for small detail material at 3 to 5 per cent of the weight of main material.

Where the panel points have been shown in detail on the estimating

plans, the quantity of weld may be obtained from the figures on the plan. When the size and quantity of weld are not shown, the estimator may use standard percentages supplied by the fabricator.

In the event that the estimator wishes to use an approximate figure, this may be obtained by dividing the stress in the member by a factor of 2.4 and the result will be the length required of the $\frac{1}{4}$-in. fillet weld. The factor value is obtained from the assumption of 0.6 kip per $\frac{1}{16}$ in. of fillet size, that is, $\frac{1}{4}$ ($\frac{4}{16}$) in. equals 4×0.6 equals 2.4.

8-16. Heavy Welded Trusses. The usual material in the heavy welded trusses will be WF sections. One of this type is shown in Fig. 8-13*a*. The material is all 14 WF sections except in two instances, one where two angles are used and the other a 12 WF section.

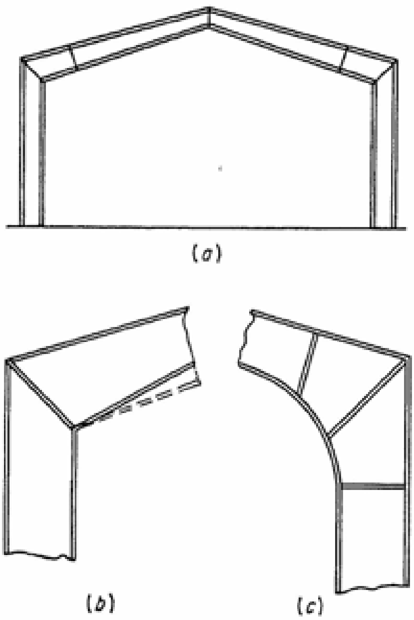


Fig. 8-14. Types of rigid-frame construction.

The usual method in regard to these angles is to spread them apart with batten plates. A 12-in. channel may have been used for this member, which would require less shopwork than that required for the angles. This choice, however, is up to the designing engineer, and the estimator will list the material as noted on the plans.

It is very difficult to make an accurate estimate of a heavy truss unless the design includes details of panel points or unless the estimator elects to sketch details from the load data which may have been included on the estimating drawings. Gusset plates may or may not be required, depending upon the detail selected.

Two methods of connecting the members of the truss at a panel point may be seen in Fig. 8-13*b* and *c*.

In the first of these details (Fig. 8-13*b*) the flanges may be cut as indicated and the web of the diagonal brought through to the web of the horizontal member. Another method would be to connect the web of the diagonal to a plate, which in turn is connected to the web of the horizontal. The detail of Fig. 8-13*c* indicates a condition where the members of the truss have been turned in a direction other than that of Fig. 8-13*b*. With this arrangement it may be possible to use more fillet weld-

ing in the connection, whereas considerable butt welding is required with the detail of Fig. 8-13*b*.

It will be observed that the details of heavy trusses are not simple. Considerable information and detail are needed in order to complete a reasonably accurate estimate.

8-17. The Rigid Frame. The rigid frame is a development of modern design and will usually provide a saving in cost of the structure, have a very neat and clear appearance, and allow a saving in headroom.

Fig. 8-15. Rigid-frame structure. (*R. C. Mahon Co.*)

A designer will have a very wide choice of design in a rigid-frame structure. Figure 8-14*a* represents a practical and simple type of rigid frame. It may consist of four beam sections; as indicated, one flange of each of the beams has been cut and bent back, and a plate section is cut and welded to the flange and web of the beam. This frame may be sent to the site in either two or four sections, depending upon the transportation limitations. It is usually necessary, however, to supply field splices at the end of the bracket, as indicated by a dotted line in Fig. 8-14*a*. This arrangement will allow most of the welding to be done in the shop and with the sections in a flat position.

The rigid frame may be fabricated of three plates much like a welded girder. When a WF section is designed, the web may be tapered by cutting or burning a portion of the web close to the flange, removing a wedge-shaped section from the web, and welding back the flange to the remaining web, as indicated in Fig. 8-14*b*. The estimator will include each of the items of shopwork in the estimate, burning or cutting, bending, and welding.

The section of a rigid frame of Fig. 8-14*c* indicates stiffeners. Stiffeners occur in connection with the design of many rigid-frame structures.

A partly completed rigid-frame structure is shown in Fig. 8-15. In the right background there are partly completed frames. A good idea of the column, or vertical, section will be obtained from this figure.

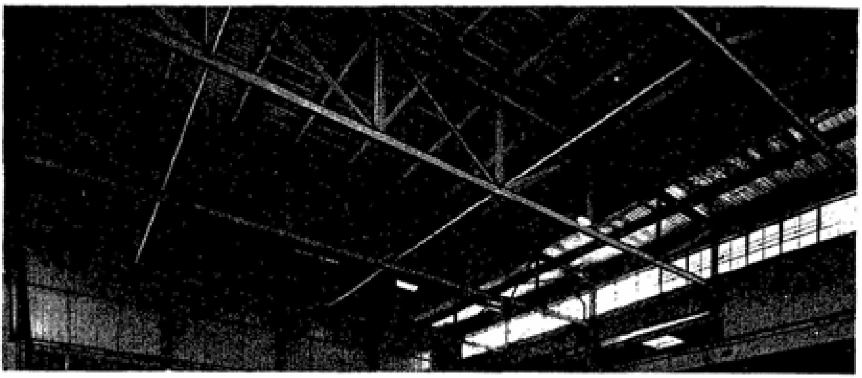


FIG. 8-16. Welded trusses in structure. (*Underwriters' Laboratories, Inc.*)

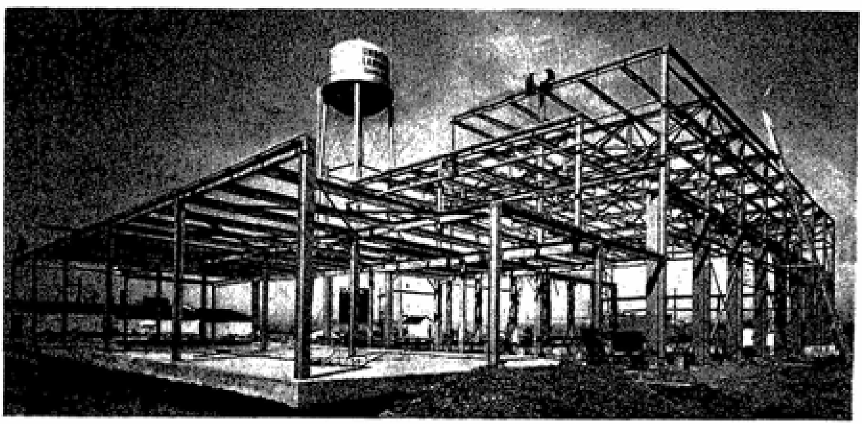


FIG. 8-17. Welded-truss framing. (*Underwriters' Laboratories, Inc.*)

The trusses which can be seen in Figs. 8-16 and 8-17 are welded trusses. These trusses have been designed and fabricated without the addition of gusset plates. This saving of material was explained earlier in the chapter.

An additional view of welded trusses can be seen in Fig. 8-18. The figure also shows bracing, and a clear view may be had of columns composed of a crane-supporting section along with the upper, or truss, column. Also shown is the heavy column-base material. At the left side

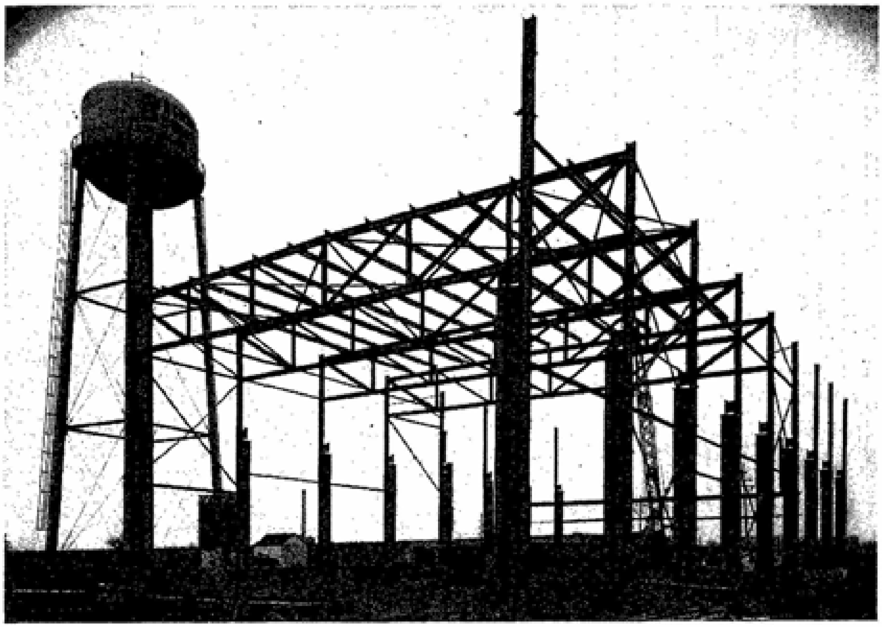


FIG. 8-18. Built-up column sections. (*Underwriters' Laboratories, Inc.*)

of the figure is seen a ladder cage. This cage and ladder is at one leg of the water-tower support. A ladder cage is provided as a safety measure for the personnel required to ascend the tower. It consists of circular sections, which are curved bars, and vertical sections, which are also bars.

CHAPTER 9

Typical Structures

9-1. Introduction. Structural framing may be divided into certain general classes according to the buildings for which it is employed. A list of the more usual structures follows:

1. Office and loft buildings
2. Schools and colleges
3. Hospitals
4. Apartment houses
5. Stores
6. Public buildings
7. Warehouse and mill buildings
8. Powerhouses
9. Hangars
10. Bridges
11. Conveyors and gantry cranes
12. Other structures

Each of the above will be considered in turn, and any particular construction required or special condition which may occur will be explained.

9-2. Office Buildings. Framing and Foundation Material. Office buildings, in general, are multistory structures. Many of these structures have banking quarters or stores on the lower floors, and framing at this point will be considerably different from that of the office floors.

An office building is shown in Fig. 9-1. When the foundation material consists of slabs, these will be medium weight to very heavy. The estimator will follow the procedure outlined in a previous chapter for the proper listing of slab material and also the indication for milling, together with the additional thickness for the milling. There may be leveling devices attached to the slabs; if so, these will be included in the estimate for both material and the necessary shop costs.

The framework at the right rear of the structure will, of course, be recognized as the temporary support for the material hoists. The framing at the top in the derrick area will be for support of the house water tanks.

9-3. Column Schedule. Following the usual procedure, the material next listed will be all the columns and column fittings, including the column base material and the splice material. The average column design for an office building, such as seen in the figure, will have many groups of columns which will be alike and which will be combined in the take-

off. However, the columns on each lift (usually for each two floors) will be listed completely before proceeding to the next higher lift. Usually, there is a progressive reduction in the weight of the columns, and by keeping each lift separate a check of the several groups of weights may be made in the event that a check is necessary. The total number of column sections in each lift is checked by comparing the total pieces on

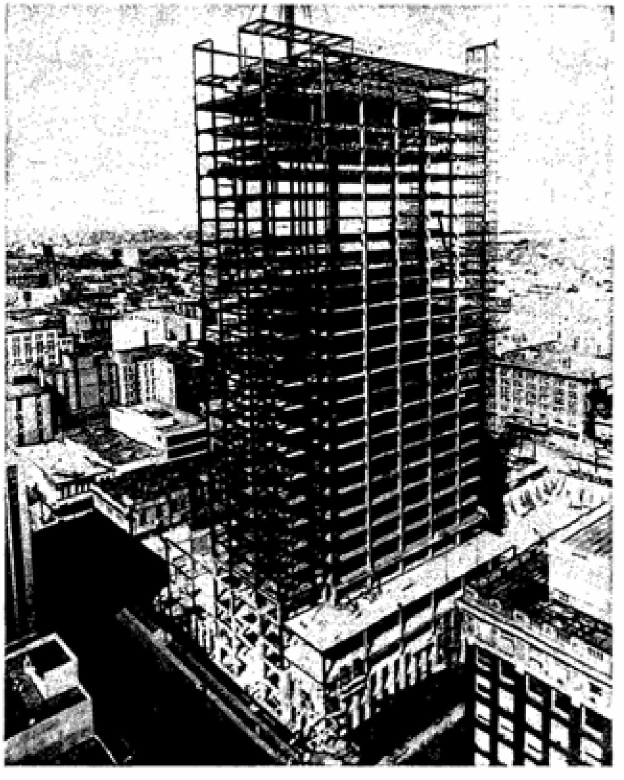


FIG. 9-1. Office building. (*American Bridge Division, U.S. Steel Co.*)

that portion of the take-off with a count of the sections in the similar portion of the column schedule.

Where there are built-up columns, that is, columns composed of WF sections and cover plates or columns composed of several sections such as four angles and a web plate, the estimate must include the quantity of fastening materials. This may be the number or percentage of rivets or the quantity of welding required.

After all column material has been entered on the take-off, the number of field bolts or rivets is included in the estimate. In the case of welded work, then include the weight of welding rod and the amount of welding to be done in the field.

9-4. Floor Framing. After the column schedule is completed, the take-off of the steel on each floor is made. It is very important to note carefully where several similar floors are combined. A good method is to note, at the head of each sheet, that several floors have been combined and are being listed.

For example, take a case where floors four to ten are typical. The reference at the head of the page will indicate that the take-off is of the fourth to the tenth floor. Alongside this entry place the figure 7 in brackets. Then at a point near the bottom of the page write "times 7." When the notations are made as suggested here, the possibility of error is considerably reduced. The error of failing to multiply the take-off of one floor by the total number involved, while not a frequent one, will happen occasionally, and all precautions should be taken to avoid errors.

It may appear to some readers that too much stress is placed on accuracy and checking against possible errors in the estimate. However, there would be little value in going to the expense of producing a figure which could not be fully accepted as entirely correct.

9-5. Bracing and Wind Bracing. Nearly all tall and comparatively narrow buildings such as the one pictured in Fig. 9-1 will require stiffened or wind-bracing connections. It is general practice for the estimating plans or the specifications to indicate that wind-bracing connections will be required. As previously stated, the wind-bracing details will be worked out on the plans or may be in a group tabulation on one of the drawings.

The structures above the roof which may support the elevator machinery, water tanks, and air-conditioning equipment are often constructed of angle framing. This framing may require either knee braces or diagonal bracing. The bracing may be indicated only by single lines and notes on the plans. Simple angle lintels may also be noted at the upper sections of an office building.

9-6. Open Areas. An example of the type of framing for a banking area may be observed in Fig. 9-2. There is nothing particularly difficult in estimating the steel in this part of the structure, but it should be noted that it is usually composed of heavier sections as compared with the balance of the framing.

The floor plans may not be fully dimensioned, and it will frequently be necessary to use a scale to obtain the lengths of the sections where sufficient dimensioning has not been shown on the drawing. An area such as that under consideration often may not be fully dimensioned. In many office structures there may also be stock-exchange floors and commodity and other trading floors. The space provided for these services usually will be a wide-open expanse with high ceilings. When these trading floors are at the lower part of the structure, the design will show heavy

girders or trusses at the elevation of the ceilings of the trading floors. The girders or trusses will support office floor columns and the framing over the open area. It will be noted that usually the girders or trusses are a heavy type and it may be necessary to provide openings in them for the passage of people. The girders otherwise would reduce the use-

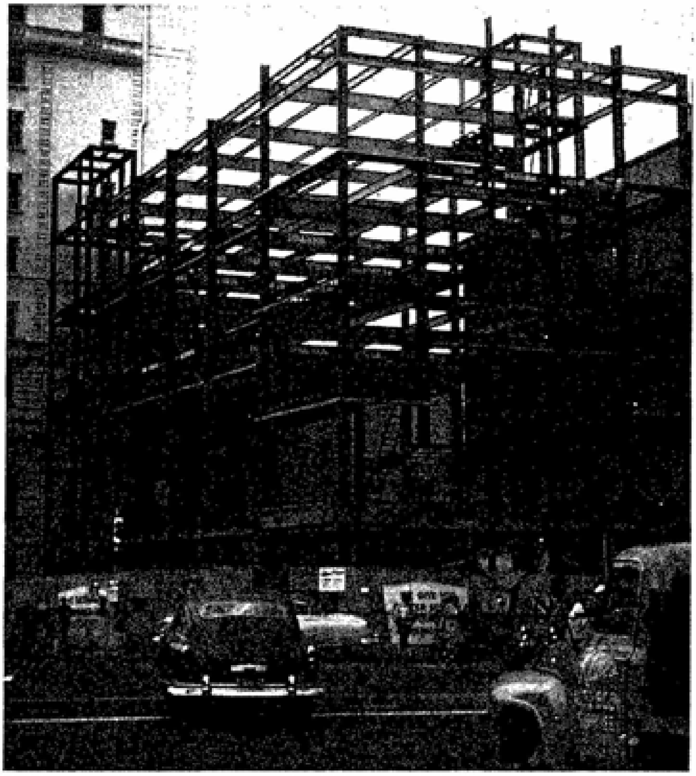


FIG. 9-2. Bank building. (*Lehigh Structural Steel Co.*)

fulness of that floor. In addition to the usual girder details the estimator will note the special framing round the openings in the girder.

There will be cases where office buildings are built above streets. Here again the upper floors will be supported on girders or trusses.

9-7. Provision for Air Conditioning. In the modern office building which is provided with air conditioning other than the separate window or floor unit conditioner the design will usually include openings through the deeper beam and girder sections for the passage of the air ducts. The estimator must be alert to this situation, as in many cases the identification may not be clearly shown. The floor plan may have a symbol representing an opening at a point on the framing where the duct is to

be located. The structural framing plans will rarely show the actual layout of air ducts. The proper quantity of material and the shop costs for the additional work round the openings in the beams must be included in the estimate.

A shelf angle is an angle attached to the web of a beam. There are

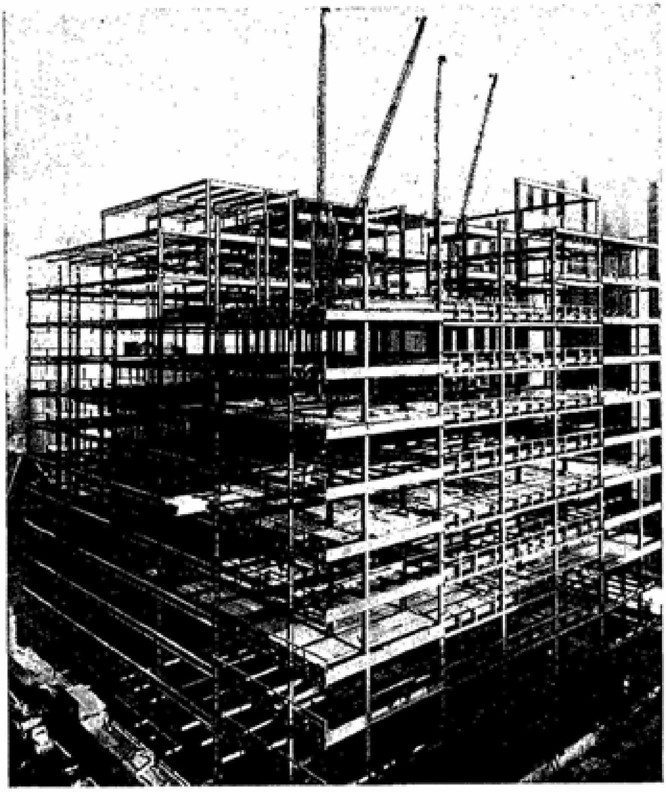


Fig. 9-3. Office-building spandrels. (*Lehigh Structural Steel Co.*)

conditions where a section of the floor may be required to be lower than the adjacent area. To provide for this situation, angles may be attached to floor beams. The estimator will include the necessary angle material and fastening material. The work of attaching the shelf angles is a shop operation.

9-8. Spandrels. Exterior walls generally have lintels or spandrels where windows or openings occur. The lintel is a single angle or a built-up section of angles or other structural members such as a plate and channels. Lintels do not usually connect to the steel framing. Lintels and spandrels both are provided to support the masonry or stonework. Spandrels are usually connected to the steel framing.

Details of some types of spandrels and lintels were included in a previous chapter. In Fig. 9-3 spandrel framing may be seen. Here some of the spandrel framing also combines window framing. A design of this nature considerably increases the fabrication and erection costs.

The details of wall framing are most generally shown by a series of sections which are drawn to a larger scale than the floor plans and which must be carefully studied before being listed on the take-off. All the material for the main members will be included, and all the smaller detail material provided for connections and supports must be added, as well as the proper quantity of fastening material.

Examine the plans very carefully for all sections round the exterior. It may be that the sections are all included on a separate drawing. Various means of identification are used by engineers to designate a section cut through a part of the framing.

The reader should not become confused by the use of the word "section." It is used to describe not only the structural shapes but also a part separated or a detail to clarify the several components making up an assembly.

9-9. Window Framing. In any office building, the framing round the window openings, other than the spandrels, may or may not be supplied by the steel fabricator. Figure 9-4 shows a structure in which perpendicular framing may be seen at the window openings. When framing such as this is furnished by the fabricator, both the shop and the erector may be held to very close tolerances. This means more expensive operations.

The supports for the elevator cars are called "sheave beams," and are usually supplied by the elevator contractor. However, when shown on the estimating plans, they must be included in the estimate or an exception must be entered on the note sheet.

Specifications or proposals for an office building may indicate that the structural fabricator is to supply the steel stack or furnace flue and/or the water tanks. When so specified, these must be estimated. Otherwise the cost for the items to be furnished by a subcontractor must be included in the estimate.

9-10. Cantilever Construction. Figure 9-3 shows cantilever framing at the corners of the building. It will be noted that the framing is a continuation of beams connecting the two columns. The connections for cantilever construction will usually be heavier than for the other framing. Also, some milling may be required for sections bearing on each other.

Many office buildings will have floors of cellular construction or other kinds of metal forms. While not the concern of the average fabricator, they will be part of the material supplied by those companies engaged in the supply and erection of this type of material.

9-11. Suggestions for Checking. In the event that the estimator or fabricator may be interested in having a check made of the take-off, a few suggestions will be made here.

The weight of each floor and the roof, including the proper column material, is tabulated. (Add half the weight of each lift of column to the respective floor framing.) There will be a definite progression of

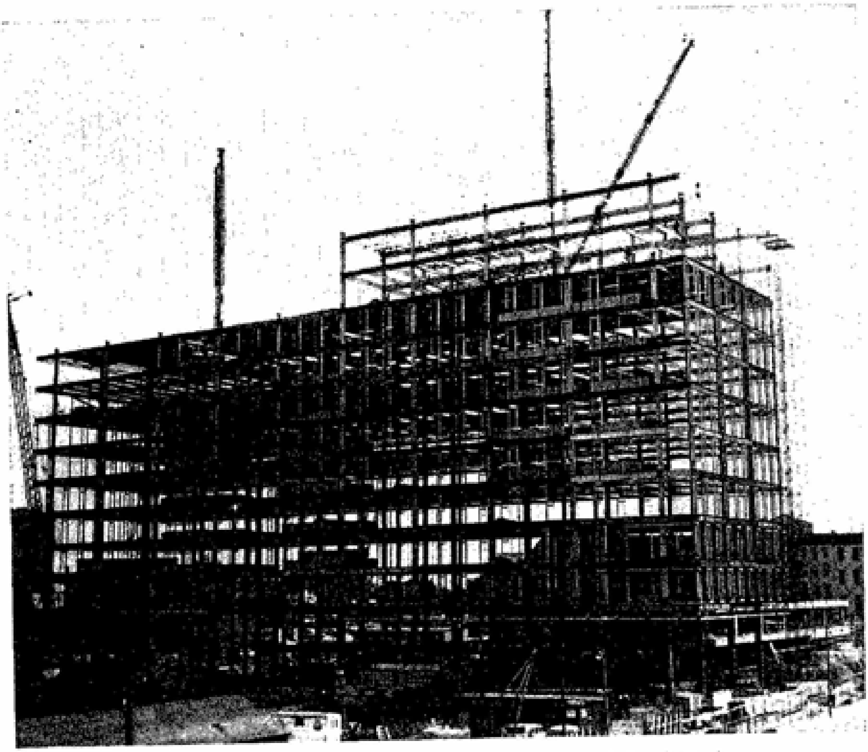


FIG. 9-4. Window framing. (*Lehigh Structural Steel Co.*)

weight except in the cases where there is heavy girder or other framing on one or several of the floors. Any noticeable deviation in weight will indicate that a more complete check of that part of the take-off is advisable. There is also a relationship between the total weight of columns and the total of the beam framing. In an average office building the columns will account for about 35 to 40 per cent of the total weight of the structural-steel frame.

An estimator may also wish to draw up a set of reference tables and may include in these tables the weight per square foot of the structure, the weight of beams per square foot of structure, the weight per square foot of column, the percentage of detail material, the number of pieces

per ton, the number of field bolts per ton, the number of field rivets, and the quantity of field weld if welding is used.

9-12. Check List. Many estimators have found check lists very valuable assets. Some fabricators have printed forms containing a list of items any or all of which may be required for a specific estimate. Check List 9-1 is a general one, much of which will apply to the take-off.

Check List 9-1. Items Required in Construction of Office Buildings, Schools, Hospitals, Shopping Centers, Public Buildings, Loft Buildings, Colleges, Stores, and Apartment Houses

Base plates	Dormer framing
Setting plates	Hip-and-valley roof framing
Slabs	Plate girders
Grillages	Trusses
Anchors	Spandrels
Shims	Lintels, exterior
Leveling devices	Lintels, interior
Columns	Window framing
Splices	Door framing
Column fastenings	Sheave beams
(Rivets or weld for built-up columns)	Tank supports
	Stack or flue
Beams	Tanks
Cover-plated beams	Rivets
Connections	Bolts
Diaphragms	Welding rods
Separators	
Wind bracing	Aluminum
Other bracing	Galvanizing

9-13. Loft Buildings. The word "loft" is generally used in connection with a large open area, such as a sail loft or hayloft, that is, areas having floors in which there are no partitions except possibly some small office sections. In many of the larger cities, where space is limited, much of the light manufacturing and storage is housed in loft buildings. The loft building of the type now under consideration is a multistory building with heavier floor systems than those of an office building.

Owing to the type of operations usually conducted in a loft building the loads assumed for the purposes of design will be moderately high. In the AISC Manual will be found tables listing the minimum live loadings for many kinds of structures. (U. S. Department of Commerce. From American Standard Building Code Requirements A 58-1, 1945. National Bureau of Standards, sponsor.)

The minimum live load for office-building offices is 80 psf (lobbies 100

psf), and the live load for loft buildings is 125 psf. Consequently with a minimum live-load requirement of more than 50 per cent above that of an office building the floor-system framing will be proportionately greater.

The pattern of framing for a loft building will usually be very simple, consisting of a series of regular spaced bays. Truck-loading areas are sometimes provided at the street level, and here, of course, the supporting framing will be heavier than that of the upper floors.

It should be noted that at the present time the multistory loft building is becoming less popular. Instead of being located in the more populous areas of a city the manufacturing plants are being located out of town. In locations where the ground cost is not prohibitive the buildings will be single-story structures covering considerable land area.

9-14. Types of School Buildings. There are, generally speaking, two types of school buildings. One type of structure will be found in larger cities, where the valuation of property is high and the amount of land available is limited, unless other buildings are removed to obtain the necessary space. The second type will be found in sections where considerable ground area can be obtained.

Schools which are built in cities are elementary classroom buildings and specialized vocational schools. Elementary schools may have, besides the regular classrooms, other areas for auditoriums, gymnasiums, and cafeterias or lunchrooms. Moderately light structural framing will occur at the classroom area. The minimum live load for school classrooms is half that of an office building, or 40 psf. The minimum for the corridors is, of course, greater.

The estimator will have to be very alert in preparing estimates for schools, as there will be many different member sizes and lengths. It will usually be necessary to scale many of the sections to obtain the length, as many engineers do not place all dimensions on the design drawings. In using the scale it is suggested that a check be made of a dimensioned distance to make sure that the drawing has been carefully laid out to the indicated scale.

The average school building will contain much miscellaneous framing, such as that round stairways and duct openings. It frequently will be required that the stair stringers be included. The stair stringers are the structural members at each side of the stair run. The stringers may have angles attached to support each tread, and material and labor will be included in the fabrication costs when stringers are furnished.

Most schools stand clear of other buildings, and there will be window openings on all four sides. The supports for the masonry over the openings will require special study to be sure that all the indicated material with fastenings and details is included. Shelf angles may be attached to

the outside flanges of the columns to support masonry at that point. There also may be anchors or bent rods affixed to the beams and columns for attachment to the masonry.

There is a tendency among some architects to require part of the material for the spandrels to be galvanized, and sometimes the use of aluminum sections is indicated. Reference should be made on the note sheet regarding the requirement of aluminum or galvanizing, and the proper costs must be added. In the case of galvanizing, where there is no galvanizing department in the plant, a figure must include the loading and shipping to and from the galvanizing contractor as well as the cost of the work. Extra material costs will be involved with the use of aluminum, but the structural fabricator may perform the necessary shopwork on the aluminum sections.

In some municipalities the use of screed angles will be indicated on the plans. These are small angles of short lengths, cut diagonally along the length of the angle. They are placed in the soft grout at the pier or concrete base and are leveled before the grout is set. This will provide a level setting for the column base materials.

9-15. Auditorium Framing. In school auditoriums usually the floor will be sloping, and extra fabrication will be required on the framing. The sections will be estimated as previously described in Chap. 5. Where there is a balcony in the auditorium, the framing here will be at an even greater slope than that of the auditorium floor and the necessary material for the connections will be estimated. These special conditions may be clearly shown on the drawings as enlarged sections, which also may indicate a type of connection for the several points.

The framing over an auditorium will consist of long, heavy sections. Girders, cover-plated beams, and sometimes trusses will be used. Information about the take-off of girders and trusses is found in Chaps. 5 and 7. There may be some curved or bent material round the balcony or stage, and the take-off of this material will also be made as previously described.

Drawings of school buildings frequently include work for other trades and the structural steel on the same plans. This situation may be slightly confusing at first, but as the estimator gains experience, the structural steel material will stand out more clearly. Where the materials for other trades are included on the structural drawings, the estimator must read the specifications and notes on the plans very carefully so as to be sure to include all the material which is to be supplied by the structural-steel fabricator.

9-16. Gymnasium Framing. The framing for the gymnasium section of the school will be heavier than the classroom steel, and the roof or ceiling may be built of girders or trusses much like the auditorium roof

framing. There may be some apparatus supports bracketed to the structural framing, and there may be suspended walkways. The note sheet should indicate any items which were excluded or which were included.

9-17. Vocational Schools. Vocational schools are specialized buildings and have framing as required for each particular type. There will be nothing unusual about preparing the estimate for a vocational school except to bear in mind that the framing will be different from that of the elementary-classroom building.

A vocational school, or possibly more descriptively, a trade school, will be designed to support the necessary equipment for a particular trade and to provide the proper working areas. Some vocational schools provide for instruction in printing, homemaking, the automobile, aircraft, and needle trades, woodworking, light manufacturing, and so on. It is obvious that some schools will require moderately heavy framing for such trades as printing or light manufacturing; and others, offering training for aircraft maintenance, for example, will require large areas without interior columns. The structure for the latter may have trusses in the roof above the working area.

9-18. Suburban Schools. Suburban schools, where large ground space is available, are very frequently single-story structures. Because of the single-story construction the steel framing usually is light. The steel framing may occur only as columns and roof beams. These schools usually have gymnasiums and auditoriums. The gymnasium and auditorium framing will be similar to that previously described for schools located in the more populated areas.

Many engineers design suburban schools with structural steel only for the columns, at the exterior walls, and at the partitions between the classrooms. The balance of the roof framing may consist of bar joists. Note that a bar joist may be described under certain trade names or may be identified as an open-web joist. These joists resemble a small, shallow truss section. One type has light tee sections used for the top and bottom chords and small-sized angles for diagonal web members. Joists will be more fully described in Chap. 13, Material Supplementary to the Structural Frame.

Most fabricators do not make joists and must purchase them from other suppliers. Many manufacturers of joists produce them in stock sizes and on a production basis. However, the steel contractor will very often be obliged to supply and erect the joists, and the cost of the item delivered to the site and erected in place must be included in the estimate. Joists are supported laterally by light angles or bars, a process which is called "bridging." The estimator must include all this material in the estimate. The joists are usually welded to the structural framing, and the bridging is either bolted or welded in the field.

Many of the columns in a school may be concrete-filled pipe or Lally columns (produced by the Lally Column Co.). These will be included in the list of buy items. There are several types of concrete-filled columns, and they must be carefully estimated. For instance, some architects will require stainless-steel shells, which are very expensive.

9-19. College Buildings. The data and information which have been presented covering the estimating of school buildings quite generally apply to college buildings. College buildings may include classroom buildings, laboratory, administration, library, and other specialized buildings, gymnasium and auditorium buildings, and possibly dormitory buildings.

The estimator will read the plans carefully and study the specifications, after which there should be no particular difficulty in preparing the estimate.

A college building will more often be a multistory structure, and not the single-story suburban-school type. There may also be designs following the general architecture of already existing buildings. When this is the case, some of the roof framing may involve dormer construction and hip-and-valley work. This will require more than the usual study, particularly for the less experienced estimator.

9-20. Hospital Buildings. Hospital buildings which provide for upward of 100 beds are of multistory construction. In the smaller types the construction will be a simple beam-and-column frame and may employ open-web joists.

The floor loading for these structures is about the same as required for the average school building. Hospital buildings most generally are long and narrow in order to provide the maximum number of outside rooms. Therefore the main items to be noted for the estimate will be wind-bracing connections and spandrels or other window-framing material, in addition to normal beam-and-column framing.

Some of the more modern hospital buildings may have auditoriums, and these will require heavier framing. There also may be special laboratories, which will require framing different from the typical materials. Cantilever construction may be required for sunshade arrangements at entrances and solariums, and this will necessitate heavier connections, which may not be shown in detail.

The material check list will be about the same as that for a school, but not including gymnasium material.

9-21. Apartment Houses. These buildings are designed for a minimum floor load of 40 psf, one-half the design loading for an office building. Consequently the framing will be extremely light. The distances from floor to floor are held at the most practical minimum, and the length of a column section will consequently be less than in an office or school build-

ing. Because of the limited space between the floor and ceiling, the engineers endeavor to locate as many beams as possible at the room partitions. Therefore the floor framing for an apartment house will be very irregular. Several beams may frame near or at one column, and the estimator may find that some of these connections will be other than standard. When the conditions indicate that the connection should be larger, it is suggested that the estimator take off 1½ connections or, if conditions warrant, 2 connections for each of these situations. Usually there is not time to work out the specific details of the connections for use in the estimate.

Apartment-house designers often employ other than all wide-flange column sections, making use of single-angle, double-angle, tee, and various built-up sections. When there are built-up sections, the necessary fastening material must be included.

Apartment houses may have balcony framing and canopy construction, which will require the use of cantilever beams or other sections such as channels, tees, or angles. Watch the plans very carefully for floors which are dropped lower than the adjacent area. Shelf angles may be required at these areas.

Much cutting of the floor steel may be required for the passage of pipes and ducts. The cut members usually require some form of reinforcing, and this should be included when necessary.

There are many cases where garage space is provided in the basement of the building. When this occurs, the spacing of the first length of columns may follow a more regular pattern than that of the upper floors. Consequently there will be offset framing for the support of the upper columns when the spacing does not correspond with the basement columns. Also, offset columns may be found at the upper floors. In all cases provide the necessary stiffeners above and below the offset.

Refer to Check List 9-1 for a suggested take-off check list. This list may be applied to estimates of apartment buildings.

9-22. Stores. These buildings may be classified in two groups: the department store located in large cities and towns and the more recent suburban shopping center. The minimum live load per square foot for stores is 125 lb. This loading is high in comparison, for instance, with that of an office building, and as a result the framing will be moderately heavy.

Most stores have selling floors located below the street level. Figure 9-5 shows the framing for a store in a large city. It will be noted that pockets are provided in the walls of the adjacent structure, which in this case is a unit of the same store. Workmen can be seen in the process of cutting pockets. This is usually a slow hand operation and will sometimes delay the erector, for normally erection proceeds from the outside

toward the center of the structure unless it is being accomplished by means of a crane outside the structure.

The stores in a shopping center will not present a very difficult estimating problem. They usually are only two or three stories in height and of course will have below the ground selling areas in most cases.

Most of the store framing will follow a regular pattern except around

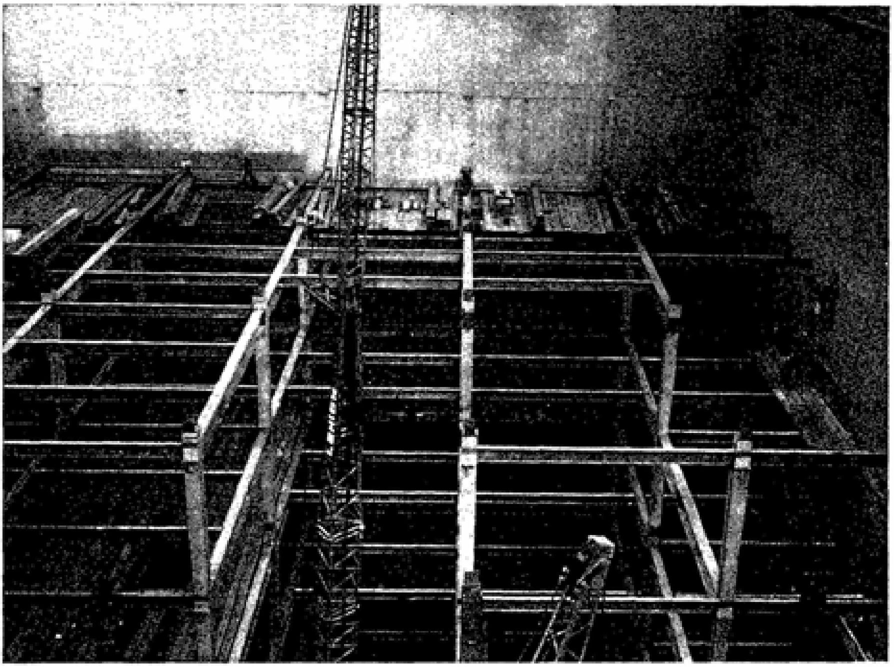


FIG. 9-5. Store building. (*Lehigh Structural Steel Co.*)

the elevators and stairs. Also the framing round the escalators will be heavier to support the drive motors and other equipment.

Many stores are air conditioned and, as previously noted, where the ducts pass through the structural framing the proper reinforcement must be estimated. Some stores may be designed with semi-rigid or rigid framing and the estimate will include the additional stiffening material and the welding as indicated. Canopy framing and other special details will be estimated as indicated.

Refer to Check List 9-1 for a suggested take-off check list.

9-23. Public Buildings. "Public buildings" includes courthouses, offices, libraries, fire stations, police stations, health stations, and so on. The general information thus far given in this volume covers most of the conditions for estimating public buildings. However, there are cases where the location of the building is unusual.

FIG. 9-6. Vierendeel-truss framing. (*Lehigh Structural Steel Co.*)

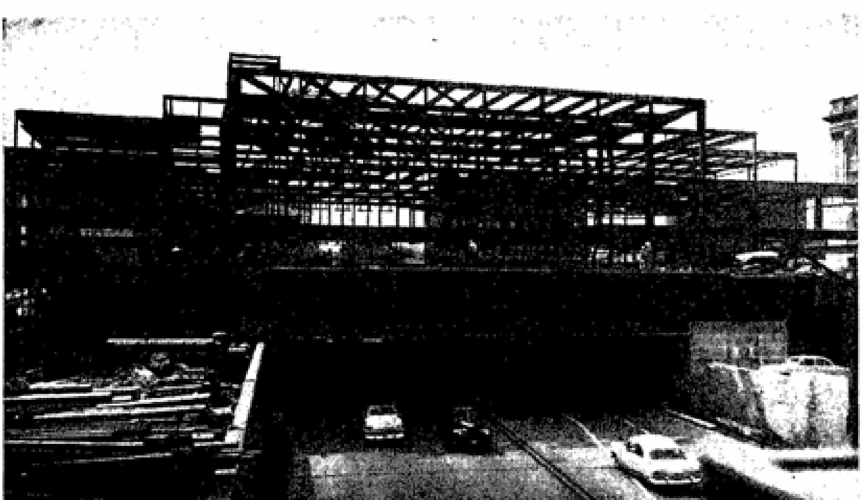


FIG. 9-7. Public building. (*Lehigh Structural Steel Co.*)

Figures 9-6 and 9-7 show the construction of a library over a main highway. In Fig. 9-6 both interior trusses and the outside, or end, truss can be observed. The interior trusses are a type which is designated as the "Vierendeel truss." This is an all-welded truss the estimating of which requires considerable experience and skill. It is intended to make full use of the floor space without interference from the structural framing,

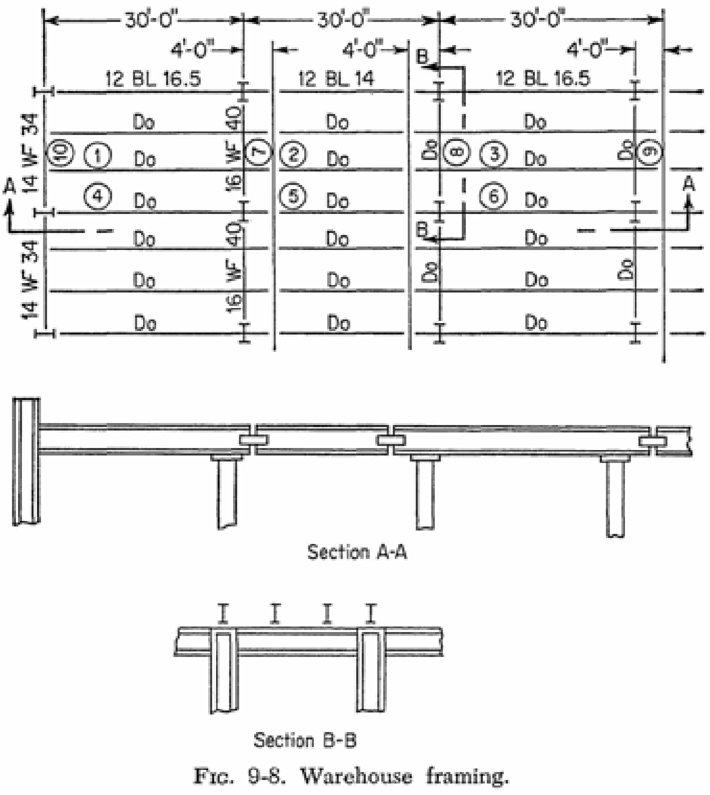


FIG. 9-8. Warehouse framing.

and as can be seen from the figure, the Vierendeel truss serves this requirement very well. The truss at the end of the building is of the average welded design and, while heavy, will not present unusual problems in estimating. Figure 9-7 is a good view looking through the structure as seen before the architectural finish is completed.

9-24. Warehouses. This type of building is often constructed of very light beam and column framing when the spans are of moderate widths. However, when wider bays are required, the use of truss framing may be more economical.

One type of warehouse construction can be seen in Fig. 9-8. It will be

noted that the roof beams or purlins cantilever, or extend, beyond the center lines of the north and south column lines. The shorter beams are supported by or connected to the ends of the cantilevered beams. (There are also warehouse designs where the framing is cantilevered in both directions.)

The framing here is relatively simple. The take-off will now be explained, as there are a few important points which should be considered and which have not been covered in the preceding work.

In the figure, numbers have been placed on several of the beams, and these are typical for the balance of the framing. A reference to section *AA* is suggested to obtain a clear understanding of the work presently under study. Beams 1 and 3 rest on top of beams 7, 8, and 9. In this detail beam 1 is indicated as framing to beam 10. (Note that the design might have had beam 1 resting on top of beam 10; this is sometimes the case. It would depend on what an engineer might require for the spandrel.)

Beam 2 may connect to beams 1 and 3 by the employment of one or two plates for each connection. To simplify the fabrication, beam 2 may only have punched holes in the web. All other fabrication may be done on the other two beams. Therefore the listing for the shorter beams is "Simple-punched." No cuts or copes are required.

Beam 1 will be either simply framed to beam 10 or coped and framed depending upon the respective elevations. There will be either two or four holes in the bottom flange to connect with beam 7, and the plate or plates for the connection to beam 2 will be riveted, welded, or bolted depending upon the job notes or specification.

Beam 3 will have the small plates attached at each end and will also be punched in the bottom flange to connect to the top of beams 8 and 9.

The length of beam 1 will be about 34 ft 0 in. Beam 3 will be about 38 ft 0 in. long. These beams may be made 1 in. shorter if it is so desired, or the remaining beam, 2, may be estimated at 21 ft 11 in. to allow for the possible overrun of the sections.

Beam 5 will be similar to beam 2. Beam 4 will be provided with a connection to the column and will have the plate or plates for connecting beam 5.

The remaining beam, 6, will have the plate or plates on each end, and the bottom flange will be punched with two or four holes to provide the connections at the top of the columns.

With the construction as shown in this drawing, it will usually be required to mill both the top and the bottom of the columns which have been indicated to have caps. The material for the column caps will, of course, be added to the take-off. As shown here, a simple plate may be sufficient for the column cap, as the beam is a very light section.

A warehouse of this type may not require any material-handling equipment as part of the building structure, and consequently the total tonnage of structural steel may be quite low. Many buildings of this type

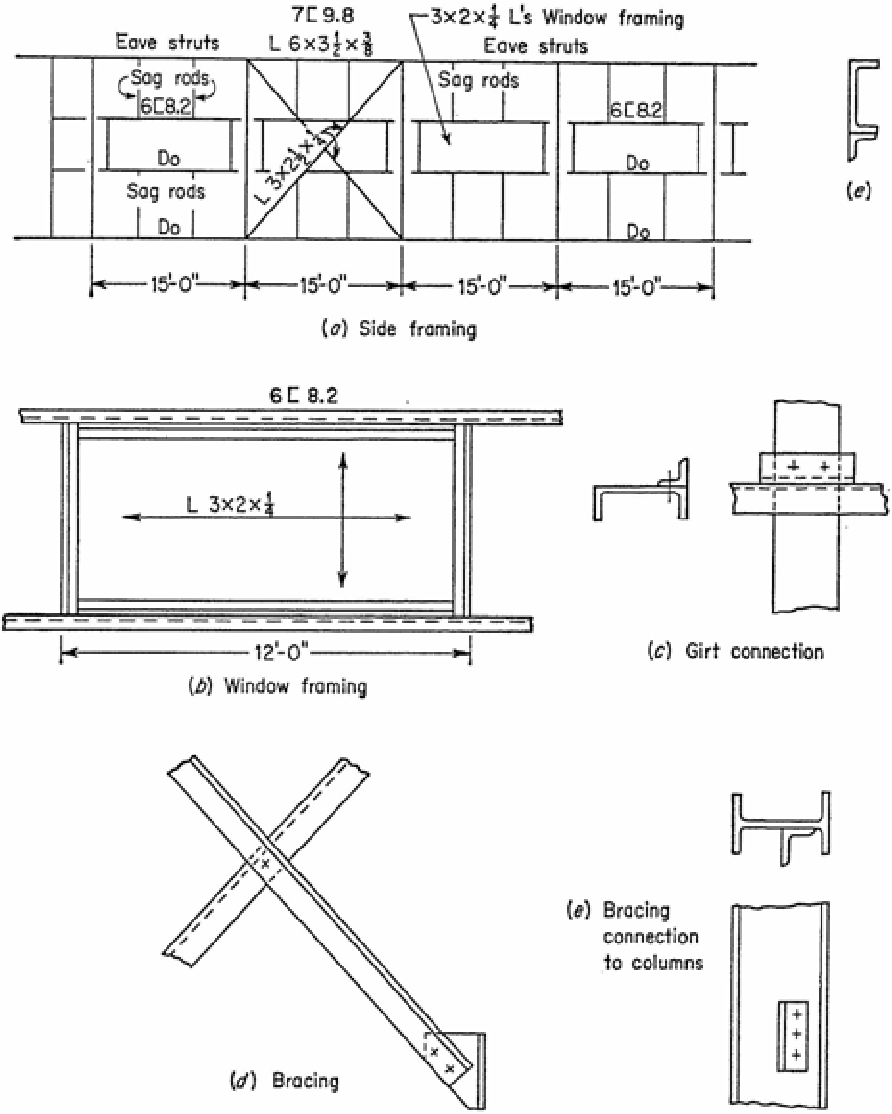


FIG. 9-9. Side-framing details.

are used for light manufacturing as well as for general storage purposes.

A section of side framing which may be used for a storage building is shown in Fig. 9-9*a*. The material required for the side framing is com-

pletely identified, and the take-off will not be difficult. The light horizontal angles required for the window framing may be attached to the channel girts by welding or rivets. The perpendicular angles will be connected to the girts with a small clip angle. A type of connection which may be provided to join the girts to the columns is shown in an enlarged detail. The diagonal bracing may occur in each three or four bays. Bracing is usually indicated on the estimating plans. The rods shown are sag rods and have threads at each end, with nuts. The purpose of these rods is as the name indicates, to take the sag out of the girts. Note that holes must be provided through the webs of the girt channels. The angle and channel comprising the eave strut will be joined as indicated by Fig. 9-9*e*. This will be done either with rivets or with welding.

A check list for warehouses, mill buildings, and miscellaneous structures is given in Check List 9-2.

Check List 9-2. Items Required in Construction of Warehouses, Mill Buildings, Powerhouses, Hangars, Conveyors, and Other Structures

Anchor bolts and anchors
Angle bracing
Base plates and bearing plates
Beam connections
Beams
Beams (cover-plated)
Bents
Bins
Brackets
Column connections (bases and splices)
Columns
Covers for conveyors
Crane runways
Crane stops
Decking for conveyors
Diagonal bracing
Diaphragms
Door frames
Eave struts
Expansion joints
Floor plate (plain and checkered)
Generator supports
Girders (plate box and latticed)
Girts
Grating
Grillages
Hangers (angle and rod)
Hoppers
Knee braces
Lintels
Monorails
Open-web joists and bridging
Pipe separators
Plates (kick and miscellaneous)
Posts
Purlins
Rafters
Railings (pipe and angle)
Rails (splices, clamps, clips, and bolts)
Rivets, bolts, including high-strength
Rods (sag, tie, and bracing)
Setting plates
Shims
Slabs
Spandrels
Stacks
Stair framing
Struts (latticed and battened)
Sway bracing
Sway frames
Tank supports
Trusses
Walkways
Wind bracing
Window framing

9-25. Mill Buildings. This type of building includes a great number of structures used for many purposes and trades, the manufacture of heavy machinery, rolling steel, the fabrication of steel, casting, electrical-equipment manufacture, and so on.

An elevation and partial plans of a mill building can be seen in Fig.

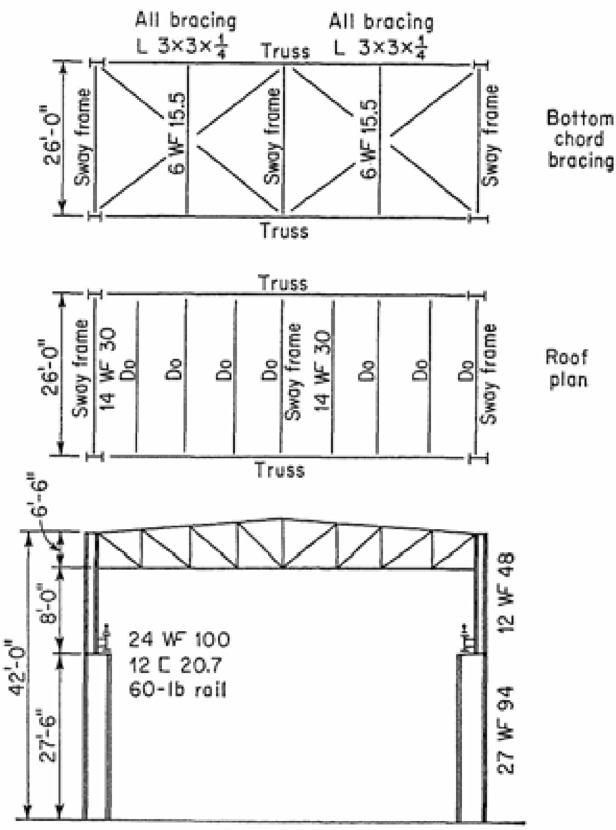


Fig. 9-10. Mill building.

9-10. The roof framing consists of trusses, and the purlins are WF beam sections. The truss is a usual type needing no explanation here, as trusses of a similar type have been described in Chap. 5.

The column is made of two sections, one of which is a 27 WF section which supports the crane runway and connects to the upper column. The upper column section supports the truss. The material for the column splice and other details of the columns are shown in the enlarged details in Fig. 9-11. The column base (Fig. 9-11*a*) will usually consist of heavier material, as indicated. The anchor bolts will also be longer and heavier

than those required for beam-and-column construction. When the column is not too long for convenient handling on cars or trucks or in the field, the splice may be completed in the shop. The splice material as indicated is not standard for all conditions but has been shown for general guidance.

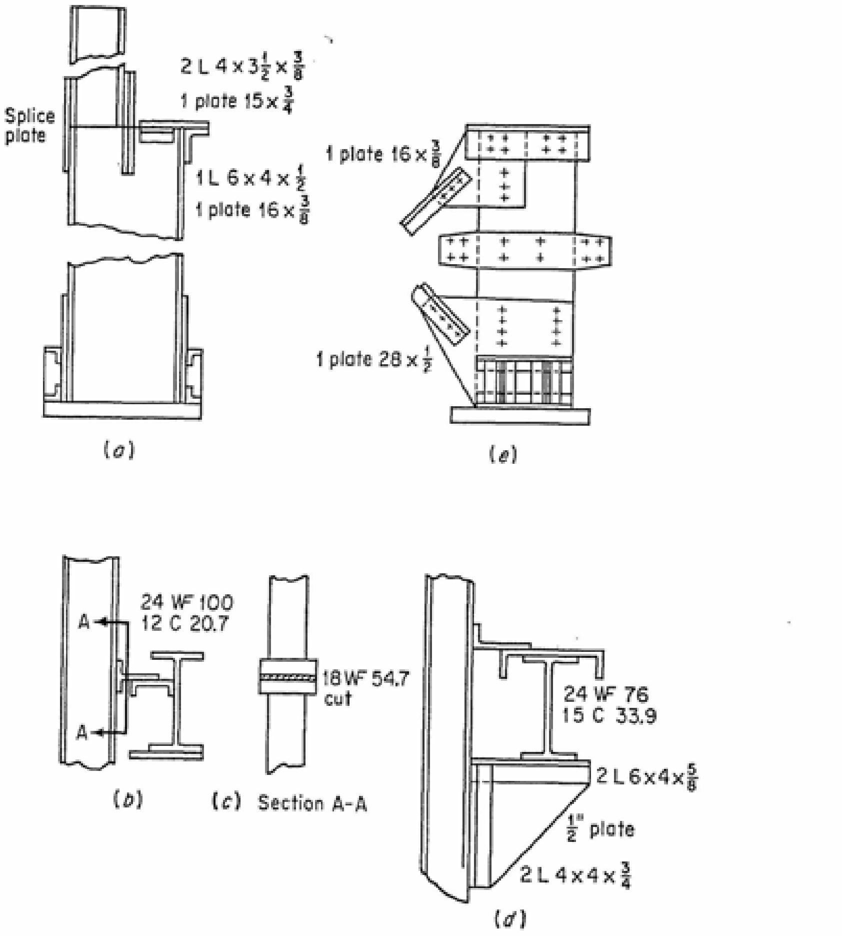


FIG. 9-11. Mill-building details.

The crane beam which is shown consists of a WF section, with a channel attached to the web. This section in turn may be joined to the columns by use of a tee (Fig. 9-11*b* and *c*). The crane rail may be secured to the top of the crane girder by rail clamps or by hook bolts.

Complete detailed information for crane rails, rail splices, clamps, and hook bolts may be obtained from the producing mills, or many of the required data will be found in the AISC Manual. It should be noted that

the fabricator may make hook bolts by bending and threading round rods. Most of the hook bolts are ⅞ in. diameter, except for the lighter rails, and will be used in pairs spaced about 2 ft centers. When clamps are used, it will be necessary to punch or drill the top flange of the crane girder, and when hook bolts are used, it will be required to have holes through the web of the crane rail.

Crane stops will be needed for both ends of the crane runway. These are built up by the fabricator, usually to a shop standard. Crane stops generally are not indicated on the estimate drawings but unless otherwise specified must be included in the estimate. Also, rail splices may not be shown but should be included at about each 30 or 33 ft of rail run. Note again that the unit weight of rail is per yard.

As a further example, a crane girder attached to a column by means of a bracket has been shown in Fig. 9-11*d*. In this arrangement the column shaft is not spliced, and also the channel is on top of the WF section. The choice of material and the arrangement of the sections are, of course, the decision of the designing engineer.

The purlins will be connected to the trusses as indicated on the estimating plans. The sway frame at the center of the structure will be attached to the trusses and to the purlin. Those at each side of the building will be attached to the columns and the purlins. The sway frame is practically a form of light truss and provides stiffening between the trusses. Bottom-chord bracing is also shown in Fig. 9-10. It will be necessary for the estimator to read the plans carefully in order to include the proper quantities for the bracing materials.

Bracing may not occur in all bays on some buildings. It is very common practice to show a roof plan in two halves on the estimating drawings. One half may be for the top-chord bracing and the other half for the bottom-chord bracing materials. In cases like this be sure to double each quantity for the other half of the building.

Perhaps it should be mentioned that the references here to "chord" are to the top and bottom main truss members. It is a very common and much-used designation.

9-26. Bracing. A major item to be considered in an estimate of a mill building is bracing. Bracing comes in many different forms, single angle, double angle, built-up sections, and round rods.

The diagonal bracing indicated in Fig. 9-9 consists of two angles which will be placed back to back as shown in Fig. 9-9*d*. These will be shipped separately from the shop and connected at the center after erection. A suggested connection to the column is detailed in Fig. 9-9*e*, a single angle punched for connecting the bracing angle in the field. The connection angles may be attached to the bracing, but having the angles fabricated to the column sections will simplify the bracing-angle work.

Punching and cutting to length will then be the shopwork on the angles.

The sway frames shown in Fig. 9-10 usually occur in every bay of the building, and the angle bracing may not occur in each bay. These conditions will be determined from the estimating plans as received by the fabricator for preparing a bid.

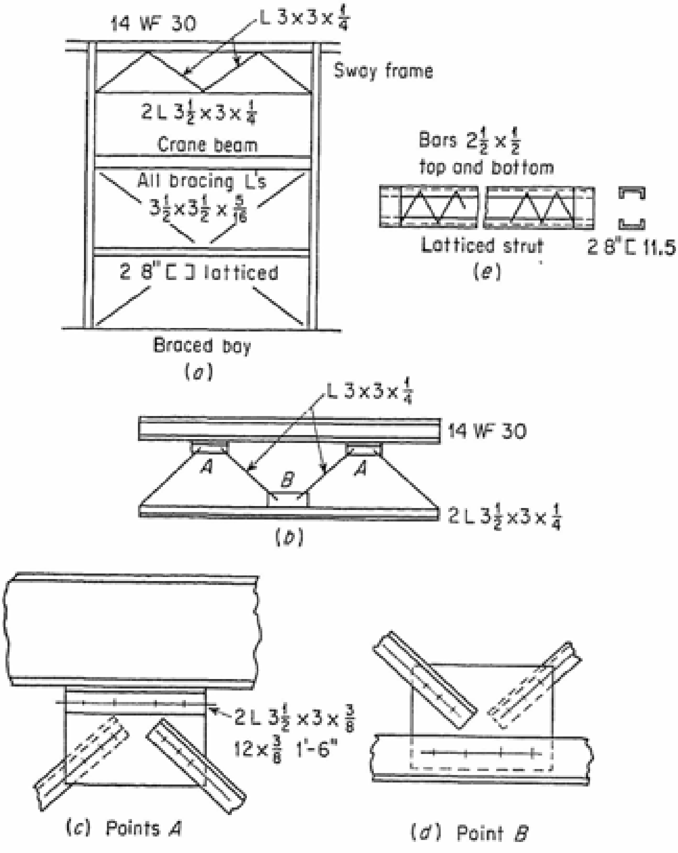


FIG. 9-12. Mill-building details.

In many cases some of the bracing is composed of round rods. Rods may be provided with turnbuckles, clevises, or both. The plans or specifications usually indicate when turnbuckles and/or clevises are required. If no reference is made, the estimator will list the rods without these fittings but will assume threading of the ends and with nuts. There will also be work on which the rods are specified to have upset ends. An upset end is one in which the diameter of the threaded section has been increased for additional strength. The upsetting may be done in the blacksmith shop, or upset ends can be made or purchased and welded

to the remainder of the rods. In any event, when clevises, turnbuckles, or upsetting is required, additional costs must be included for the labor or by-outs.

An elevation of a braced bay is shown in Fig. 9-12*a*. The bracing here consists of the sway frame, the diagonal angles, and the latticed strut. Figure 9-12*b* is a slightly enlarged detail of the sway frame, and the details of Fig. 9-12*c* and *d* are enlarged details at points *A* and *B*.

A sample of material for the connection is listed. The plate, which is similar to a truss gusset plate, is attached to the 14 WF section with a pair of angles and to the bottom horizontal angles by a plate. The diagonal angles are turned in opposite directions and connect to the gusset plates as indicated.

9-27. Struts. Connections for the latticed strut and the diagonal angles are shown in Fig. 9-11*e*. The double-channel strut will be connected to a plate on each flange of the column. The angles, if single, will be attached to a plate on one side of the column. When there are double angles for this bracing, they will be connected to plates on each side of the column and will be joined with batten plates about 3 to 5 ft apart along their lengths.

Finally, in connection with bracing in general it should be noted that when sufficient information is furnished, such as the stress figures, it is possible to develop considerable detail data along the same line as that described in working up connections or gussets for trusses. One thing is certain and should be obvious, and that is that heavy bracing will require heavy connections.

9-28. Powerhouses. The estimating of a powerhouse is usually assigned to the fully experienced estimator. There are several kinds of power-generating stations, the steam plant, the water-powered plant, and presently the atomic power plant, each of which will have certain features not found in the other types.

Figures 9-13 and 9-14 show two power stations, both of which are steam plants. A number of the important features may be seen in Fig. 9-14.

9-29. Turbine Room. The section of the building in the foreground and left foreground of Fig. 9-14 is the turbine room. This portion of the structure is quite similar to a mill building in that the roof steel is supported by trusses and there are a bridge crane and craneway, which are required for servicing the turbines. The crane for most modern plants will be of quite large capacity, as the sections to be handled are heavy. Therefore, the runway in turn will consist of heavy structural framing. As shown in this figure, it is built of plate girders. Lateral bracing is clearly seen in the figure, and there are lateral trusses which support each alternate roof truss.

9-30. Boiler Room. The remaining part of the building is the steam

and furnace section. The tanklike units below the girders at the top are steam drums. The average steam drum is very heavy. It is supported by hangers to girders above or rests on the framing. When it is supported by hangers, the rods are of large diameter and usually pass through heavy slabs or billets.

The work assigned to the boiler room may be divided into two sepa-

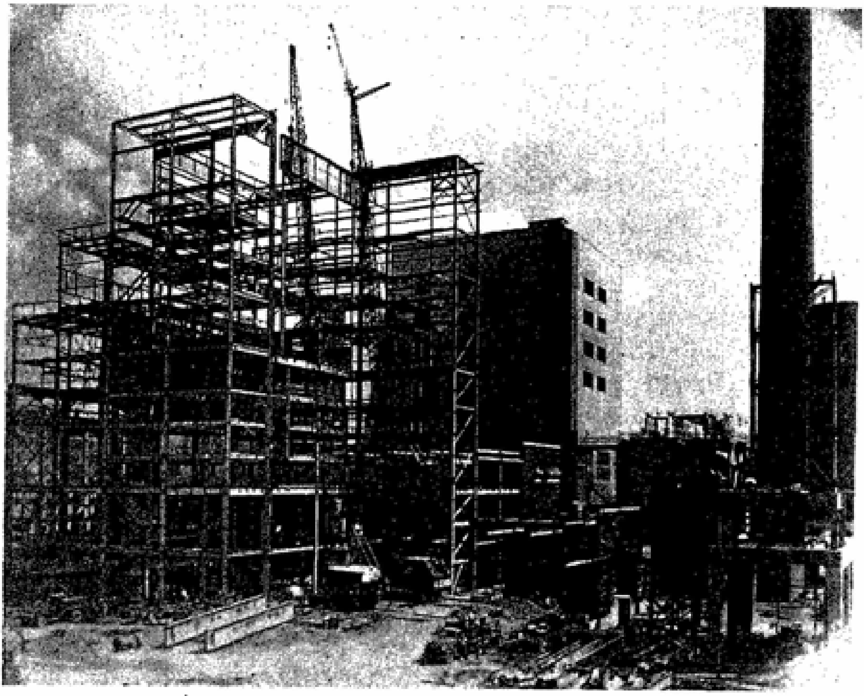


FIG. 9-13. Powerhouse. (*Lehigh Structural Steel Co.*)

rate contracts. The contractor for the boiler work may include framing for the boiler-supporting steel, and this may in turn be sublet to the structural fabricator.

9-31. Hoppers. When steam is generated by the combustion of coal, hoppers are built into the structure for direct feed of fuel to the furnaces. The hopper framing and material require close attention by the estimator. The hopper consists of both vertical and horizontal framing and has two or more sloping faces. Usually hoppers come in several sections, as they cannot be shipped in one piece because of shipping clearances.

Several conditions must be kept in mind in connection with the take-off of hoppers. The specifications may indicate that all seams will be dust-tight. This will require additional welding. The hopper may have to be

shop-assembled and match-marked to guarantee easy fitting in the field. The discharge gates and chutes may be supplied by others; if so, this will be indicated by the estimator on the note sheet.

The use of stainless clad and stainless steel for hoppers is not unusual. As this will cost considerably more than the usual structural steel, it must be carefully noted and figured. Also, the structural steel may be specified to be of another grade than that specified for the balance of the structure.

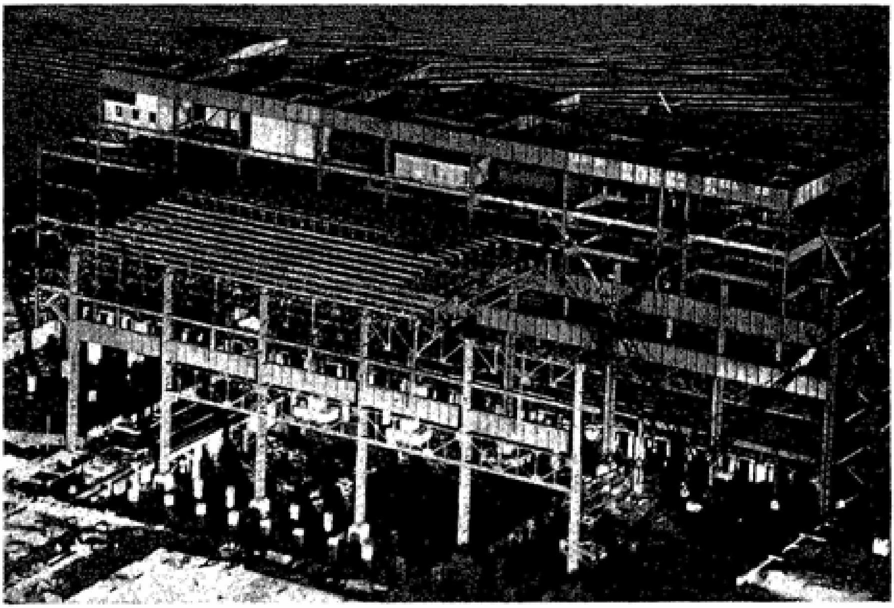


FIG. 9-14. Powerhouse. (*Lehigh Structural Steel Co.*)

9-32. Precipitators. Many power plants have precipitators of various kinds for the removal of dust and elimination or reduction of smoke. These units may be on the roof or adjacent to the main structure. Some may be fabricated by steel contractors either as a subcontract or as part of the main, or base, contract.

When turbine supports are part of the steel contract, the indicated tolerances must be carefully studied, as turbine supports require an extreme accuracy, much closer than the usual structural allowances. Naturally this will increase the fabrication costs.

In the construction shown in Fig. 9-13 the installation of a heavy plate girder at the top of the structure may be seen; also, much of the bracing has been erected. The light framing at the exterior and between floors is girt framing. The girts support the light wall covering, some of which may be observed on the walls of the completed structure in the background.

9-33. Supplementary Materials. Much of the floor area consists of grating. This can be supplied by the steel fabricator or, when not of a type which can be constructed by the fabricator, can be included in the estimate as a buy-out.

Round the openings and edges of the grating, perpendicular sections of plates known as "kick plates" may be called for. These may be required to be supplied by the fabricator. The requirement may be indicated in the specifications or proposal form or on the plan only as a symbol or dotted line. This is an item that can be easily missed in the take-off.

Power plants usually need a considerable quantity of railings. Here again the question of which trade will be required to supply this material must be investigated.

9-34. Hydro Plants. Except the boiler-supporting steel and the hoppers, much of the framing thus far described for power plants is needed for a plant with water-driven turbines. The generator room is about the same, as are the transformer area and other sections of the plant.

Atomic plants are being rapidly developed. Here again much of the framing is like that of the steam plant, except that there are no hoppers and there is a section for atomic materials.

Power plants may have service buildings. These most often have beam and column framing. Other structural material needed is the lighter framing for the switch yard and also, in connection with the transmission of power, for the supporting towers for the power lines.

Both switch-yard material and the material in the transmission towers may be required to be galvanized. There is a trend toward the use of aluminum for towers and switch-yard materials. The base cost of aluminum is high, but some of the other considerations will justify the additional expenditure.

9-35. Hangars. These structures, which are used for the assembly, maintenance, and protective storage of aircraft, are among the largest covered structures in respect to spans between supports. (Other large structures having unobstructed areas are exhibition halls and other buildings of this type.)

There are many different types of hangars. The majority make use of cantilever construction. Because of this cantilever type of construction and the very long truss spans, most hangar work consists of very heavy framing.

9-36. Cantilevered Trusses. The cantilevers may be supported from the construction at the center core of the hangar. The center section will be used for tool and parts storage, for office areas, and for some of the maintenance work.

Some types of hangars are supported by trusses suspended either by

cables or by structural shapes or built-up members. An excellent view of a suspended type of framing is given in Fig. 9-15. The trusses are supported at the center point by heavy WF suspenders, which in turn connect to other WF sections arranged at the center of the structure.

All connection material at the several points is very heavy. However, as is quite usual, the engineers will show much necessary detail information on the estimating plans, and it is then necessary for the estimator only to follow the data and notes carefully to produce an accurate cost for the work.

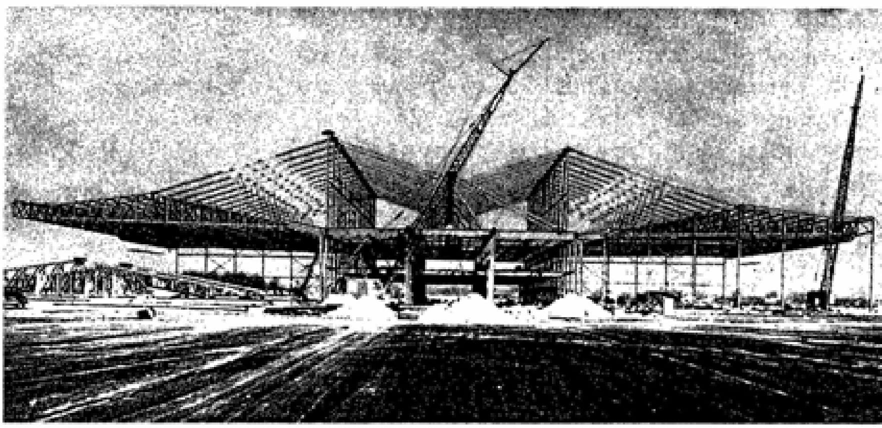


FIG. 9-15. Hangar. (*Lehigh Structural Steel Co.*)

The hangar (Fig. 9-15) has no supporting framing at the exterior except at the ends. Along both sides are a series of door guides attached to the ends of the trusses. These must be carefully estimated, as there may be leveling devices included with the structural material.

9-37. Door Supports. Door tracks may be set in the masonry. These will be light railroad rails, and the estimator will look at the plans for special notes in connection with the alignment of the rails. All necessary information of this nature must be set down in the notes for the attention of the erector.

In many cases it is necessary for the trusses to be shipped to the site for further assembly, as the shipment limits may preclude handling the completely built-up truss from the fabricating shop.

9-38. Doors. On work which includes the furnishing of doors the estimator will note that the work in the shop will be moderately difficult, the cost for assembly may be required to be included, and much mechanical equipment may be required to be attached.

9-39. Bridges. Bridge construction includes structures of the most ele-

mentary form and those which are quite complex. A bridge may be a structure provided for foot traffic, railroad traffic, or vehicular traffic and may bridge a river or stream or serve as a highway separation.

The elevated highway and the viaduct are basically bridges. Much of the information given here relative to bridges also applies to viaduct or elevated-highway construction. Viaducts or elevated highways consist of a number of moderately short spans supported on steel or on concrete piers.

9-40. Specifications. A large number of bridges are built for the purpose of highway grade separation. The plans may be prepared by states, municipalities, and through-way authorities. Most of these authorities have established their own specifications, and the estimating plans may refer to the general specifications. These specifications may, in turn, concur with or refer to the Standard Specifications for Highway Bridges of the American Association of State Highway Officials (AASHO). It would be well for an estimator to obtain and read a copy of the AASHO specifications, as there are several differences in the required methods of fabrication as compared with the general building specifications. The steel fabricator engaged in considerable bridge fabrication will almost always have copies of the various specifications on hand.

9-41. Simple Spans. A simple beam span may serve for crossing up to 60 or 70 ft. The estimating of these spans is not difficult and requires a minimum of experience. A few important points should be kept in mind in connection with the estimating of the simple beam bridges.

The beams will be listed as indicated, but check of the notes must be made to see whether or not camber is required; if so, this must be noted on the take-off so that the cost will be included. The beams usually are spaced about 5 to 7 ft apart by the use of diaphragms. The diaphragms on these structures may consist of channels to connect to the beams by means of connection angles or connection plates in the case of welded work.

The next item will be the end bearings. These will occur at the ends of all stringers (beams). Details of bearings will be included later in this chapter.

As the lengths of the bridge spans increase, the type of member will change from simple beams to built-up sections. Many of the highway grade-separation structures have moderately long spans, and the main sections to be required are the heavier WF sections, 36 in. deep and with cover plates.

9-42. Composite Construction. The composite design of the structures will require cover plates on the bottom flanges of the beams, and shear connectors or spirals will be attached to the top flanges.

9-43. Shear Connectors. There are several kinds of shear connectors. Among these are the spiral shear connector, serpentine-shaped bar connector, rectangular flat connector, channel-section connector, I-beam-section connector, and Nelson shear-connector studs.

The spiral shear connector is fabricated or manufactured by the Porete Manufacturing Co., North Arlington, N.J. Complete design data can be found in the handbook entitled "Alpha Composite Construction Engineering Handbook," which may be obtained from the Porete Manufacturing Co. These spirals are formed of ½-in.-round, ⅝-in.-round, and ¾-in.-round bars. There is a variation between the number of loops per foot of span. This information is usually shown on the design drawings, but there also is a complete table in the handbook which lists the weight of spiral bars in pounds per linear foot of beam for the various mean diameters and the several different spiral pitches.

The spirals will be welded to the flange of the beam or girder at each point of contact, and the estimator should calculate the amount of weld which then will be included in either the fabrication cost or the field cost. The spirals may be attached in the shop or in the field. Some erectors will prefer the work to be done in the field, one reason being that it is difficult to walk on the top of the girder when spirals are attached in the shop and another being the breaking loose of the welds in the handling of the sections either in transit or during erection.

In connection with composite design it should be noted that, in addition to bridge work, floors in other structures will also follow this design. These structures may be garages, commercial buildings, and apartment houses. Therefore the estimator is cautioned to look for the composite design of framing on other than bridge work.

A table of recommended spirals and welds will be found in the Porete handbook, but in most cases there will be an indication on the estimating drawings of the length and size of the weld at each point of contact with the girder. Note that the welds are deposited on each side of the spiral bar at the point of contact.

The Nelson Stud Welding Division of Gregory Industries, Inc., of Lorain, Ohio, produces a granular-flux-filled welded stud which has many advantages for installation and probable savings in cost. The use of Nelson studs is becoming increasingly more popular. The studs consist of short lengths of round bars which weld to the top flanges of the beams or girders and with an upset head at the other end. In general appearance, the studs, when in place, look like bolts without nuts standing on top of the beams.

These studs, when received for installation, are each supplied with a ferrule and granular-flux load. The studs are end-welded with a light-

weight stud-welding gun. An electric arc created between the stud and the flange of the beam melts the end of the stud and a corresponding spot on the flange. After a preset arcing period the welding tool plunges the stud into the molten pool of metal, completing the weld. Completely portable equipment is used either in the shop or in the field.

The studs are completely self-contained units and do not require any additional welding rods or welding materials. The stud-welding gun is, of course, special equipment. A fabricator will usually have the necessary equipment on hand when sufficient work of this type warrants the purchase of it. Otherwise it is also possible, at this time, to rent or hire the equipment.

Equipment for producing the proper electric arc is different from that for producing the power supply for the normal hand or automatic welding operations.

It is theoretically possible to install 50 or 60 studs per hour, but the correct figure for use by the estimator can be obtained only from the records and results which are supplied for his use by the fabricator.

In the event that a reader wishes more complete information on composite construction design, attention is directed to a McGraw-Hill Book Company, Inc., publication, "Composite Construction in Steel and Concrete," by I. M. Viest, R. S. Fountain, and R. C. Singleton. This publication fully covers design and practical applications.

Estimating plans may indicate a choice of two or more types of connectors from which a selection can be made by the fabricator. Very often the fabricator will have a preference and the estimator will have been informed as to the type of connector which is to be included in the estimate.

One factor must not be overlooked regarding framing which has shear connectors. In the event that the connectors are applied in the shop, it is necessary to use additional care in loading and shipping. It is possible that the loading costs will be increased when shear connectors are shop-attached.

During erection it is difficult to walk on top of beams or girders on which connectors have been installed. This situation applies to almost all kinds of shear connectors.

9-44. Welded Bridges. Most bridge-designing engineers prefer to have the cover plates attached to the rolled WF sections by welding. This method is usually more economical; otherwise, all holes may be required to be drilled through the beam flanges. In estimating the welding, note that it almost always is continuous all round the edges of the cover plates.

Both the all-welded girder and the riveted girder are used for the longer spans. Figure 9-16 shows a riveted-girder span. Careful examina-

tion of the figure reveals a number of factors to be considered in the estimate of a like structure. There is a hinged connection at the end of the sixth panel from the pier at the right of the figure. A duplicate of the hinge is near the opposite end of the girder. Usually the hinge material is drawn in complete detail on the plans or on a bridge standards drawing which would be included in the estimating set. Note that bending of the bottom-chord material is required, and note also where the section of web plate must be cut before fabrication. Bracing members and brack-

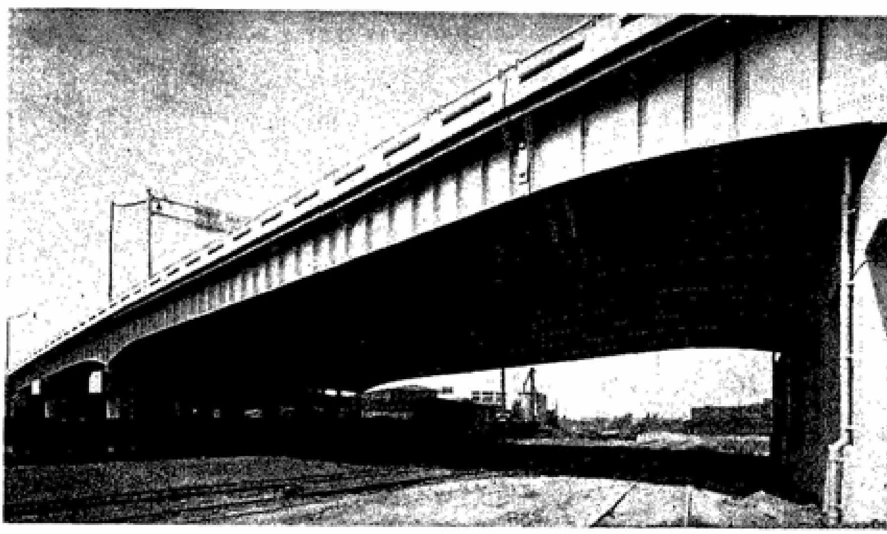


FIG. 9-16. Bridge plate-girder span. (*R. C. Mahon Co.*)

ets may be noted, and also the railing and drain pipes. The railing, drains, and drain pipe may or may not be included by the structural fabricator, but the estimator will check the specifications and add the proper information to the note sheet. A heavy girder span is shown in Fig. 9-17.

Estimating bridge components as seen in these two figures requires a careful study of all the details and information supplied for the quotation. However, if the estimator reads the specifications, the notes on the plans, and all other references, there should be no difficulty in producing the proper complete estimate. It naturally follows that any estimator will require the proper amount of experience before he has the ability to estimate on the more complex work.

9-45. River Crossings. As an example of the more complex work, refer to Fig. 9-18. The assemblies here are bridge-tower sections, and the figure shows quite clearly many of the components as well as some of the sizes of the sections as compared with the height of the workmen.

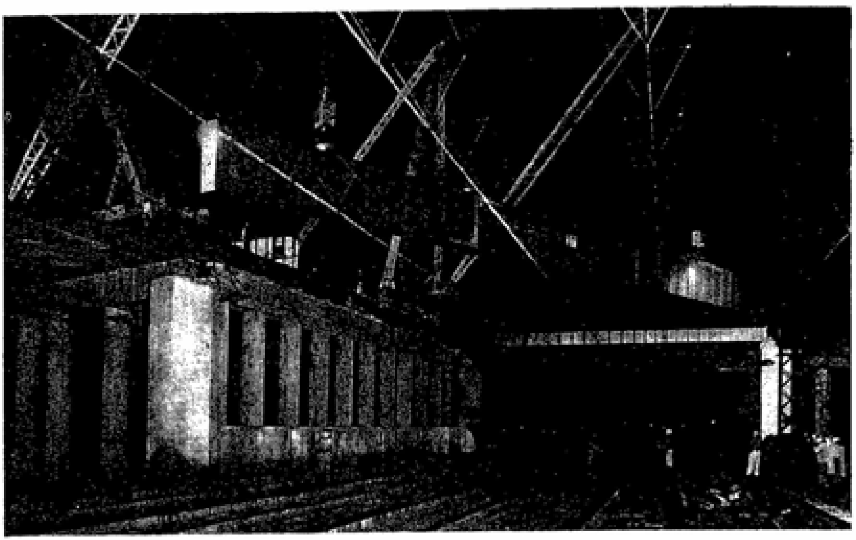


Fig. 9-17. Erection of heavy girder. (*Harris Structural Steel Co.*)

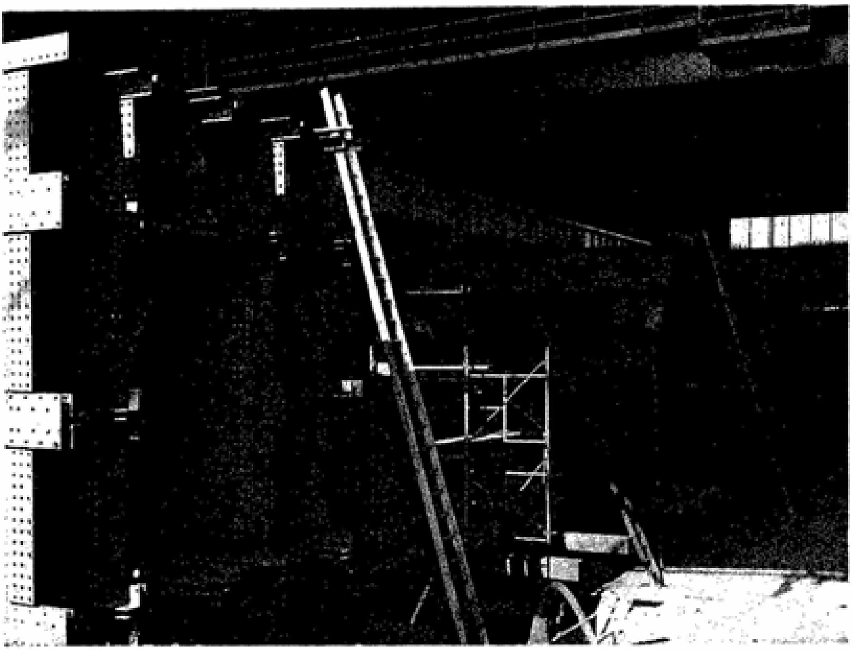


Fig. 9-18. Bridge-tower sections. (*Bethlehem Steel Co.*)

Figure 9-19 gives many of the sections incorporated in the bridge tower. This tower is that of a suspension bridge. It follows that estimators on this class of work will be dealing with a very special type.

A very long suspension span is shown in Fig. 9-20. The towers support-

FIG. 9-19. Bridge towers. (*Bethlehem Steel Co.*)

FIG. 9-20. River-crossing bridge. (*American Bridge Division, U.S. Steel Co.*)

ing the cables are of steel construction, whereas the towers supporting the bridge structure in Fig. 9-21 are masonry. The two steel towers in Fig. 9-21 are for the temporary support of the steel members during erection and will be dismantled and removed after the sections of the bridge are connected. Additional data on temporary supports, or falsework, will be included in Chap. 11.

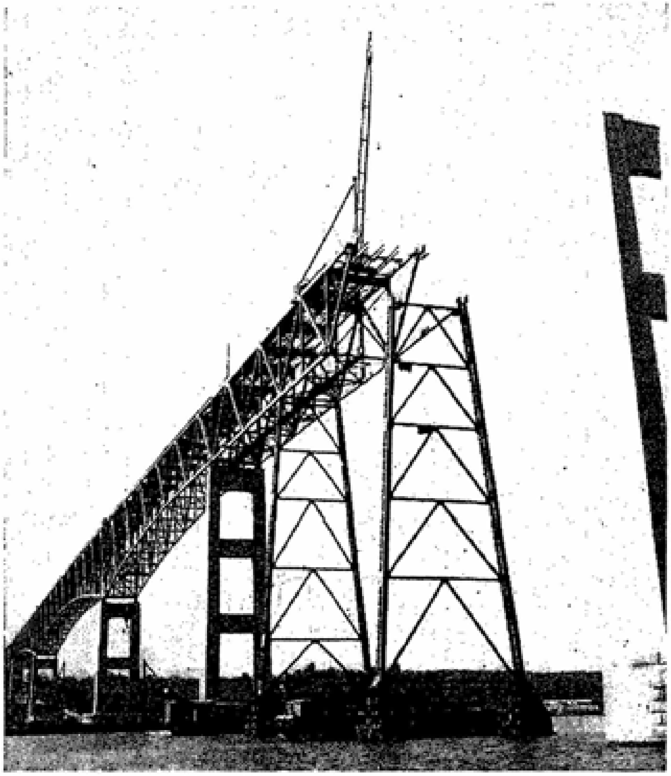


Fig. 9-21. River-crossing bridge. (*Harris Structural Steel Co.*)

The welded-girder spans are very popular. When the estimator is in the employ of a fabricator who is engaged in considerable bridge work, welded designs may make frequent appearances in the estimating department.

Naturally the most important factor for the estimator is the size, kind, and quantity of welding necessary. Butt welds and continuous welds are required on much of this work. If the symbols and figures are followed properly and listed accordingly, the estimate should be correct.

After the estimating of all the girders and stringers has been completed, the next items are diaphragms and bracing. Diaphragms may be

channels, beams, or built-up members; the estimating of them is comparatively simple. In almost all cases the connection material is of special design and is nearly always detailed on the plan or on a standards drawing. The bracing is vertical and/or horizontal or both, depending upon the type of structure.

Drains and downspouts may be required to be included in the structural-steel estimate. There usually are special castings and may have to be purchased in finished form.

9-46. Bearings. Bearings are an important item. They will occur on each end of all girders and stringers which are bearing on the masonry. There are many types of bearings, some comparatively simple and others requiring much fabricating. Note that practically every set of bearings will need considerable machining; this information must be included in the estimate. Some of the heavier bearings will be castings, and it may be necessary to obtain a sub-bid from an outside supplier.

The remaining structural items are the expansion dam, the sidewalk and mall framing, and the fascia. Some expansion dams are of simple design, and many others require a large amount of special fabrication. Provision must be made for adjustment to conform to the pitch of the roadway. Also, the plates level with the surface of the roadway may require the burning and shaping of the matching fingers. The fascia, which is the framing at the outer edges of the structure, may be composed of several components, some of which may require bending. Here again check the information carefully.

Anchor bolts may be specified to be included for both the steelwork and the railing posts. The railing may be required to be included but will be estimated as a separate item.

Railroad bridges often need wrought-iron or special steel plates under the roadway ballast. While the weight is approximately that of steel, the material cost will be greater. Note also that bronze, lead, or other materials may be needed in connection with the material for the bearings.

Check List 9-3 is applicable for bridge material.

9-47. Miscellaneous Structures. It is not practical to list and describe every kind of structural frame which an estimator may be required to figure, but a brief description of a few more will be included.

9-48. Conveyors. Conveyors may be within buildings and supported by the structural framing of the building. When the conveyor system is an independent structure, it normally consists of quite light truss framing and the supporting bents or towers. The structural fabricator may supply all the conveyor structure except the mechanical equipment and at times may be required to fit the mechanical parts to the framing. Light steel or sheet-metal decking may be required. Also, overhead covering or hoods and supports may be part of the contract.

Check List 9-3. Items Required in Construction of Bridges

- Anchor bolts
- Anchors for railing
- Angle bracing
- Ballast plates
- Bases (fixed and expansion)
- Blast plates
- Bracing
- Brackets
- Checkered plates
- Cross frames
- Diagonals
- Diaphragms
- Expansion bearings
- Expansion joints
- Fastening materials
- Fixed joints
- Floor beams
- Girders
- Knee braces
- Latticed girders
- Pins (including driving pin and nuts)
- Railing
- Railing posts
- Rollers
- Shoes (expansion and fixed)
- Stringers
- Struts
- Supports for utilities
- Sway bracing
- Trusses

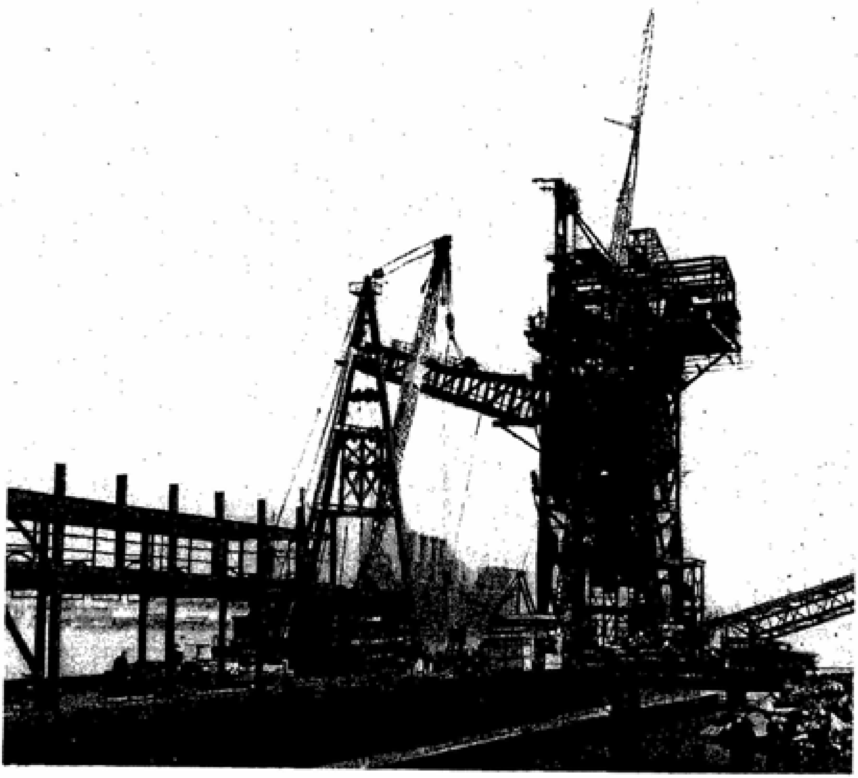


Fig. 9-22. Coal-unloading tower. (*Lehigh Structural Steel Co.*)

The estimator will note that the trusses will usually be required in pairs, with the conveyor supported between each pair of trusses. Practically all conveyor material will be light and proportionately more expensive per ton to fabricate.

9-49. Cranes. Two examples of material-handling cranes are shown in Figs. 9-22 and 9-23. The unloading tower of Fig. 9-22 is seen during the process of erection. The boom of the tower is being set in place with the aid of a hoisting lighter. The tower will have enclosed sections for

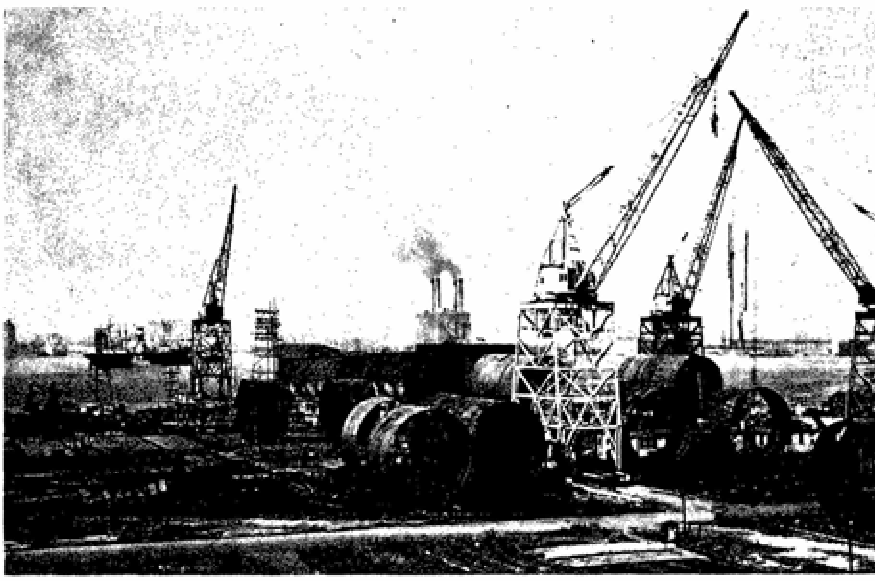


FIG. 9-23. Tower cranes. (*Clyde Iron Works.*)

housing the machinery. One such section may be noted at the top of the tower.

Several tower cranes are shown in Fig. 9-23. The framing at the top below the house will frequently be quite heavy, and it supports the rotating trucks. These cranes may be rotated to a full circle. The entire crane structure moves on rails set on ties or concrete at the ground level.

9-50. Refineries. Figure 9-24 shows a portion of the steel framing required to support refinery equipment. Figure 9-25 gives a section of a refinery in which may be seen some of the piping supports as well as other structural work.

9-51. Subway and Tunnel Framing. Subway and tunnel framing is usually not too complicated. In subway framing it is the practice of many engineers to design the columns to start on top of a beam or grillage section and to end under the roof beams. This requires milling at each end of the columns.

Tunnel framing under water is often composed of castings delivered to the site in segments. The estimator's work on such framing may be considered as specialty estimating. Other tunnel framing is similar to the subway construction.

9-52. Viaducts and Expressways. The viaduct or expressway designed to carry vehicular traffic through populated areas will very frequently be required to be estimated. A double-deck arrangement is shown in Fig.

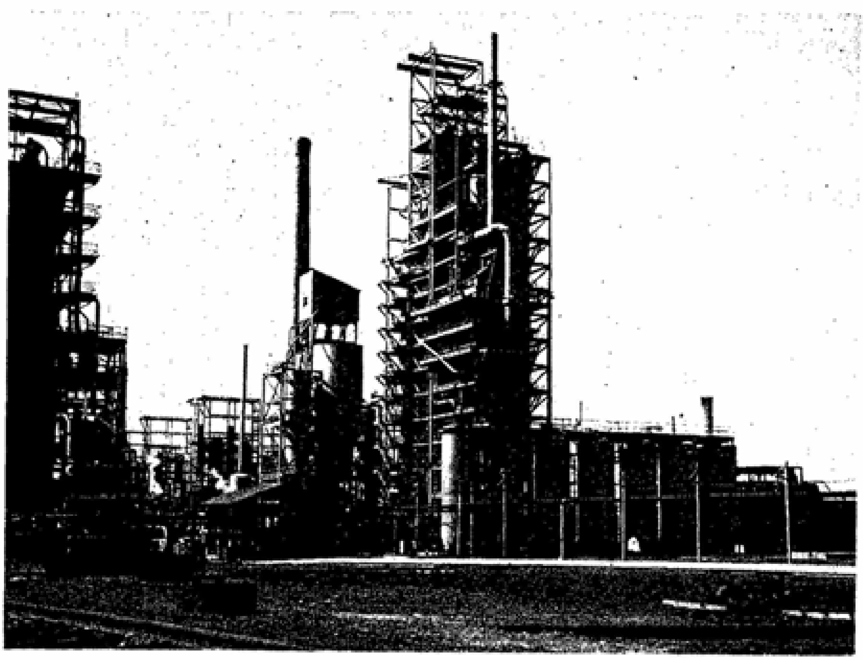


Fig. 9-24. Refinery structures. (*Standard Oil Co. N.J.*)

9-26. An estimate of this structure would cover many different problems, several of which are readily observed. The lower-level beams have been cut at the ends to provide the slope. Some of the column sections and girder sections are in pairs. Bracing and expansion-dam material also may be seen.

Erection equipment is shown in Figs. 9-27 and 9-28. A good view of the traveler appears in Fig. 9-27. The hoisting engine is mounted on the platform of the traveler. Part of the rails on which the equipment travels is seen below the frame of the platform. The lower sections of a guy derrick and an upper part of a boom on a crane are visible. The girder in the foreground is cantilevered over a shoe, or bearing, on top of a column.

In Fig. 9-28 it will be noted that the boom for the traveler is on the

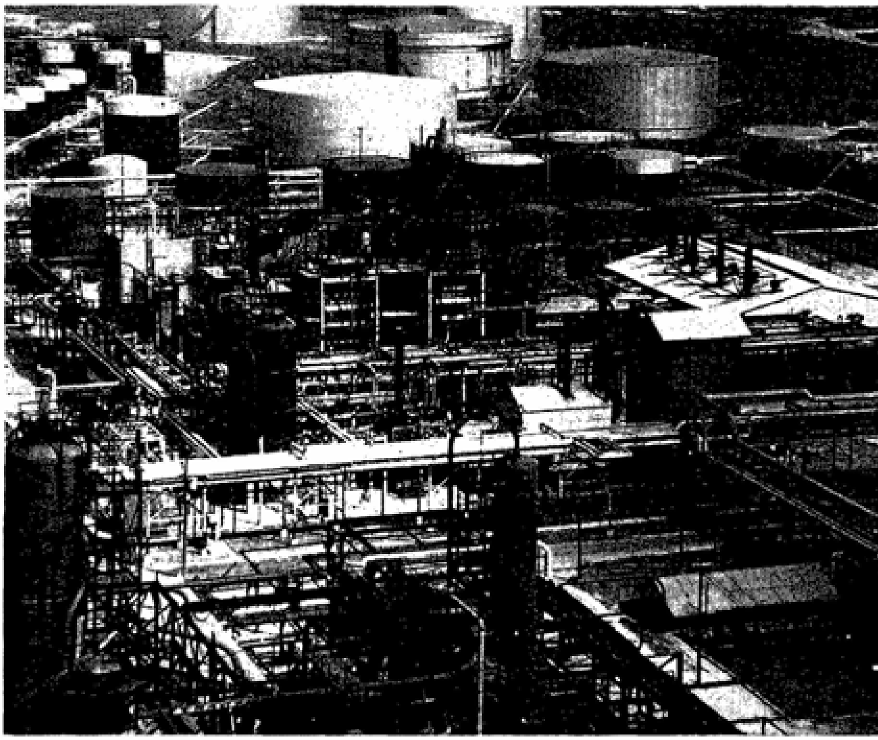


Fig. 9-25. Refinery structures. (*Pure Oil Co.*)

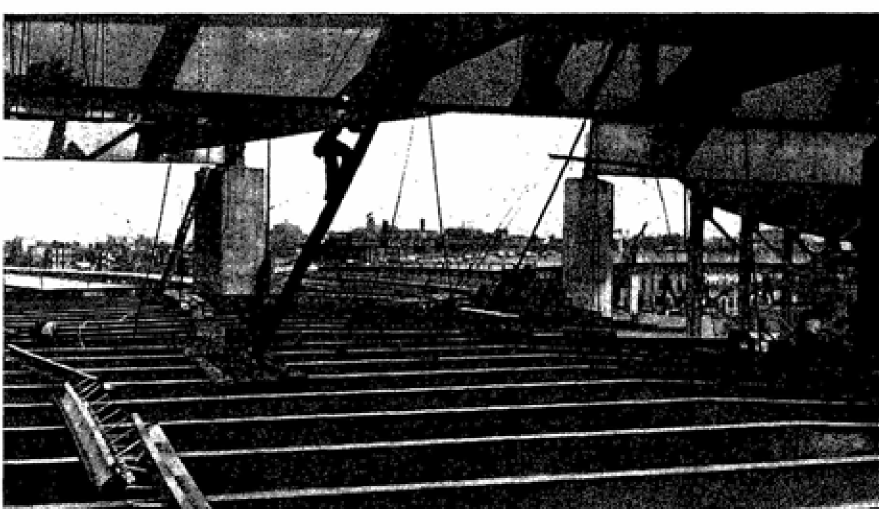


Fig. 9-26. Elevated expressway. (*Harris Structural Steel Co.*)

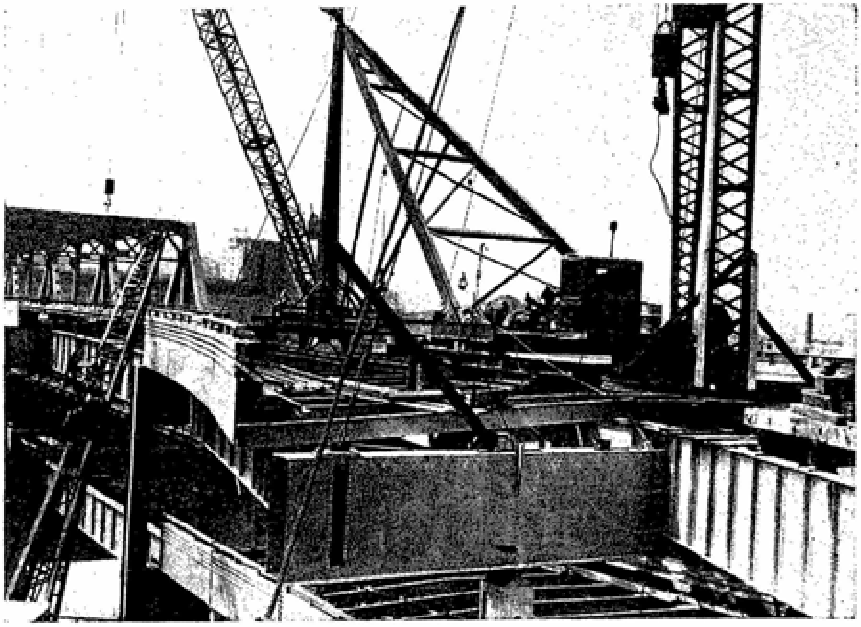


Fig. 9-27. Expressway construction. (*Harris Structural Steel Co.*)

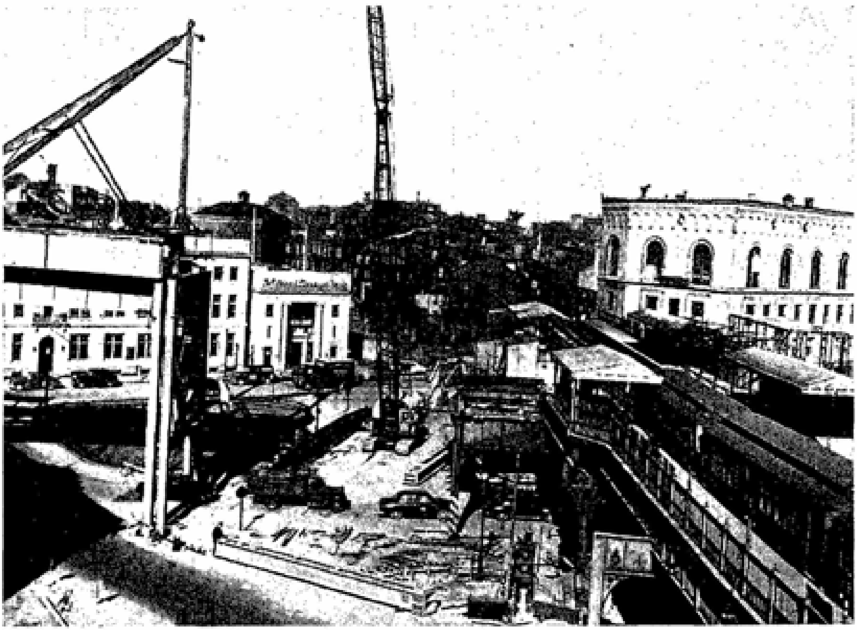


Fig. 9-28. Expressway traveler. (*Harris Structural Steel Co.*)

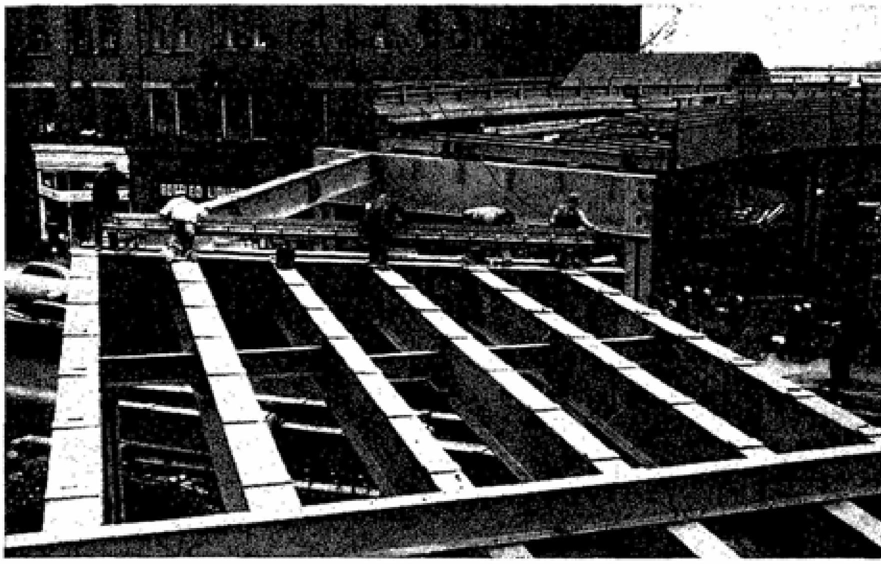
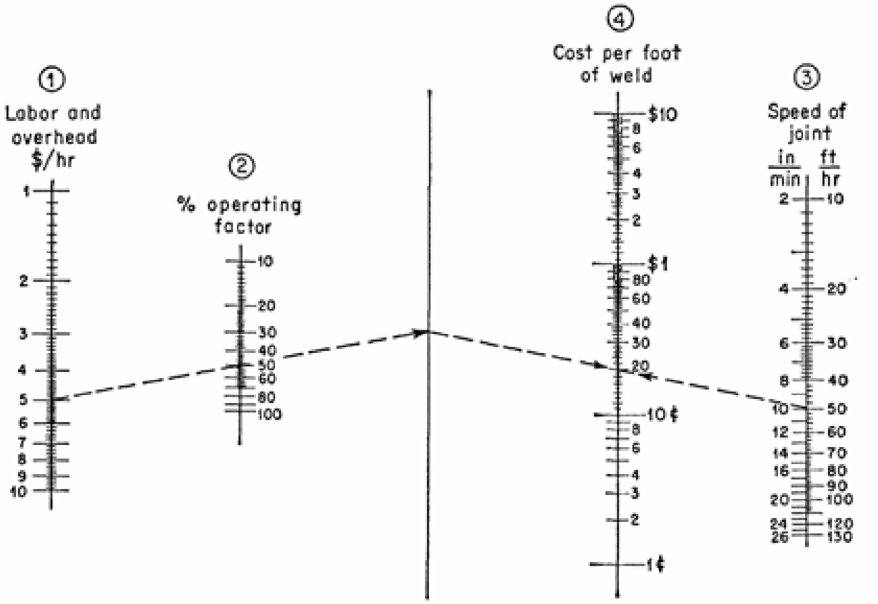


FIG. 9-29. Expansion dam. (*Harris Structural Steel Co.*)



Problem: Find cost of 1/4" fillet weld

① Labor and overhead = $ 5 per hour

② Operating factor = 50%

③ Speed of joint = 10 inches per minute (obtain from actual time or from tables of the Jetwelding and Fleetwelding bulletin SB-1363 or Procedure Handbook of Arc Welding, Section II

④ Read cost = 20¢ per foot. Note: This cost figure does not include electrode cost. To determine this use "lb of electrode required per foot of joint" from above references and multiply by electrode selling price. Add this to that obtained in step ④

FIG. 9-30. Welding-cost estimator. (*Lincoln Electric Co., Inc., copyright* 1957.)

ground. The usual method is to set up the traveler, including the boom, by aid of the tractor crane. This crane will usually erect the first portion of the steelwork on which the traveler will stand.

An expansion dam in the process of erection is shown in Fig. 9-29. The short bar sections are anchors to connect to concrete; these are in very common use for this purpose. The oval openings in the girder at the center of the figure are often required in order to insert rivets. A cost must be included for cutting out the material and putting a smooth finish on the edges of the holes. These rivets will be more difficult to drive and consequently cost more either in the shop or in the field.

CHAPTER 10

Fabrication Costs[1]

10-1. Introduction. Each fabricator will have his own approach to the compiling of his costs. Owing to the many variations it is not possible to produce one set of costs which can be applied in all situations. However, much basic information can be included here which should be of great help to the estimator. In addition it is essential for the estimator to know and study the accounting and production methods of the fabricator by whom he is employed.

Usually the estimator is not given access to all the accounting data, but he must know the proper amounts to be included for all overhead charges that are applicable to the bid figure. These items may include insurance and taxes. It is difficult to be specific about overhead, profit, and other variable charges, as naturally each fabricator may use different applications and different figures. So this item will have to be left open.

Practically every fabricator will furnish the estimator with a standard cost form on which will be placed those figures the estimator is expected to complete.

10-2. Standard Forms. A standard form for a structural fabricator should include the following items:

Materials
- Rolled steel sections
- Rivets
- Bolts, including high-strength bolts
- Welding rod, wire, flux
- Raised-pattern floor plates

[1] In the event that a reader wishes to have accurate information regarding current quotations this can be found in current editions of leading trade magazines, particularly the *Engineering News-Record*, a McGraw-Hill publication. This magazine gives a tabulation of the bid figures of various state and municipal work divided into the various trade units. Reference to these figures may give an estimator information about jobs comparable with the one on which he is working. Complete estimates of typical work will be found in the Appendix.

Paint
Bronze
Lead
Boxes and strapping materials
Car-blocking materials
All other materials specified as part of the contract

Transportation
Drawings
Templates and patterns
Shop fabrication
Painting
Loading
Warehouse charges

There are different methods of setting up the forms. Some fabricators may set up a subform to develop the material costs from the several factors involved, and others may separate the items as indicated here.

10-3. Miscellaneous Items. There are many fabricators who will fabricate and/or supply all or some of the following materials.

Joists
Open web
Long span
Steel decking
Gratings
Sash
Doors
Reinforcing bars
Railings
Fences
Stairs
Ladders
Metal wall—corrugated or insulated
Metal roof material
Castings

10-4. Cost of Rolled Steel. This cost will be one of the first items considered, as it is the major item and may account for one-third to one-half the fabrication costs. Where there is a minimum of fabrication, the material will represent a higher part of the total cost.

The base price of rolled steel usually remains constant for about a year, depending, in many cases, upon the length of the mill's labor contract. There may also be cases where the fabricator is covered by a

contract with the mill or mills for a set price on a time or tonnage basis.

Current prices are published in several trade and engineering magazines. These figures indicate the mill quotations on the various rolled sections and the location of each mill. There will be different base prices on each of the several items, such as shapes, plates, bars, and rails.

10-5. Mill Extra Charges. To the base price of each of the several classifications there must be added the mill extra charges. Several charges may apply to one section. As the cost will be considerable, these charges must not be overlooked.

The mills publish the list of extra charges, and a copy of this list should be in the hands of every estimator qualified to make up cost estimates. There are different extra lists for each of the several mill products, structural shapes, plates, floor plates, bars, rails, and other items. Each of the extra charges must be checked to see which apply to the sections under consideration in the estimate.

The important charges for a structural contract are:

1. Metallurgical requirements
2. Inspection
3. Dimension section
4. Dimension length
5. Cutting, cambering
6. Quantity
7. Packing
8. Marking
9. Loading

Further details of the application of the extra charges will now be furnished.

1. *Metallurgical Requirements.* The estimator will determine the classification of material from the specifications. At the present time most of the structural steel for buildings is required to meet the ASTM A7 specification. There is no addition to the base cost for this requirement at this time. However, the mills may revise any or all of these charges at any time they wish.

The metallurgical requirements for steel in bridges and in welded work often are not ASTM A7. Therefore an extra charge may be required to be applied. All other chemistry extra charges will be added when required. Structural silicon steel is often used in bridges or viaduct columns and in other bridge members. The proper extra charge must be added, which in the case of this material is considerable.

2. *Inspection.* Usually inspection in conformity with standard mill practice will suffice, and at present, if this is accepted, there is no extra charge. Should other inspection be required, it is necessary to contact the mill or check with the fabricator's purchasing agent.

3. *Dimension Section.* This is an important extra charge and applies to practically all structural shapes. Some mills may make minor excep-

tions, but generally the extra will obtain. The extra charge is approximately 10 per cent of the base to above 20 per cent, depending entirely upon the type and size of section. The lowest charges are on some of the WF sections (12 in. heavy to 30 in. heavy, with exceptions). The high charges are assessed on rolled tees.

4. *Dimension Length.* An extra charge is made for cutting for sections of any length except in the case of some 30- to 60-ft pieces, on which a leeway of 5 ft will be permitted by the fabricator or purchaser. Therefore this extra charge, which amounts to around 5 to 10 per cent of the base, must be added to all sizes on the estimate, with the possible exception of some materials ordered in long lengths for details. The detail material will be cut to the required length in the fabricator's shop. Both the section extra and the length extra will be required on practically all the shapes.

5. *Cutting, Cambering.* Cutting extras will be required for close tolerance. Generally, when close tolerance is required, the fabricator will prefer to have it done in his own plant.

Cambering is indicated on the plans in practically all cases and is required on much of the highway bridge work. It may be done at the rolling mill if the fabricator so desires, in which case the proper charges must be added to the estimate. The cost for cambering may be 10 to 15 per cent or more of the base cost of material. Many fabricators prefer to have cambering done on their own premises and may advise the estimator as to how to apply the cost.

6. *Quantity.* The extra charge for the quantity may amount to 10 per cent or more of the base price of material. It is advisable for the estimator to consult with the purchasing agent as to his method of combining units on the purchase order. Otherwise the mills usually determine an item quantity extra by the total weight of the individual size; that is, each weight, gage, or thickness of a structural section is an individual size.

7. *Packing.* Unless steel bands or paper wrapping is specified, no extra charge is made for this item.

8. *Marking.* The steel will have the customary mill marking. Unless specified marking is required, there are no extra charges.

9. *Loading.* It is customary for most mills to load in lifts of 5 tons or over. Extra charges will be assessed if lifts of less than 5 tons are specified.

This may appear to be a rather lengthy explanation of mill extra charges, but the amounts involved may be considerable and the estimator must include all that are applicable. Where there is more than one extra, each must be included, as the inclusion of one will not exclude others. Note particularly the extra charges for section, length, and cutting. All three will be required on many sections.

10-6. Warehouse Material. Throughout the country there are a number of suppliers of unfabricated steel. These organizations purchase the rolled steel from the mills in long lengths and warehouse it for future sales. Some customers will pay extra for the fast delivery of an order, and in such cases the fabricator may buy the material from the warehouses rather than directly from the rolling mill.

Many fabricators maintain a practically permanent inventory of steel which they may apply directly to an order which carries a premium price and requires a prompt or early delivery. There will be cutting waste on stock material. Also, investment costs are involved. The estimator should be advised by his employer as to the additional costs to be included for stock or warehouse material.

There may be times when the fabricator will purchase small quantities of material from a warehouse to complete work on a contract rather than await a delayed delivery from the mills. Some estimators may be advised by the fabricator to include a small additional sum to compensate for the expense.

10-7. Fastening Materials. Bolts, rivets, washers, and welding rods are items required to complete the fabrication of the work. Their cost will be included with the cost of the rolled steel or may be listed separately on the summary.

The prices for these items may be supplied by the purchasing department or obtained from a supplier. There will be the usual quantity extras for purchase of a minimum quantity. Note that the cost of high-strength bolts will be quite high in comparison with ordinary bolts. High-strength bolts are quite popular and will frequently be specified. They are a heat-treated bolt, and each bolt must be used with a pair of hardened washers.

Much stress has been placed upon the mill extra charges, but because of the fact that the base cost of certain items may be increased as much as 50 per cent or more, it is imperative that all extra charges be included in the material cost of rolled steel.

10-8. Class A Structural Steel. The AISC "Steel Construction Manual" lists classifications under a heading Class A Structural Steel.

Where a job specification has indicated that the AISC specifications apply to the work, the estimator will take note that any or all items of Class A structural steel may be required to be included. Any items which are not to be included must be specifically noted so that the proper information is given the buyer at the time the quotation is presented.

There may be some changes in the list of items. It is advisable that reference be made to the most recent revision of the classification list in the latest AISC Manual.

An approximately complete listing of Class A items is included here but is, of course, subject to revisions as noted above:

Class A Structural Steel, AISC Code of Standard Practice

Anchors for structural steel
Bases of steel or iron
Beams, purlins and girts
Bearing shoes for bridges
Brackets made of structural steel
Bridge pins
Bridge railings of rolled structural steel
Checkered or raised-pattern floor plates connected to the steel frame
Columns of steel, iron, or pipe or cement-filled pipe
Counterweight boxes for bridges
Crane rails and stops with detail fittings
Door frames constituting part of exterior wall framing
Expansion joints
Girders
Grillage beams
Hangers of structural steel if attached to the structural-steel framing and shown on the framing plans
Lintels shown on the framing plans or otherwise enumerated
Marquees, structural frame only
Monorail beams of standard structural shapes
Separators, angles, tees, clips, bracing, detail fittings, rivets and bolts, all in connection with the structural steel frame
Struts of structural steel or pipe
Tie rods, sag rods, bracing rods
Trusses

The fabricator may include any additional miscellaneous material as he desires. The estimator will be advised which of the additional items are to be included. Usually a listing of items other than Class A items will be made in the notes.

10-9. Castings. Certain work will require castings. Heavy bridge bearings may be made of cast steel. Most generally castings will be obtained from those companies whose exclusive business it is to make them. Therefore the cost of making the patterns and of the castings will be obtained from the supplier and included in the estimate.

The fabricator may, if he wishes, machine the castings and also fit parts of the castings to the fabricated steel.

10-10. Paint. With few exceptions a coat or coats of paint will be specified to be applied before the fabricated steel leaves the shop. The quantity required will vary according to the kind of paint specified and the method of application. The kind of paint and perhaps the name of a paint manufacturer may be designated in the specifications. In order

to determine the quantity of paint, other factors must be considered: the type of framing, the normal area a gallon of paint will cover, the number of coats, and whether the paint is to be applied by spraying equipment or brushes.

Many fabricators will have compiled data relative to the number of gallons of paint required per ton of steel framing. Without investigating fully all the factors entering into the cost of paint to obtain an exact figure, an approximate cost may be used of 2 to 4 per cent of the cost of the steel as received from the mills. This cost will represent only the material and not the cost of application.

10-11. Bronze. The item of bronze is one which must not be overlooked. It is general practice on the part of many state engineers and other designing engineers to include bronze in connection with the bridge bearings. The bronze may be in the form of solid plates, bronze overlay, or patented types of plates, two of which are designated by the trade names of Lubrite plates and Radilube.

All bronze items are very expensive, and of course sufficient cost must be included in the estimate. The cost may run from fifteen to twenty times the cost of steel. The weight of bronze is about 3 per cent above the weight of steel.

10-12. Lead. Sheets of lead are sometimes placed under column footings and may be used elsewhere in a steel structure. The weight of lead is 710 lb per cu ft and the weight of rolled steel is 490 lb. (Each of these figures and also the weights of many other metals and substances may be found in the AISC "Steel Construction Manual.")

The cost of lead is around twenty times the cost of steel. An exact quotation may be obtained from the trade papers or magazines. The magazine quotations may be for large quantities, and a differential must be added for the smaller quantities.

10-13. Boxes, Blocking, Binding, and Strapping. These several items may be included in the shop overhead but, if not, must be added to the cost of other materials entering into the contract. Export shipments and certain domestic work may require the boxing of short-length materials and fittings, including fastening materials, to prevent losses. Binding and strapping materials may be used on certain work such as tie rods, sag rods, bracing rods, and anchors. Some fabricators like to use considerable strapping, including strapping of beam sections. In this way the chance of loss during transportation is reduced and the size and weight of an individual load can be controlled.

A check list is most useful to ensure the inclusion of all materials other than steel which will be required for a contract, and all necessary costs must be added to the estimate.

10-14. Transportation. Most fabricators maintain a traffic department having the responsibility of obtaining all freight and trucking rates. When this is the situation, the estimator may consult with the traffic manager to obtain all the transportation costs which must be included in the estimate.

The base material costs as given to an estimator by the purchasing department may include the cost of incoming transportation. If not, it must be added either as a total cost in connection with other freight charges or as an independent item.

The charges on incoming material are usually simple carload rates. However, the outgoing rates may not be simple. Shipments may consist of a less than carload lot or may consist of a multiple load requiring three or more cars. A long girder or truss may require multiple loading. Railroads have established different rates for multiple loads as opposed to carload rates.

An estimator may be obliged also to include trucking charges, storage charges, lighterage charges, and unloading crane or other unloading charges.

10-15. Drawings. Nearly all structural work is what may be called "custom-made." A simple formula for the cost of drawings cannot be set down.

Drawings may be provided from one or from several sources. They all may be prepared in the drafting room or department maintained by the fabricator. They may be supplied by engineers or draftsmen employed by the buyer. They may be prepared by an independent drafting organization or outside detailer.

The fabricator may or may not include overhead in his drawing costs; it can be included in general plant overhead costs. Some of the costs are drawing paper, supplies, and blueprints. In accepting drawings as supplied by the buyer, there usually are charges incurred by the fabricator to confirm these drawings for his shop use. Many fabricators have drawing costs supplied to the estimator by the chief draftsman, who then assumes the responsibility for the correctness of the figures.

In the event that the estimator has drafting experience, he may analyze the work which will be required to prepare the drawings for the shop and field. It should be of interest here to examine some of the items to be considered in the development of a drawing cost.

1. Upon the receipt of contract plans the first work to be done in the drawing room will be the preparation of the mill order lists, which will usually be processed by the purchasing agent or department.
2. The floor plans and the column schedule will be made.
3. Special layout work will be done to facilitate the details.

4. The detailing may be assigned to the men best qualified for the several classes of work, beams, columns, trusses, girders, and other framing. As the details are completed, they will be handed to the checkers, who will examine and approve the details or indicate corrections.

After the details are checked, they will then be blueprinted and sent to the shop for use in fabricating or to the template shop for the preparation of templates.

It can be readily understood that the development of a drawing cost must be done by an experienced person. Where there is considerable duplication, the cost will be moderate. On a difficult job such as a conveyor or wind tunnel, the costs of drawings will be high. Therefore the cost may approximate 20 per cent of the material-fabrication cost or exceed 100 per cent of the cost of material fabrication or shopwork.

10-16. Templates. In nearly all large fabricating plants the preparation of templates is a function of the fabricating or shop division. In some smaller shops the draftsmen may prepare the templates. In the latter case much layout work may be done full size directly on the template material, and then figures may be transferred to the drawings for future reference.

In order to complete his figures, the estimator must obtain information on the costs of template making. This may be supplied from a series of cost records which have been accumulated in or for the template shop. An estimator with drafting experience may be able to project a figure for use on practically any estimate.

10-17. Shop Fabrication Costs. The cost of fabrication is, of course, the major item of cost. If the fabricator is to remain solvent, this must not exceed the estimate.

The methods employed by nearly all fabricators to obtain shop fabrication costs and the factors used by each to gain this end are almost always held confidential and are rarely released for general information. There are thus many different ways to develop the costs, and the costing methods of any one fabricator will not be described here.

Some time is needed before an estimator is qualified to prepare the costs of fabrication. It should be clear that a full study of the fabricator's methods and systems is necessary.

In most of the modern fabrication shops, the margin of error, plus or minus, between the estimated costs and the final actual shop costs will rarely exceed 1 or 1½ per cent. Some of the methods used in making up an estimate may not seem to agree with hairline accounting practices, but by the use of proper procedures, percentages, and balances the estimated costs will come remarkably close to the actual final costs.

It may be claimed that a difference of 1 per cent would represent a

considerable sum, but some of the other assumed percentages, for instance, overhead, may show a much greater variation over a moderate period of time. A plant management may decide and order used an overhead figure of 40 to 50 or even 100 per cent. Assuming that the figure of 50 per cent is the one selected, at the end of a year or other period of time this percentage may range perhaps from 47 to 52 per cent, much more than the 1 or 1½ per cent which has been considered in the fabrication-cost estimate.

The figures and information which have so far been obtained from the physical take-off of the estimating drawings will be assembled on a subsummary or a summary form. Each of the many different summary forms represents the individual fabricator's method of combining the work which is similar for fabrication and assigning a cost unit to it.

The cost of fabricating beam framing may be obtained by summing up the weight of all the beam work in a structure, then selecting a tonnage unit figure which will represent a good average cost for that particular type of beam framing. In order to clarify this approach to a cost, consider the several different classifications of beam framing. Many of the conditions were explained in connection with the material take-off.

10-18. Material and Work Classifications. The Time Study. Practically all beams are included in the following classifications:

Beams
- Plain, cut to length, no other fabrication
- Punched, web or flange or both web and flange
- Framed, connections attached
- Framed also with cuts or copes
- Riveted with cover plates
- Welded with cover plates
- Sloping with connections or punched, no connections
- Curved or bent with connections

Assuming that a job has beam framing including punched beams, framed beams, and framed and coped beams, the unit cost for each of the three classes may be applied separately, or it may be the practice of a fabricator to apply a unit cost to the combination of all three types. This would then be designated as a cost for all simple beam framing.

As previously indicated, it is not possible to describe a method of setting up a cost procedure which would apply to all fabricators. However, one of the best methods is to follow through a time study of the labor and time required to fabricate some of the sections and assemblies most often used. Before proceeding with a time study a representative listing of the various classifications of work will be given. This does not include the beam framing, which has been listed.

Columns
- WF or H sections
- Round and concrete-filled
- Welded cover-plated
- Riveted cover-plated
- Built-up of angles, WF sections, channels, and tees with or without plates

Girders
- Riveted light sections
- Riveted heavy sections
- Welded light sections
- Welded heavy sections

Trusses
- Riveted light sections
- Riveted heavy sections
- Welded light sections
- Welded heavy sections

Grillages and bases
Purlins
Girts, side and end framing
Angle bracing
Rod bracing
Built-up struts and bracing
Lintels
Door and window framing
Stairs
Crane rails and fittings
Bunkers and hoppers
Tank work
Bridge shoes and bearings
Expansion joints
Sag rods, tie rods, anchors

Some fabricators may classify all fabrication into each of the separate units. Others may group the material as, for instance, beams, columns, girders, and miscellaneous framing. As has been previously stated, the estimator is not advised to follow any one pattern but to choose one for study in order to get a general idea of the many factors entering into the development of the cost of fabricating a structure.

A time study could be made of every one of the hundreds of individual pieces and sections comprising the frame of a structure. This study could not be made, however, until after all the details were completed, and obviously the estimator would not have the details at the time of estimating except in certain cases where details are supplied for the purpose of obtaining an estimate. However, much of the information obtained from a time study can be applied to the production of an estimate. A number of examples will be included here.

There is one item of shop cost which is a recurring figure: the cost of moving the material throughout the shop for the various operations. This cost may be applied against each operation or may be accumulated and charged at the completion of fabrication of a section or of an assembly.

The first operation is the selection of material from the incoming-material yard, or stockyard. This material will be moved into the shop to the layout area. The material is placed on skids, as may be seen in Fig. 10-1, foreground. At this point it is checked for length and size. Markings with paint or crayon and center-punch markings are made on the sections to indicate the fabrication required.

Measurement may be made by hand on each piece, but if the material is a group of sections to be fabricated alike, then it is more practical to use templates. The templates will have been made and are ready for use before the material has been placed on the skids. In a properly managed plant all the operations will be coordinated.

The shopmen in the right foreground of Fig. 10-1 are doing a burning operation on the material at that point.

FIG. 10-1. Section of fabricating shop. (*Lehigh Structural Steel Co.*)

10-19. Examples of Costing Methods

Example 10-1. The beams of Fig. 10-2*a* require punching and cutting.

Note that most of the dimensions have not been included in these sketches. This is because they have no direct value in the cost study.

In addition to the unloading, handling, and layout costs the remainder of the costs are:

24 cuts @ x hr
48 holes punched @ y hr

The holes are all flange holes and require the sections to be turned over and put through the punches a second time.

This completes the fabrication of these six beams except for cleaning, painting, inspection, and loading out.

Many fabricators have established rates on a time basis for many of the standard operations such as punching, riveting, welding, and so on. A cost on a dollar basis is impractical as the rates paid per hour will continually change. However, should an estimator wish to use the dollar basis, a very interesting approach can be seen in the Lincoln Electric Co., Inc., nomograph, Fig. 9-30.

It will be noted that, in using this nomograph to obtain the cost per foot of

weld, it is necessary to obtain several unit values. Usually these factors can be obtained from the shop management or from a combination of average hourly cost plus overhead (when overhead is not added as a unit factor to the sum of all costs). Also, an operating factor is necessary for use with this nomograph.

The Lincoln Electric Co., Inc., in its "Procedure Handbook" indicates a labor and overhead cost of about 80 to 86 per cent, an electrode cost of about

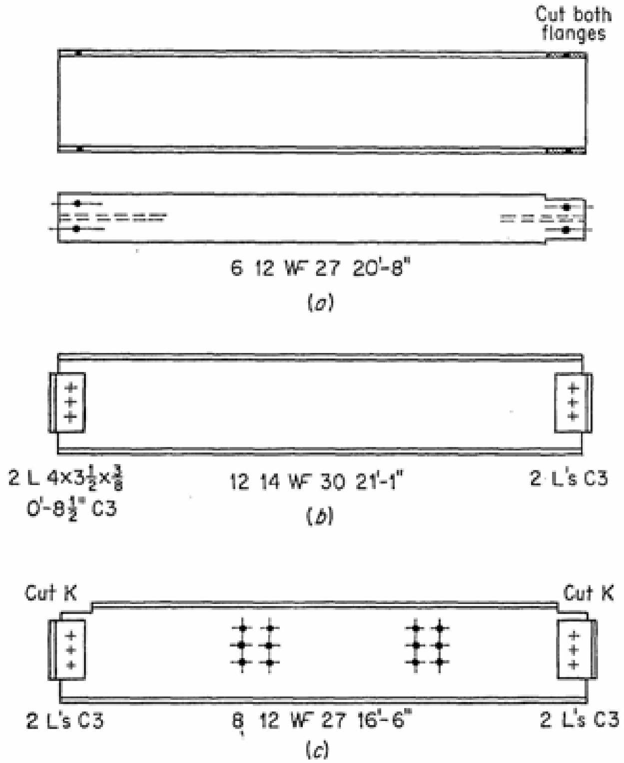


Fig. 10-2. Beam details.

8 to 15 per cent, and equipment costs around 2 per cent. The speed of joint is variable according to the type and position of the joint. The fabricator may have accumulated a set of values for use here; if not, many tables will be found in the Lincoln Handbook.

Example 10-2. The next sections (Fig. 10-2*b*) are simple framed beams. The detail angles identified as LC3 are standard wherever possible and are prepared in quantity, often at a section of the shop which is called the "detail-preparation area." The labor required for these 12 pieces is:

72 holes punched @ x hr
48 angles C3 prepared by the detail section @ y hr
72 rivets driven @ z hr

A fixed rate of time should be applied for the preparation of all details and this amount applied as indicated here.

Example 10-3. The eight beams shown in Fig. 10-2*c* will be similar to the beams in Example 10-2 as far as the end connection angles are concerned, but will require the cuts at the ends presumably to clear adjacent beams in the framing. Also, there are 12 web holes in each beam, a total of 96 web holes.

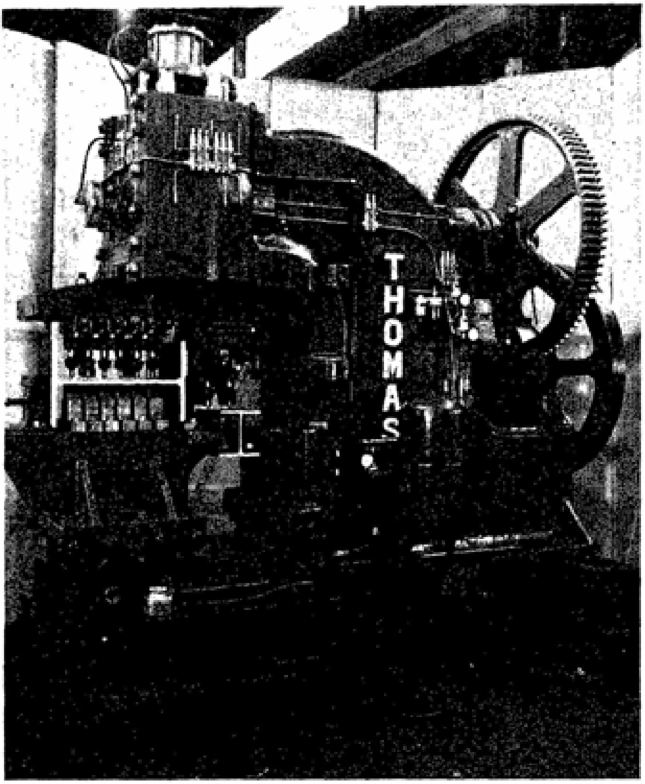


FIG. 10-3. Multiple punch. (*Thomas Machine Manufacturing Co.*)

Here is a case where the multiple punch (Fig. 10-3) may be used. It is standard practice for fabricating plants to establish and use as much uniform spacing of holes as possible. This is particularly valuable when the use of multiple punches is possible. The number of punches may be set up according to the capacity of the machine and the requirements of the work. The individual punches may be made inoperative when set up on the machine but not required for a specific operation.

If the punching of the groups of holes is done on a single punch machine (Fig. 10-4), considerable extra movement of the sections is required. That is, it would be necessary to move the beams to and away from the punch to spot and punch the several holes.

The shopwork on the beams (Fig. 10-2*c*) is as follows:

16 cuts K (type of cut) @ v hr
32 angles C3 prepared by detail section @ w hr
144 holes punched @ x hr (multiple punching)
48 rivets to connect angles @ y hr

These items complete the shop costs on these eight beams. The layout, handling, inspection, painting, and loading costs will, of course, be added to all work.

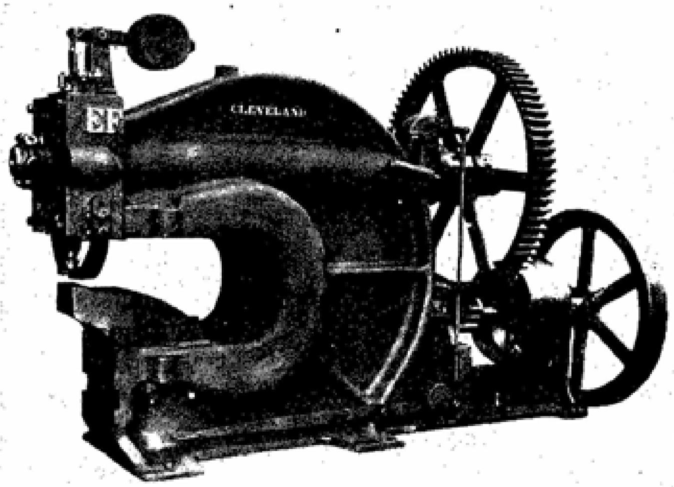


FIG. 10-4. Single punch. (*Cleveland Punch and Shear Works.*)

Example 10-4. The detail of Fig. 10-5 is for a group of five beams to which diagonal bracing will be connected. The angles C4 and C10 and the plates P2 will be assumed to have been prepared at the detail section. The shopwork for the preparation and assembly of the beam sections will be:

80 holes punched in the web @ v hr
50 holes punched in the flange @ w hr
130 rivets to drive @ x hr
20 detail angles as prepared by the detail section @ y hr
5 plates P2 as prepared by the detail section @ z hr

Standard templates will probably be used for angles C4 and C10, but a special template will be made for plates P2.

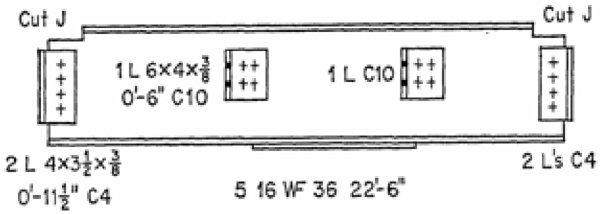
The punching can readily be done on a multiple punch set up as shown in Fig. 10-4. It will be noted that not too much extra handling would be necessary, as the sections could be web-punched on one pass and then easily turned for the pass for flange holes.

Figure 10-6 is a detail of a beam spandrel section, and from a study of the previous examples the shopwork on this group of 10 units will be easy to follow.

Example 10-5. Figure 10-7 shows a group of bracing members. The 24 angles of Fig. 10-7*a* are simply cut to length and punched. The angles may be run through a duplicator (Fig. 10-8) in a long section and cut after punching. The shopwork is:

Punching 144 holes @ x hr (duplicator or single punching)

Note that the picture shows a beam being fabricated but that angles will be fed automatically in the same way.



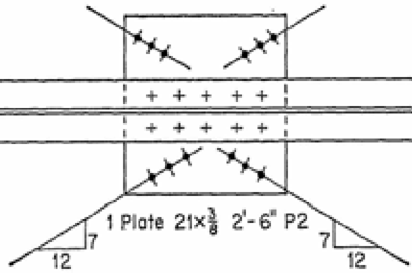


Fig. 10-5. Beam detail.

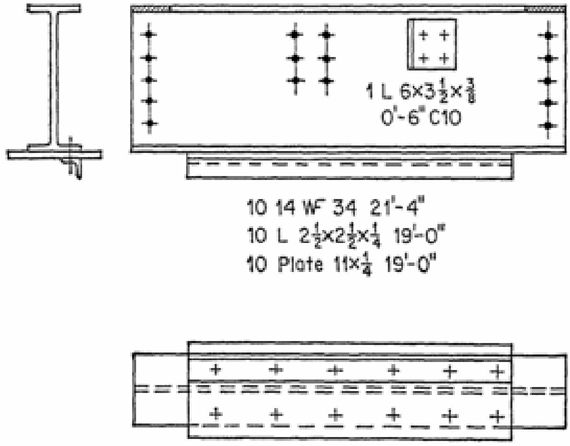


Fig. 10-6. Beam detail.

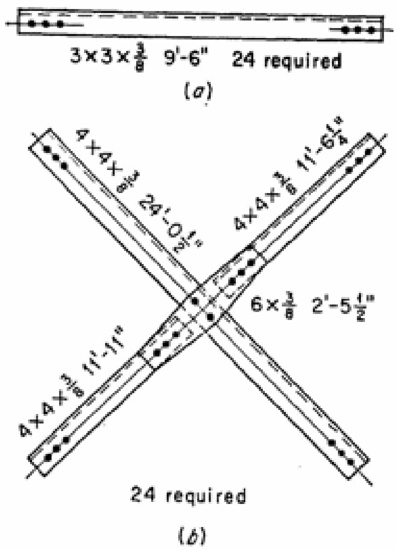


FIG. 10-7. Angle bracing.

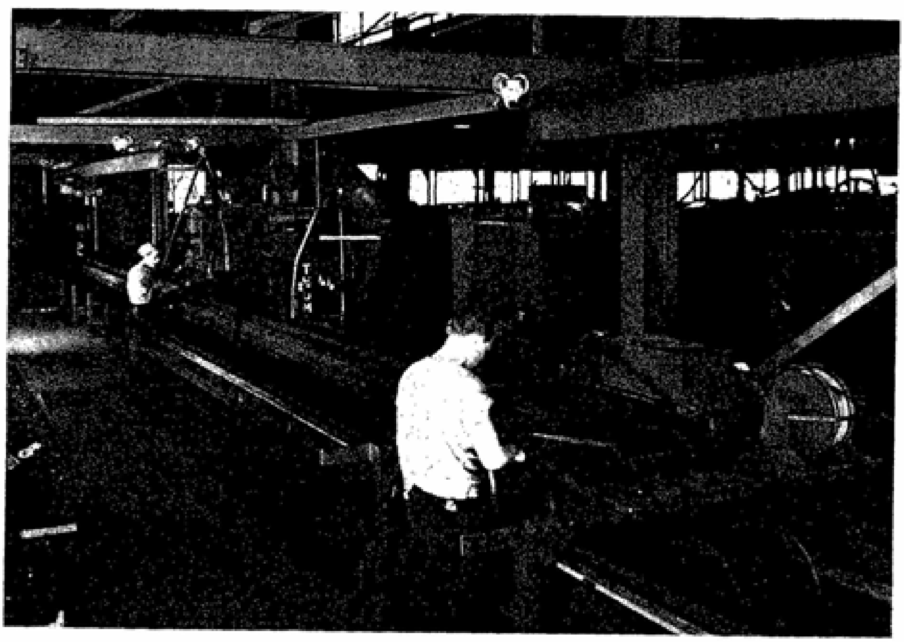


FIG. 10-8. Duplicator. (*Thomas Machine Manufacturing Co.*)

It is usual practice to draw bracing as shown in Fig. 10-7*b*. This group consists of three units: one long angle and two shorter angles. The connecting plate is shown attached to one of the shorter angles.

The plates may be cut and punched in the detail area. Shearing will be required and also the punching of 192 holes. All work will follow a template.

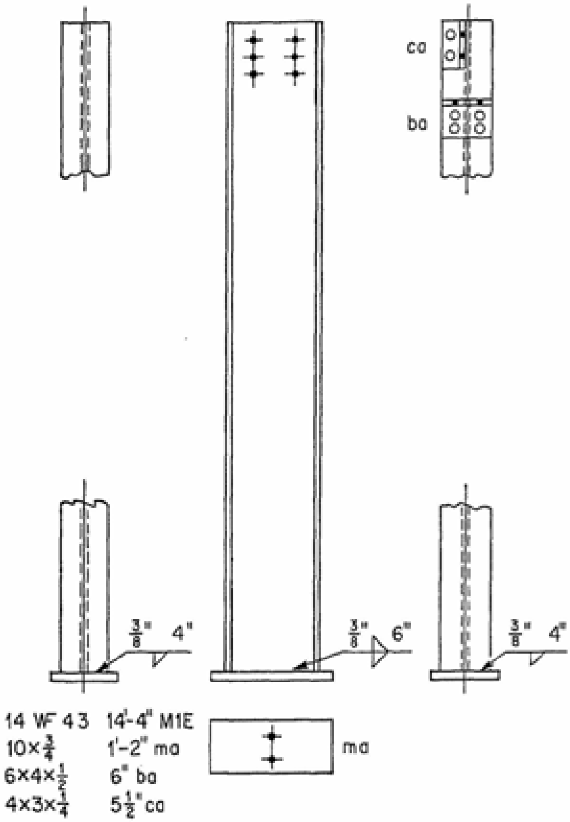


Fig. 10-9. Column detail.

The 72 main angles may be run through the angle duplicator or a single punch. The shopwork will be:

Cutting 72 angles @ x hr
Punching 480 holes @ y hr
Driving 72 rivets @ z hr

Example 10-6. The next assembly to be considered is a column section (Fig. 10-9). A list of all the material for this assembly is shown at the lower left of the drawing. Many of the dimensions have been left out of the sketch, as they would not particularly affect the cost figures unless the section were very long. In cases of very long sections there may be additional handling expense.

The two sections of detail angles and the plate may be made ready at the detail area of the shop.

It is noted that the column shaft is to be milled one end (M1E). The entire fabrication items will be:

Mill one end of the column @ v hr
Punch 6 holes in the web @ v hr
Punch 6 flange holes @ w hr

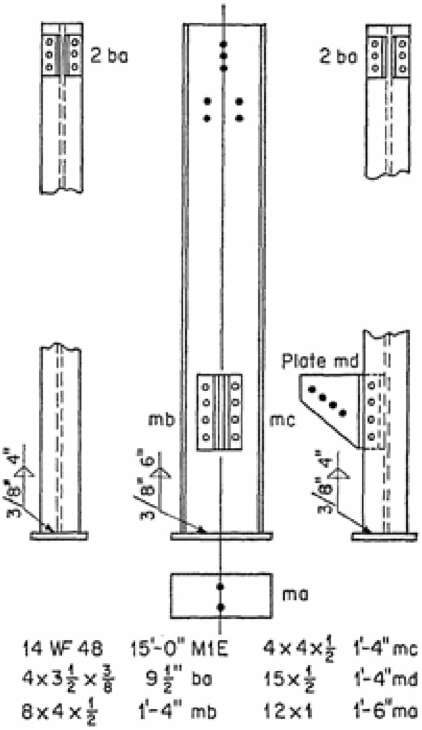


Fig. 10-10. Column detail.

Attach 2 angles, 6 rivets, @ x hr
Weld the base plate, 20 in. of ⅜-in. weld, @ y hr.
Add for the detail material 2 angles, 1 plate @ z hr

The remaining work on this column is the same as for the other section: layout, handling, inspection, cleaning, painting, and loading for shipment.

Example 10-7. A column section is shown in Fig. 10-10. The list of material is at the lower left of the drawing.

The detail material will consist of six angles and two plates. It will be assumed again that these details will be cut and punched in the detail area and moved to the assembly area for attaching to the column.

The work on this column section will be:

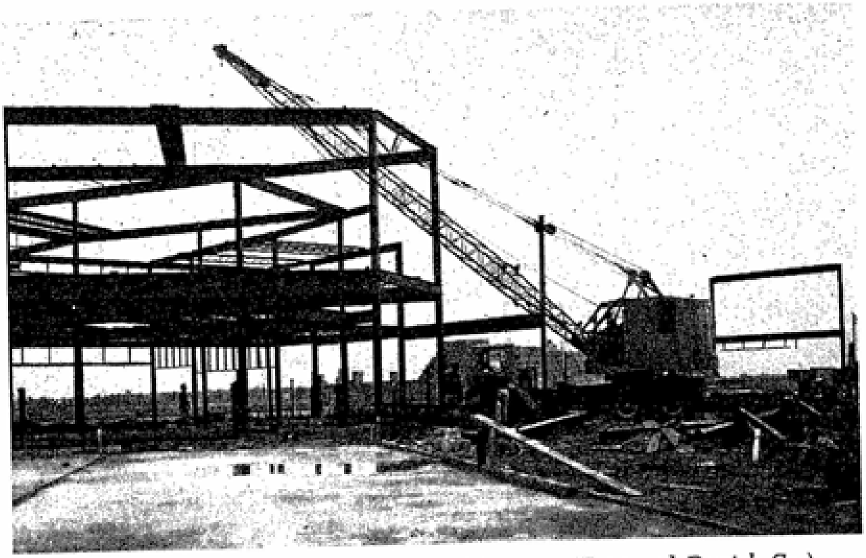


FIG. 10-11. Beam-and-column framing. (*American Hoist and Derrick Co.*)

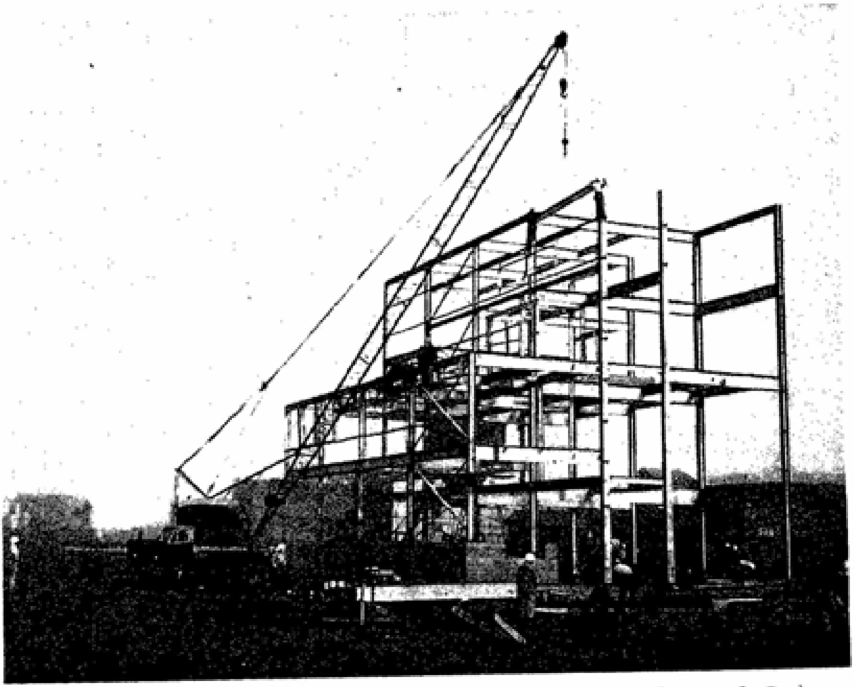


FIG. 10-12. Beam-and-column framing. (*American Hoist and Derrick Co.*)

Mill one end of the section @ v hr
Punch 31 holes (15 web, 16 flange) @ w hr
Drive 24 rivets @ x hr
Attach base plate, 20 in. of ⅜-in. web, @ y hr
Add for detail material 6 angles plus 2 plates @ z hr

These seven examples should present a general idea of the procedure to be used in developing a shop cost for any required section or assembly. It is of course obvious that as the assemblies become more complex the work will increase as well as the fabrication cost.

It is not practical to give a definite shop cost for any particular structure, as there will be at least a moderate variation of cost between two buildings of almost similar framing. For example, refer to Figs. 10-11 and 10-12. Each of these structures consists of average beam-and-column framing. However, the framing of Fig. 10-11 is not rectangular; instead, it has many skewed connections, whereas the framing of Fig. 10-12 will have simple standard connections. The shop labor required for the fabrication of 1 ton of ordinary beam framing without some of the margin costs such as handling and overhead may require 6 or 7 man-hr or may be close to 20 man-hr for a difficult structure. By the same token, it may range from a total of 100 man-hr for a truss or girder, or it may consume 2,000 man-hr for a heavy, difficult girder or truss.

10-20. Inspection. It is normal practice to inspect all fabrication after its completion in order to make sure that the various members will fit together properly after arriving at the site of construction.

As the estimator finds details available, it should not be too difficult to follow along the lines which have here been described. The handling costs on large, heavy trusses and girders will be materially increased as compared with the lighter beam work. These additional costs must be thoroughly considered in preparing the fabrication costs.

10-21. Painting and Cleaning. Many specifications have very strict requirements regarding painting and cleaning. Other specifications permit normal hand cleaning with wire brushes.

Where the cleaning is required to be done by sandblasting, shot blasting, or flame, it is necessary to add a considerable sum to the estimate to provide for this expense. In addition to the shop labor sand or shot must be supplied and used for the blasting or oxygen for the flame cleaning. Also, the estimator should find out from the management whether special equipment has to be purchased or rented; if so, additional costs will be included.

Paint will be applied by brush or by means of spray equipment. The cost of painting is usually considered on the basis of a fixed sum per ton of steel. This figure will of necessity be an averaged figure which has

been selected by the management after compiling a considerable number of data.

Most paint manufacturers indicate an approximate area of coverage per gallon of paint of each type or grade as supplied. Therefore it is technically possible to calculate the area to be painted and divide by the production rate of the painters. This line of reasoning, however, will not supply a practical unit rate per ton. For instance, an $8 \times 6 \times 1$-in. angle will have very nearly the same surface area as an angle $8 \times 6 \times \frac{1}{2}$ in., but the weight of the 1 in. thick angle is twice that of the angle $\frac{1}{2}$ in. thick. Likewise, when the steel in a structure consists of heavy beam sections, as compared with a structure in which most of the framing is light trusses, there will be a considerable difference in the cost per ton for the painting.

An average cost of cleaning and painting will be around 10 per cent of the fabrication cost. When flame cleaning or sandblasting is required, this cost can be around 30 per cent of the fabrication costs. All overhead costs are excluded in these approximate percentages.

The use of spray equipment requires a supply of compressed air for the spray guns. The paint thus applied may give greater coverage per gallon and also will reach many small pocket spots which are practically inaccessible to brushes unless exceptional care is used with the brushwork or unless very small brushes are used.

10-22. Loading. The loading of structural steel on trucks or on cars will range from the very simple pickup and placement of a load to an extremely involved operation. Because of the vehicle-loading weight limits as prescribed by state laws it usually does not take many structural sections to reach the capacity allowed, and consequently the ordinary truck loading does not present a difficult problem. The load will, of course, be required to be secured to the truck. By the same token the loading of average beam-and-column work into railroad cars is also not complicated. The carloads will ordinarily be upward of 25 tons. The usual car supplied for structural steel is the gondola, or open-top equipment. Some blocking will be placed on the floor of the car to facilitate the passing of a sling or cable round part of the load when it is to be lifted out. In nearly all cases it is unnecessary to load above the sides of the cars, and therefore it is usually not required to secure the load. The average railroad freight cars suitable for loading steel are about 40 to 65 ft long. The flatcars without sides are about 40 to 50 ft long.

It is not unusual to be required to ship girders or trusses of 100 to 150 ft long and in special cases even longer. In such cases more than one car will be required to move the shipment. For example, consider a girder 125 ft long. One of the most practical methods of loading is to use a group of 3 flatcars. The center car of the three may not carry

any of the load. Its function is to complete the connection between the other two cars and the rest of the train. Swivel bolsters will be constructed and will be attached to the remaining two cars. One bolster will therefore be near each end of the girder. The provision made for the bolsters to turn right or left will allow the train to swing round curves without the load projecting beyond a safe clearance. For instance, if a long section were secured in one car without the bolster action, it would project beyond the right of way or safe clearance range on almost any curve. The cost of preparing the bolster and supplying any other material for securing the long girders may not be within the scope of an average estimator's work. In some cases, however, it may be required to include these costs in the bid figure.

Long trusses may be loaded in about the same manner as long girders, but it will usually be required to attach rods or guy wires to the top of all truss shipments for stability in transit. It usually is not practical to load trusses flat. They bend easily in this position, and also they are very often more than 10 ft deep. The average freight car is about 9 ft 6 in. wide. The estimator will also consider the tie-down and bracing materials required for the shipment of trusses. The usual method is to secure trusses to the car sides to prevent any movement of the load until it arrives at the destination.

Railroad-car inspectors are strict regarding the safety of the movement of large and heavy structural materials. Ample bracing must be provided by the fabricator before the shipment will be accepted.

CHAPTER 11

Erection Methods and Costs

11-1. Introduction. In order to have a better understanding of the conditions in the field, it is advantageous for an estimator to spend a period of time observing the actual erection of a number of structures. This is not always possible, however. Hence it is advisable here to describe the major equipment and point out some of the problems encountered in connection with the erection of several different types of structures.

Nearly every structure will present special problems for the erector. Some of these are the type of the structure, the location of the work, the condition of the ground, the adjacent structure, interfering power lines, and many other situations. The erector must ordinarily use considerable ingenuity and advance planning to complete his work in accordance with the specifications and keep within the allowed costs.

11-2. Cranes. Major erection cannot be accomplished without the use of power-driven equipment. It may be possible to erect a small structure such as a greenhouse with a hand gang, but for large and medium-large work this is very impractical.

The manufacturers of cranes have developed a very broad, flexible line of equipment. An erector will choose the most suitable for each job to be erected, assuming, of course, that he has or can obtain the equipment of his choice. Otherwise he may have to improvise an equivalent substitute.

11-3. Truck Cranes. Probably the most versatile crane is the truck crane. Truck cranes can be moved over the road under their own power and can be made ready very quickly after arrival at the site of the work.

All mobile cranes can pick up progressively less weight as the boom is moved from vertical toward horizontal: to express this in the language of the field, the more the crane booms out, the less the pick. In order to provide additional stability, these cranes are equipped with outriggers. An outrigger is an adjustable support which is projected beyond the wheel base of the crane. Many outriggers are beam sections which slide out from pockets built into the frame of the truck or carrier.

The ends of the beams are then supported on jacks. In Fig. 11-1 the two outrigger beams and the two jacks can be seen at the lower center. One is in front of the rear wheels and the other at the rear of the wheels.

Truck cranes can be obtained which will pick up 50 tons, using a boom 50 ft long and with a minimum radius. These cranes can be fitted

Fig. 11-1. Truck-crane outriggers. (*Harnischefeger Co.*)

with booms up to 210 ft long but will still, of course, be capable of picking up comparatively light loads. The truck crane of Fig. 11-2 has a long boom and jib, not, however, the 210-ft boom mentioned above.

The most practical boom arrangement for steel erection is a main boom and a jib. Refer again to Fig. 11-2. The narrower section at approximately the upper one-third of the boom is the jib. Attached to the end of the main boom the main-load block and hook can be seen. The single-line block and hook attached to the end of the jib are also shown. This arrangement permits the truss to be erected and held in place while a smaller piece is raised with the jib line and connected to support the truss before releasing the main hook.

11-4. Crawler Cranes. Crawler cranes travel on "cats," or continuous wide treads, and are used on much of the highway bridge work. They are also very practical at other locations where the ground is soft. They do not need outriggers and can be had with very heavy capacities.

While crawler cranes can travel on surfaces too soft for the usual truck equipment, they have the disadvantage of being unable to move long distances under their own power. They are not suitable for normal

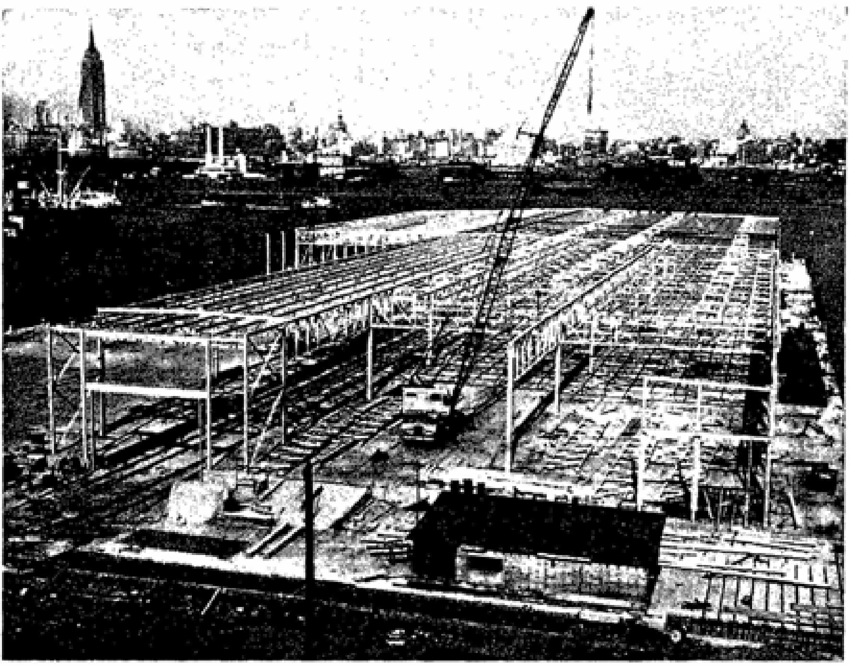


FIG. 11-2. Truck crane with boom and jib. (*Harnischefeger Co.*)

road travel because of their weight and speed and the damage done to the road surface by their rough "cats." The dismantling, moving, and reassembling of the boom and sometimes the "cats" constitute a quite expensive operation. The cranes are moved on railroad flatcars or on special crane-carrier trucks. When they are moved by truck carrier, it is usually necessary to obtain highway permits and special routing because of light-capacity bridges or other adverse conditions.

A crawler crane is shown in Fig. 11-3 in the process of raising the steel for a tall, narrow structure. When it is possible to move a crane round the perimeter of a building of this type, its use is quite practical. Considerably less equipment is required than with derricks.

11-5. Locomotive Cranes. As the name indicates, these are cranes which travel on railroad tracks. They can be had with very considerable

lifting capacity, but it should be evident that their usefulness is limited. When the location of the work is such that the use of a locomotive crane is advisable, it will pay to move it in.

The crane must be coupled in a train and moved to the destination as part of the train, for it is not permitted to move over the main lines

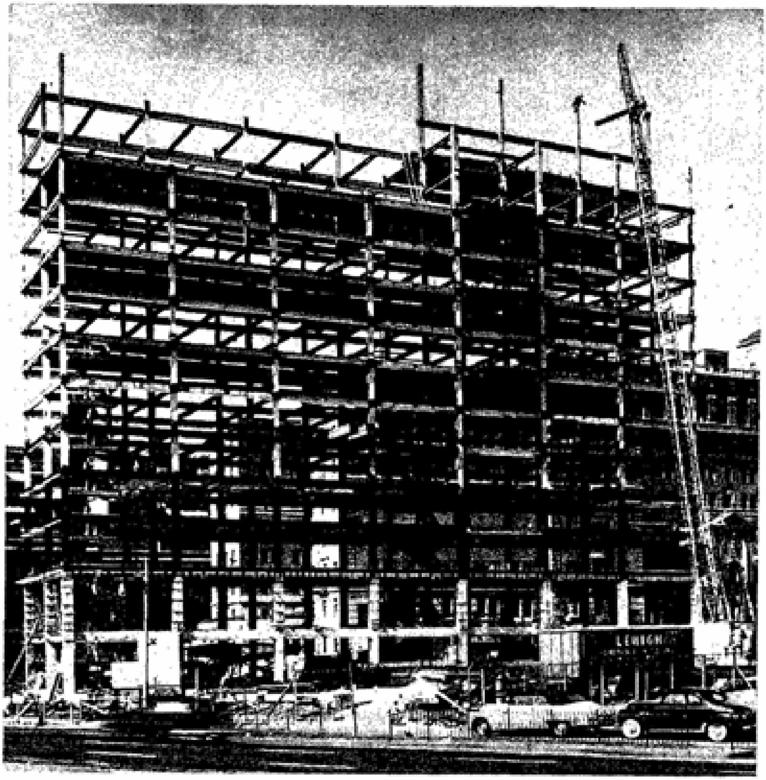


FIG. 11-3. Crawler crane erecting. (*Lehigh Structural Steel Co.*)

under its own power. It is equipped with standard railroad trucks and couplings and will move under its own power at the site of the work. A locomotive crane is not very stable when the boom is extended to the side unless outriggers are set, for the wheel spacing is only that of the standard railroad-track gage.

11-6. The Guy Derrick.[1] The guy derrick has been in use for many years. It is still employed on many structures although, since the development of suitable cranes, these in many instances have replaced it.

However, derricks are used on most of the tall structures which have

[1] The operations in raising a derrick will be explained in detail in the next section, as the cost of setting up, raising, and dismantling this equipment is an important portion of the erection cost.

large floor areas or which are too high for practical crane operations. A crane may be used from within such a structure to decrease the boom-out distance, but this is usually a disadvantage to the other trades in completing their work.

The guy derrick, as the name implies, is supported by guy cables

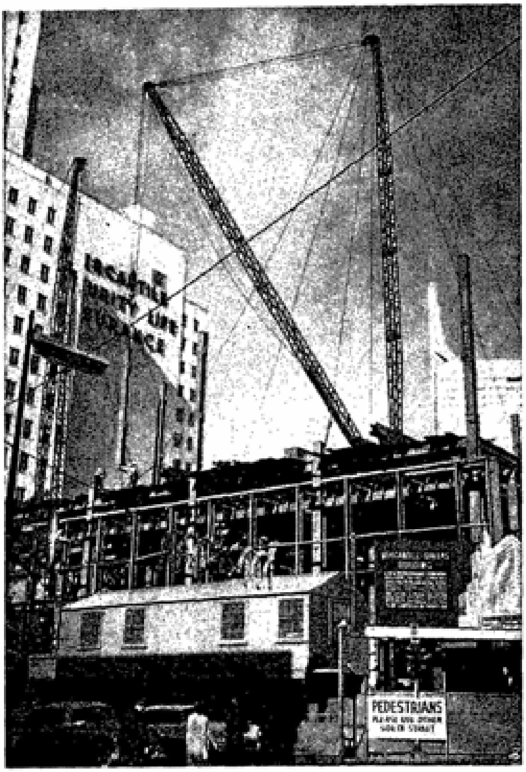


FIG. 11-4. Guy-derrick erection. (*American Hoist and Derrick Co.*)

attached to the mast. There are generally six to eight cables in a set, and they are upward of 7/8 in. in diameter, depending upon the capacity of the derrick.

A guy derrick consists of a mast and a boom and is powered by a hoisting engine. Figure 11-4 shows two guy derricks. The derrick at the right is in the process of column setting, and the derrick at the left is being raised to the level of the floor on which the ironworkers are standing. Note that both the mast and the boom each consists of four sections. Guy derricks basically consist of a top and bottom mast section and a top and bottom boom section. The splices, or center sections, may be added as required up to the capacity of the derrick.

The mast guys can be seen attached to the top section. At the top of the mast is a unit referred to as a "spider." The guys are fastened to the spider, which is stationary but so constructed that the mast may be rotated 360°. There are bearings and a pin at the bottom of the mast.

The normal method of rotating the derrick is by the aid of a long sec-

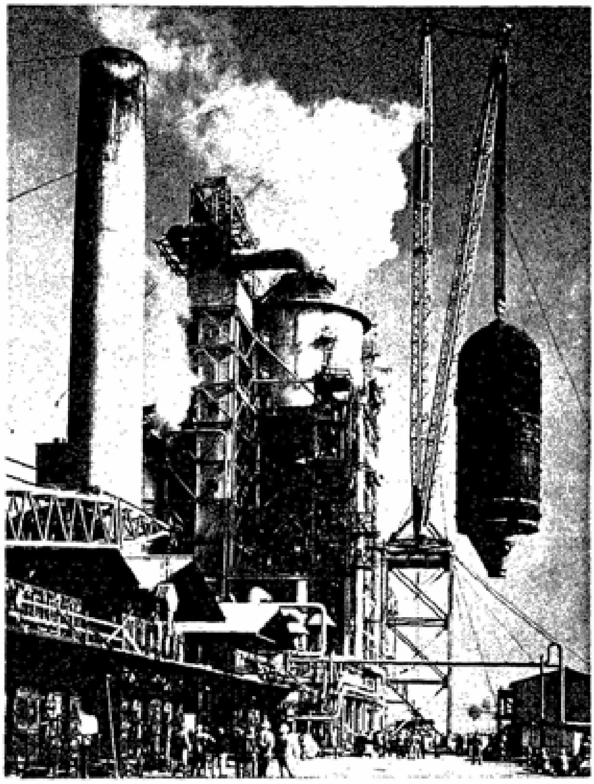


FIG. 11-5. Heavy guy derrick. (*American Hoist and Derrick Co.*)

tion of pipe or timber set into brackets at the foot of the mast; this is usually described as a "bull stick." When the derrick is properly plumbed perpendicular, one man can cause it to rotate in the required direction. When necessary, he can be aided by other men or can use a tackle line for help.

There are also derricks which are rotated by use of a "bull wheel." This unit may be seen at the base of the derrick shown in Fig. 11-5. Cables are connected between the bull wheel and the hoisting engine, and power from the engine is applied for turning the derrick in the desired direction.

Guy derricks lift to their rated capacity in any position of the boom and in this respect are superior to cranes. The boom is usually held about 10 ft shorter than the mast in order to clear the mast guys. Each time it is necessary to work at another segment of the structure, it is necessary to bring the boom to the mast for turning, as it is usual practice not to remove the mast guys while setting steel. There are occasions when one or two guys on the same side of the derrick as the boom may

Fig. 11-6. Reeving guy derrick. (*Standard Oil Co. N.J.*)

be temporarily moved, but this is only to take care of a special situation; they must be replaced before the mast is rotated to provide the proper support for the derrick.

A view of the end of a boom equipped for a very heavy lift is seen in Fig. 11-6. The three workmen (there is one man in the upper center) are running the cable, otherwise described as "reeving up the load block." An additional view of this derrick is given in Fig. 11-7; a heavy pipe or cylinder is being set in place.

11-7. Raising a Guy Derrick. On normal construction the columns will be two stories in length, and the derrick will be raised two stories on each "jump." About the same procedure is followed by all erectors in raising derricks.

A brief description of the raising operation follows (see Figs. 11-8

and 11-9). First, to clarify a few of the erector's descriptions of material:

A choker line is a short cable sling.

Side kicker lines are guy lines attached to the foot of the mast and the boom to prevent movement at that point.

Boom guys are temporary guy cables attached to the boom.

FIG. 11-7. Guy-derrick heavy erection. (*Standard Oil Co. N.J.*)

Boom lines are lines running cables from the hoist to cable blocks on the boom; they draw the boom up and down.

Load lines are lines running from the hoist through to the end of the boom and attached to the load block, which in turn connects to the lifting hook.

Now examine Fig. 11-8, which shows two views of Step 1 for raising the derrick.

STEP 1

Operation 1. Attach five boom guys.

Operation 2. Pull boom up close to mast (dotted lines); add choker to keep mast and boom close.

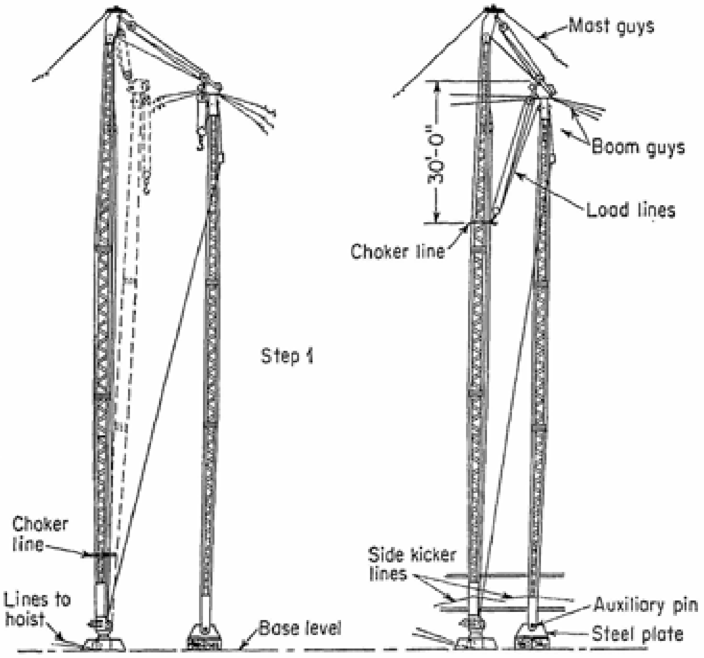


FIG. 11-8. Steps to raise guy derrick. (*American Hoist and Derrick Co.*)

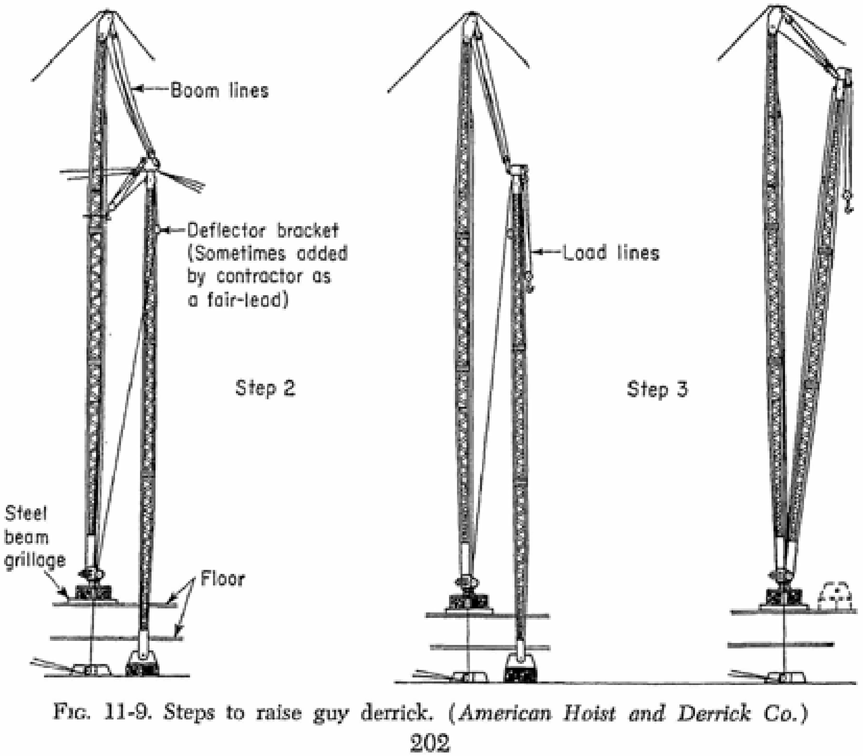


FIG. 11-9. Steps to raise guy derrick. (*American Hoist and Derrick Co.*)

Operation 3. Remove boom pin, and step out boom to rest on temporary shoe.

Operation 4. Remove choker line, and swing boom 180°.

Operation 5. Raise choker line to a point about 30 ft below top of boom (two-floor jump).

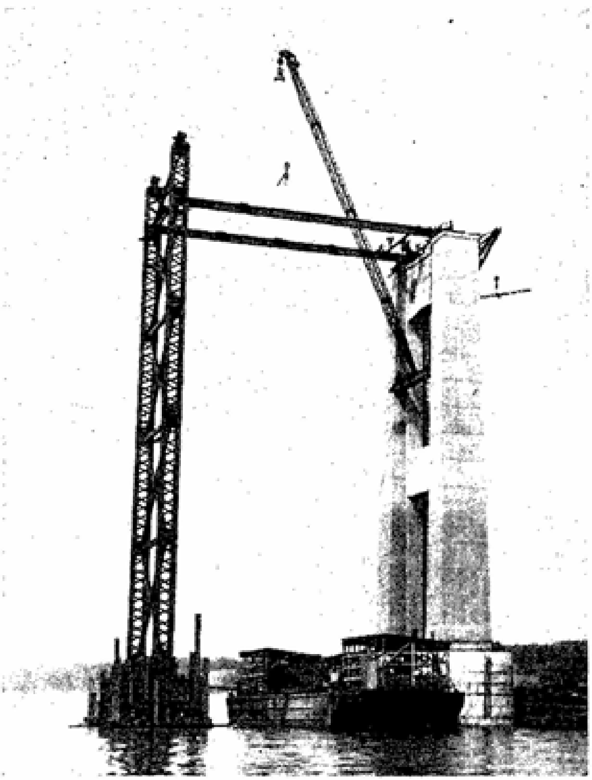


FIG. 11-10. Chicago boom. (*Harris Structural Steel Co.*)

STEP 2

Operation 1. Apply power to load lines, and draw mast up to next level (two floors).

Operation 2. Set mast on regular grillage or derrick beams.

Operation 3. Secure base of mast with side kickers.

STEP 3

Operation 1. Disconnect boom guys.

Operation 2. Rotate boom 180°.

Operation 3. Raise boom to connect to brackets on the mast.

This should give a general idea of the steps required to raise a derrick. A few details have been left out which are important to the erector but not to this description. Some of these details concern the raising of the mast guys two stories and tightening all clamps, wires, and turnbuckles.

11-8. Chicago Boom. An erector may have occasion to use a boom without the mast, as shown in Fig. 11-10. This arrangement has been

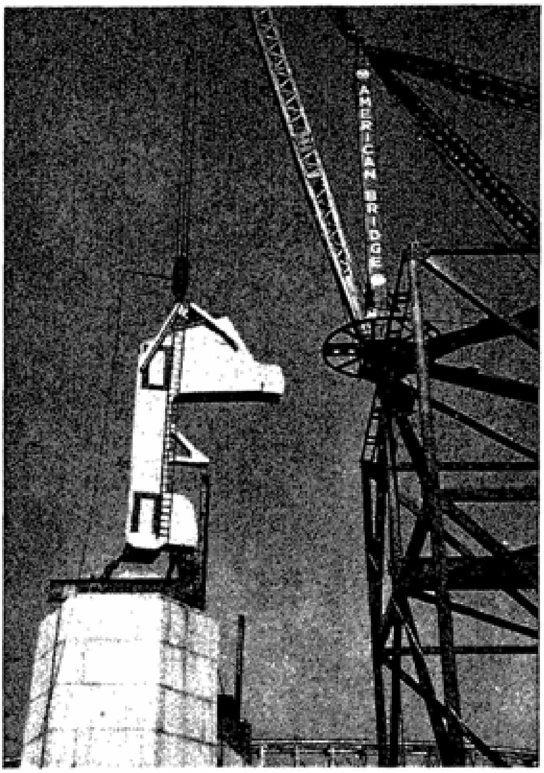


FIG. 11-11. Stiffleg derrick. (*American Bridge Division, U.S. Steel Co.*)

called by some erectors a "Chicago boom." The lower end of the boom is secured to a shoe and a pin, and cables are arranged to raise or lower the boom as desired. A boom of this sort can be used on a building operation to raise steel from the street to an offset on one of the upper floors or for any other practical purpose.

11-9. The Stiffleg Derrick. Three views of stiffleg derricks are given in Figs. 11-11 to 11-13. As may be observed in these three figures, a stiffleg derrick consists of a comparatively short mast section and a longer boom section, both of which are supported by a pair of back legs. These legs in turn are attached in some special way to the mast or to the temporary structure.

It will be noted that the stifflegs pictured in Fig. 11-12 are of very rugged construction and have a lift value of 150 tons. By the use of pins and bearings at the top and bottom of the mast, the mast and boom unit may be rotated, not to the full 360° circle, however, because of the fixed back legs. It will also be noted that the rotation will be accomplished with the aid of swing lines or cables round the bull wheel.

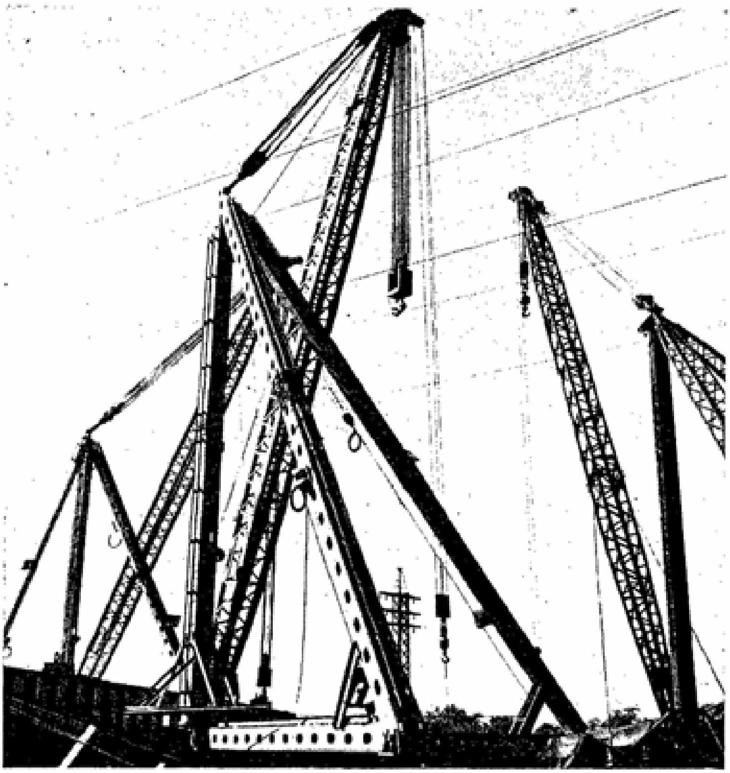


FIG. 11-12. A 150-ton stiffleg derrick. (*Harris Structural Steel Co.*)

An example of a very heavy fabricated bridge section is also shown in Fig. 11-11. The structure upon which the stiffleg derrick has been placed is a temporary tower, which will be moved away as erection progresses.

Stiffleg derricks are very practical for the very heavy bridge work. The boom may be lowered to practically a horizontal position and will still be able to pick the heavy load.

11-10. Traveler. Three types of travelers are seen in Figs. 11-14, 11-15, and Fig. 11-16. A traveler consists of a stiffleg derrick or derricks mounted on a specially designed platform. The hoisting engine is also mounted on the platform, and this is set up on the framing of the struc-

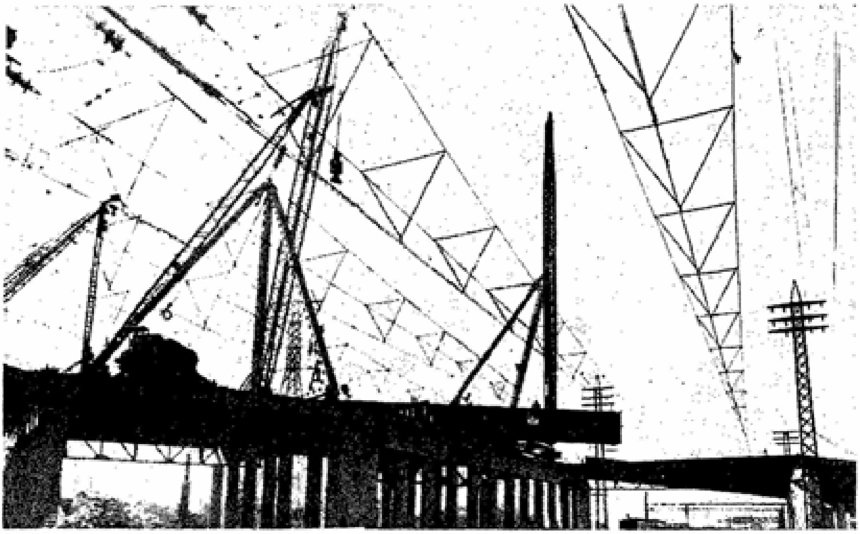


Fig. 11-13. Stiffleg derricks. (*Harris Structural Steel Co.*)

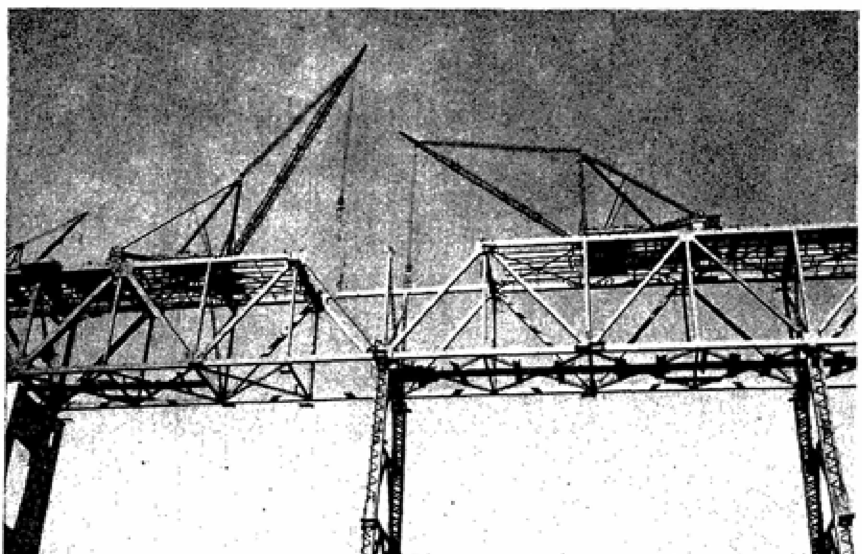


Fig. 11-14. Travelers on bridge. (*Harris Structural Steel Co.*)

ture. In Fig. 11-14 two travelers are shown approaching each other and erecting bridge members. As the various members of the structure are erected, the traveler is moved forward. The traveler deck can be mounted on wheeled trucks and advanced over railroad rails, or other methods of rolling ahead can be provided.

The traveler shown in Fig. 11-15 is a slightly different type having a quite long boom. A jib will also be noted at the end of the boom. A still different traveler is shown in Fig. 11-16. These are double units, and a

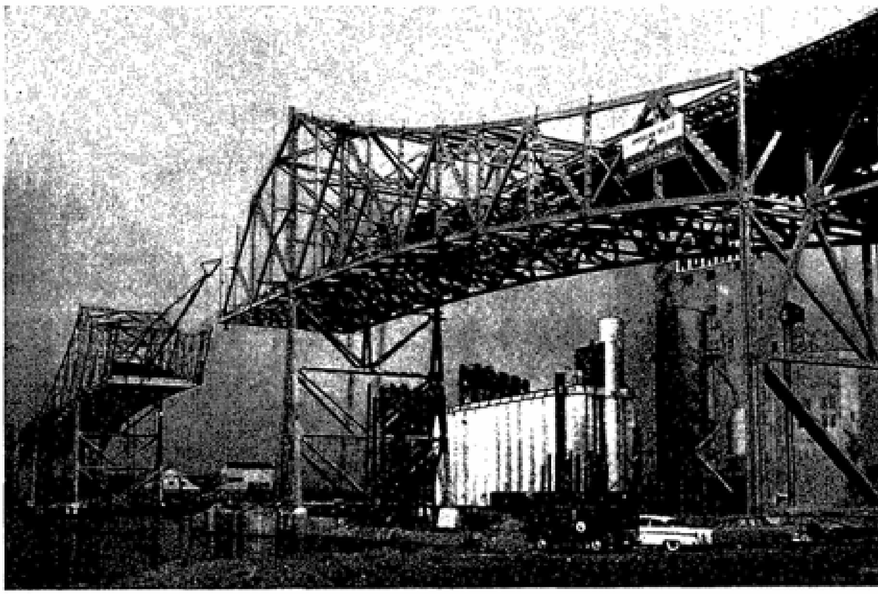


FIG. 11-15. Traveler. (*American Bridge Division, U.S. Steel Co.*)

FIG. 11-16. Double travelers. (*American Hoist and Derrick Co.*)

section of the bridge structure is being raised into position by being hooked or attached at four different points.

A traveler represents a very considerable investment and is not com-

mon equipment except in the companies engaged in erecting considerable bridgework over water. Traveler erection is not confined to erection over water. It often is used for viaducts and may also be used for other structures where the size of the work warrants the expenditure of moving in and setting up the traveler.

11-11. Falsework. Another very important item and also quite an expensive one is falsework. Falsework is temporary framing built to support the erection equipment or part of the framing during the process of erection. The falsework shown in Fig. 11-17 was built up from several barges. The bridge structure was completed on top of the falsework at a point removed from the bridge site and subsequently was floated into position for final erection with a minimum of interference with river traffic.

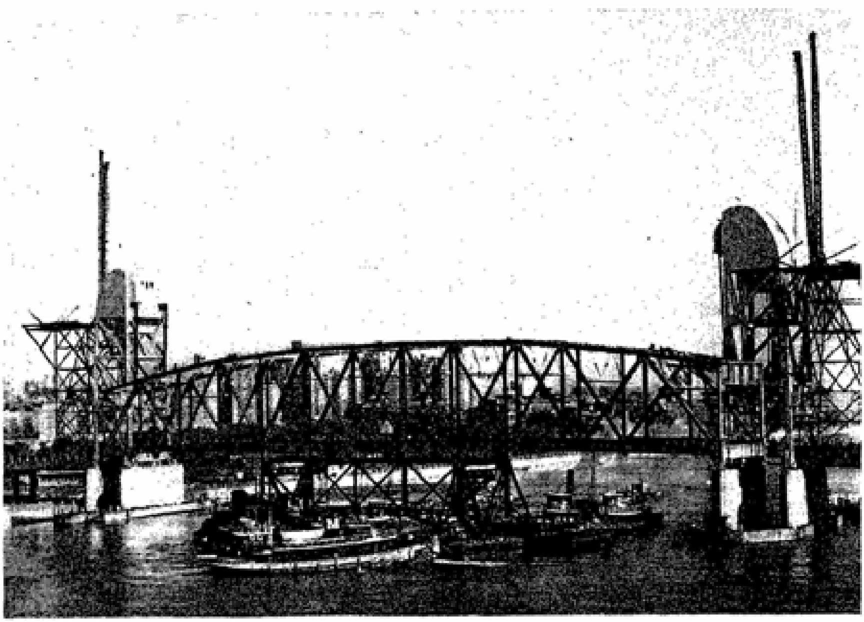


FIG. 11-17. Bridge structure on falsework. (*Harris Structural Steel Co.*)

Also shown in Fig. 11-17 are two temporary tower platforms constructed for the support of the two guy derricks. All this temporary material must be dismantled and returned to the erection storeyard for possible future use.

The two towers of Fig. 11-18 are for the temporary support of the bridge structure during the erection. An enlarged view of two temporary towers is shown in Fig. 11-19. A close examination of this figure will give a very clear idea of the amount of material and the fabrication required

to supply this falsework. The estimator will recognize much of the framing and bracing as being similar to what was described earlier in this volume. Should he be required to figure this work, it will be exactly along the same lines as for a permanent structure.

11-12. Air Compressors. A proper supply of compressed air is a major consideration for much of the heavy construction. (A small job may be

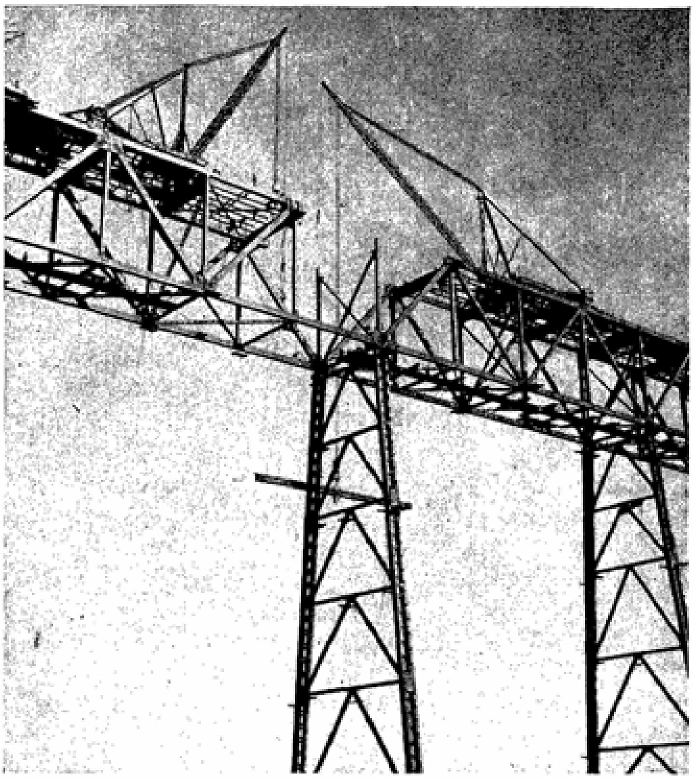


FIG. 11-18. Falsework and travelers. (*Harris Structural Steel Co.*)

accepted as fully bolted, in which event hand tools may be sufficient.)

When work is permanently connected by the use of rivets or high-strength bolts, the air supply is very important. Enough capacity must be on hand to operate the maximum quota of tools. The completion of work will be delayed and the costs will increase if the job is not planned so that the riveting or bolting advances in close step with the erection.

Air compressors come in a wide range of sizes. They may be powered by gasoline engine, electric motor, or diesel engine.

11-13. Welding. Portable welding equipment will be supplied for work which is to be field-welded. For a small operation the current necessary

for the welding may be obtained from a small gasoline generator. The current supply for a large operation may be obtained from a large diesel generator and sent through to the welders by use of the proper transformers or other equipment.

11-14. Tools. The supply, repair, and replacement of small tools are an important item of erection cost. The estimator may not be obliged to

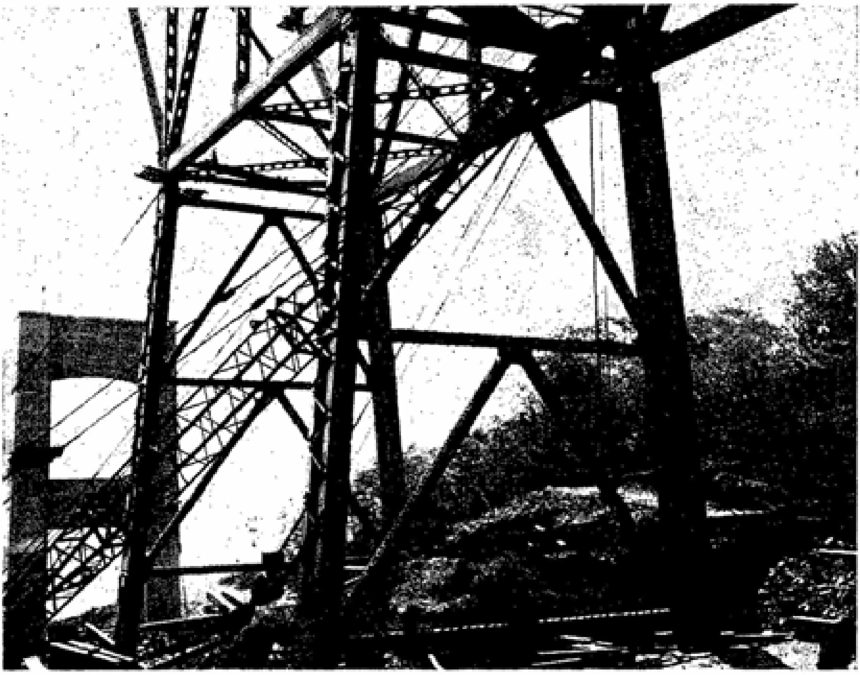


FIG. 11-19. Close-up of falsework. (*Harris Structural Steel Co.*)

include small-tool costs in his estimate except as an overhead item. However, in order to appreciate the large amount of tools and equipment required for erection, a fairly complete list is given here.

Erector's Tools and Equipment

Air back-out punches
Air boring machines for wood
Air chipping hammers
Air compressors and air receivers
Air dollies
Air drills—close quarter or center spindle with drills, reamers, and sockets
Air hammers with extra parts, including plungers
Air hose of required sizes and with couplings, valves, and parts

Erector's Tools and Equipment (Continued)

Air impact wrenches with necessary sockets
Air rivet busters with chisels and spare parts
Air rivet sets
Axes, adzes, and ship augers, carpenter's brace and bits, files
Backing-out punches—hand
Balance beams
Bells—signal, hand or electric with cord or cables
Blacksmith tools and equipment, including forges and fans
Blocks for cable—single, double, triple, quadruple
Blocks for cable—snatch, fiddle; also, spare sheaves for blocks
Blocks for rope—gate, snatch; spare sheaves for blocks
Blocks for rope—single, double, triple, quadruple
Brooms and shovels
Brushes, paint and wire
Buckets—bolt and water, including dippers
Bull wheel
Burning outfits—torch, hose, gages, tips, couplings, lighter, wrenches, and keys
Cable—guys, clamps, running cable
Cable—slings sorting; hoisting spreaders; column anchor slings
Chisel bars—heavy and light
Claw bars, connecting bars, crowbars
Cranes—truck, tractor, railroad
Cutters—cross, straight, side
Derricks—bull wheels, guys, clamps, turnbuckles, splices, blocks
Derricks—sheaves, pins, foot block, bull stick, spider, boom shoe
Derricks—overhauling weight, raising guys, splice bolts
Derricks—shackles, jumping beams, stone and concrete anchors, derrick car
Drilling ratchets, drills and reamers
Driftpins
Electric cable, drills, motors, switches, transformers, fuses, circuit breakers, parts for hoisting engine controllers
Fitting-up bolts, falsework bolts, plates, washers
Gin poles, pole shoe
Hoist-engine toolboxes
Hoists—gasoline, electric, diesel, air-steam
Hoists—single-acting crab, double-acting crab
Gasoline storage house—hand pump, safety can, grease, grease gun
Goggles—burners, welders, general-purpose; lenses, clear, shaded
Hammers—hand, handles for hand tools, hatchets
Hooks—cant, carrying-girder, plumbing-up, timber

Erector's Tools and Equipment (Continued)

Jacks—hydraulic, Norton, screw, track, wedge, handles, fittings, gages, hand pumps
Keel—yellow and black
Ladders
Lanterns—red, white
Lights—flood, generators, cable, oil gasoline
Locks and keys
Mauls
Oil—engine, air hammer, cylinder, oil cans
Old men
Picks
Pipe, pipe fittings, cutter, tongs, stock and dies
Pumps
Punches—center
Railroad—track, splices, ties, frogs, splice plates, switches, track, gages, trucks
Respirator
Rivet forges—fans, pans, pokers, shovels, tongs, tuyere irons
Rivet—buster, catching cans, dollies, club gooseneck heel, shackle, spring, banjo, dolly chains
Rope—manila, float lines, scaffold lines, tag lines, slings
Safety hats, and belts
Saws—cross cut, hack, hand, saw blades
Scale boxes
Screw clamps
Shackles, screw pin
Steamboat ratchets
Tanks, water, tapes, tarpaulins
Timber rollers, dollies
Timbers—needle beams, rivet floats, scaffold plank, floor planking
Tool houses, offices, trailer offices, office furniture, office supplies, transit, level, tripods and rods
Turnbuckles
Water hose
Wedges—steel, wood
Welding machines, lead wires, ground wires, helmets, shields, clamps and electrode holders
Wrenches—open and chain, monkey, Stillson, socket

11-15. Preliminary Cost Data. In order to produce an erection cost it is necessary to obtain considerable information from the estimating drawings. At the conclusion of the take-off of the material and perhaps

after the setting up of fabrication costs the estimator will have become quite familiar with the structural requirements of the job.

However, in addition to having complete information relative to the structural framing itself there is much to be considered about the conditions at the site of the work. Individual practices vary in connection with the physical examination of a site. It is the practice of some fabricators or erectors to have a qualified person visit all sites of structure which are being estimated. Others may depend upon information obtained from the plans and specifications or on that supplied by the buyer.

Although there is no set rule regarding inspection of a site, there are cases in which it is noted in the specifications that the fabricator or erector is expected to examine the site fully; otherwise, any situation which may arise after the contract is signed is the responsibility of the seller.

In the event that the erector does not see the location of the new structure before the contract is signed, a visit or several visits are necessary before the actual beginning of erection. This is in order to ensure the selection of the proper equipment and, if necessary, to revise a previous plan or procedure.

11-16. Erector's Information.[1] There are a number of important facts which the erector should know about the proposed work, and the estimator is in a position to tabulate this information. It should be noted that most of these data are needed whether the erector or the estimator prepares the erection costs.

As mentioned at the beginning of this chapter, estimating an erection cost is much more difficult than estimating the quantity of steel in the structure or even the fabrication costs. In addition to the special problems on each structure it is necessary to be familiar with all state and local codes and requirements, including all safety measures. These safety measures alone represent important additions to the cost of the work, but safety is a most important consideration and must not be ignored.

Some of the more important items from the take-off in which the erector will be interested are:

1. Tonnage as estimated
2. Number of pieces for derrick or crane erection
3. Number of pieces for hand line erection
4. Number of bracing rods
5. Number of sag or tie rods
6. Number of girders
7. Number of trusses
8. Number of bridge stringers

[1] Note that references made to the erector also apply to an estimator qualified to prepare the erection estimate.

9. Number of bases or number of bearings
10. Quantity and size (diameter) of rivets
11. Quantity and size (diameter) of machine bolts
12. Quantity and size (diameter) of high-strength bolts
13. Quantity and size of turned or rivet bolts
14. Quantity and type of welding

The erector will also be interested in the number of sections which require adjustment in the field. These sections may include

Adjustable spandrel sections
Window framing
Door tracks for hangar doors
Hangers for doors
Crane rails
Bridge railings
Bridge fascias
Bridge expansion dams

Should the plans indicate any other items for field adjustment such as mechanical equipment, the erector must also have this information.

11-17. Field Assembly. In many cases trusses and other units are partially completed at the shop and are sent to the field for further assembly before erection; ordinarily this is because of transportation limitations. The erector should know the number of pieces to be field-assembled and the quantity of rivets or high-strength bolts required for the work. He must provide blocking or skids to support the various sections during the process of field assembly. The furnishing, transporting, placing, and removing of blocking are an additional field cost. Other necessary information is the weight of the heaviest piece to be lifted and the length of the longest assembly.

11-18. Sketches of Structures. An erector, in the event that he has not examined the estimating plans, may be interested in a small sketch of the structure. This sketch will show a typical plan and an elevation or section giving the number of floors and a few of the major dimensions. Some of the sizes may appear on the floor plan, but it should be unnecessary to show all beams or all dimensions.

The estimator may be supplied with standard forms on which some or all of these items may be entered.

11-19. Specifications. Many other items included in the specifications apply to the erection of the structure. There are other costs which are practically fixed charges: insurance, overhead, rental of equipment, oxygen, acetylene, fuel, and coal (for rivet heating) and/or electric power.

Special items may include:

Railroad protection including pay for railroad employees
Traffic protection. Barriers and pay for guards
Site protection of trees, shrubs, landscaping, walks, roadways, and roadway surfaces
Watchmen
Field painting
Railroad siding
Sanitary provisions
Fences
Overhead bridges
Time penalty or bonus for early completion
Local labor rates
Water, electric power, compressed air (at times supplied by owner)

11-20. Insurance and Bonds. A very important part of the erection cost is insurance. The basic coverages usually include workmen's compensation, personal liability, and property damage. Many other coverages may be required, some of which are: fire insurance, railroad protection, and hold harmless. Some of the special insurances have very high premiums, and the insurance broker or expert should be contacted sufficiently in advance of the bid date so that the rates may be obtained or established.

In many cases the insurance carrier will request information to be supplied to the insurance-company engineer. After the engineer collects the information, which may include an inspection of the plans and a visit to the site, the underwriters will establish a job rate for the insurance. This will be applied to certain estimate figures and the cost added to the amount to be bid for the construction of the structure.

Another cost which may have to be included is the cost of bonds. The bonds may be bid bonds and/or performance bonds.

11-21. The Erection Estimate. In general practice the erection estimator is supplied with a standard form for use in making up an estimate. Such forms vary according to the erector's or fabricator's methods of applying the costs and charges. Because of the many differences in erection-estimate forms it would be confusing to show one of the standard forms here. However, in the event that an estimator does not have a form to use, he should be able to develop one after a study of the factual data he wishes to include.

Costs may be divided into sections, for instance, equipment costs, direct erection costs, and all other costs. Some of these may be included in erection overhead, depending upon the individual policy of the erector or fabricator.

Equipment Costs

Unloading tools and equipment
Setting up office and tool houses
Unloading and setting up crane(s)
Unloading and setting up derrick(s)
Unloading and setting up hoists
Setting up air plant
Setting up welding plant
Moving crane(s)
Jumping derrick(s)
Receiving plant
Receiving falsework
Setting up falsework
Moving falsework
Receiving blocking and skids
Setting up skids
Dismantling falsework
Setting up jenny winch
Loading out falsework
Loading out blocking
Loading out plank
Dismantling derrick(s)
Dismantling crane(s)
Loading out derrick
Loading out hoists
Dismantling air plant
Dismantling welding plant
Loading out air plant
Loading out welding plant
Dismantling jenny winch
Loading out tools
Loading out balance of equipment

Erection Costs for the Framing

Unloading steel from cars
Unloading steel from trucks
Sorting steel
Erecting steel
Bolting machine bolts
Bolting high-strength bolts
Riveting
Erecting bracing rods, tie rods, sag rods
Adjusting spandrels
Plumbing up
Aligning girts, window framing
Aligning crane and other rails
Aligning expansion dams
Assembling trusses
Riveting or bolting trusses
Aligning fascia
Aligning railing
Drilling or reaming
Grouting
Removing old work

Other Costs

Wages for lost time
Travel time
Nonproductive and overtime
Maintenance men
Master mechanics
Watchmen, flagmen
Insurance
Welfare
Pension and tax expense
Superintendent or foreman
Engineers—civil or P.E.
Timekeeping and field clerks

All Other Miscellaneous Costs

Transportation charges
Fuel and electric power
Oxygen and acetylene
Telephone and office expense
Paint and painting
Permits

All Other Miscellaneous Costs (Continued)

Overhead and profit
Crane freight and haul
Crane rental
Survey for setting bases
Special equipment
Licenses and tests
Contingencies

All these items are not required for every structure. For instance, a bridge will require different costs and equipment as compared with a building. Some companies use more than one printed form, depending upon the structure.

It is not practical or advisable to give a complete cost to be applied directly to a specific structure. However, it may be of some help to follow the cost of erection of a structure by using a composite set of figures collected after the completion of work on a number of office buildings. These figures must not be used as direct costs of any present construction, as it is necessary to consider each estimate independently of any other work which may appear similar.

11-22. Office-building Erection Costs. The requirements for the structure in this example are assumed to be as follows:

10,000 tons
36 columns in plan
140,000 high-strength bolts
36 slabs
15,000 pieces
30 stories high
140,000 machine bolts
500 spandrels
No field paint by fabricator
Production per derrick per day 30 to 35 tons, 60 pieces

To unload the hoist, derrick, tools, and air-plant office and tool houses, including the setting up of the office and tool houses, will require approximately 146 man-hr. A saving of about 16 hr will be made if the office and tool house are the trailer type which can be hauled to the site on wheels and there connected to the necessary utilities, water, electric, and telephone.

The setting up and dismantling of the derrick will consume a total of about 250 man-hr. The derrick may be raised 14 times; this will take about 48 man-hr per jump, or a total of 14×48 equals 672 man-hr.

Ordinarily each derrick gang consists of eight men as follows: one pusher (assistant foreman), one hoisting engineer, six bridgemen (two connectors, two floormen, one signalman, and one bull-stick man).

There will be a different arrangement for the crane gang. Neither the

signalman nor bull-stick man may be required. Note, however, that certain union agreements may require the signalman on crane work, or other differences may occur in the union agreement. When a crane is used, it may be required to employ an oiler or a chauffeur.

Unloading, sorting, and erecting the steel may be listed separately or can be combined. The total figure for this work based on about 35 tons per day per gang is $10{,}000 \times 64 \div 35 = 18{,}285$ man-hr. Clarifying these units, the man-hours per day for a derrick gang is 8×8 equals 64. The item of 10,000 is the total tonnage of the structure, and the figure 35 is the daily production.

The building framing is usually accepted as being plumb if the error does not exceed 1 in. in 500, that is, up to 1 in. in each 41 ft 8 in. of height, except in the case of columns adjacent to the elevator shafts, where the requirement usually is 1 to 1,000. Plumbing up may be done by one man and a helper and will require here about 3,400 man-hr. In addition, some of the civil engineer's time may be required in checking with a transit.

Each man engaged in placing the machine bolts will place about 200 per day, or a total required time of 700 days (5,600 man-hr). The placing of high-strength bolts will usually require two men per gang with the necessary air tools and should take approximately 5,600 to 8,000 man-hr. It will serve no particular purpose to continue to detail all the costs for the erection of the structure in this particular example. The estimator will, however, carefully study the lists of items which have been given and apply all the necessary costs for whatever structure is under consideration.

CHAPTER 12

Structural Aluminum

12-1. Introduction. Structural aluminum has a very important place in modern construction. When the initial costs can be discounted, a number of other considerations, under certain conditions, greatly favor the use of aluminum framing.

The first cost of aluminum is considerably higher than that of the equivalent section in structural steel. The comparative base cost per pound is partially compensated by the much lighter sections of aluminum required.

12-2. Weight. The weights per cubic foot as shown in the AISC Manual are given as 165 lb for cast or hammered aluminum and 490 lb for rolled steel. The weight per cubic inch of the wrought-alloy aluminum material as shown in the "Alcoa Structural Handbook" (Aluminum Company of America) is in the range of 0.098 to 0.102. This is approximately the same as the AISC figure.

Structural steel was previously found to be 0.28 per cubic inch, and the average aluminum weight may be taken as 0.10. Therefore it is evident that the weight of structural steel is nearly three times that of aluminum. In making equivalent comparisons of cost the difference in weight has an important bearing on the total cost of the materials.

12-3. Maintenance and Handling. The maintenance costs of exposed steel as compared with exposed aluminum structures will usually become an important factor for consideration. Steel must be coated with galvanizing, paint, or other protective materials, whereas in practically all aluminum installations protective coating, either before or after installation, is not necessary.

The lighter weight of aluminum often has an important bearing on the selection of structural framing. For example, two beams of approximately the same strength will be compared:

One 8 WF 17, 10 ft 0 in. (steel), weight 170 lb
One 8 I 6.35, 10 ft 0 in. (aluminum), weight 64 lb

These comparisons are uniform throughout the full range of structural shapes and show the possibility of using less manpower for handling the

materials. Two men could carry the one steel section, or the same two men could carry two aluminum sections at the same time.

Aluminum framing is often designed for use in difficult locations where power-operated handling equipment cannot be readily available. Therefore it is evident that much moving of the framing materials by hand is possible.

Cooling towers used in connection with air-conditioning installations are frequently erected on top of structures which originally were not designed to support too much additional loading. In many cases aluminum framing is very satisfactory and will add much less weight to the original framing.

12-4. Range of Sections. The range of sections available for structural framing is as follows:

Angles—unequal legs
Angles—equal legs
I beams, American standard
Channels, American standard
Wide-flange sections including H beams
Rectangles
Tees
Special tees
Zees
Bulb angles
Special channels
Wing channels

Army Navy Series
Bulb angles
Channels
Wide-flange sections
Tees

In addition to this range of shapes it is possible that some of the other extruded shapes may be used in construction of structural framing.

More detailed information indicating the range of sizes of the aluminum shapes is given in Table 12-1.

12-5. Elements of Sections. Certain of the aluminum standard structural shapes are produced by rolling, and other standard structural shapes are produced by extrusion.

Full details regarding the elements of the sections and also a description of the method of production can be found in the "Alcoa Structural Handbook."

Besides the standard structural shapes it is possible to obtain nonstandard structural shapes which are suitable for many special conditions.

Table 12-1. Range of Sizes of Aluminum Sections

Angles, equal legs, $\frac{1}{2} \times \frac{1}{2} \times \frac{1}{16}$ to $8 \times 8 \times 1$
Angles, unequal legs, $\frac{3}{4} \times \frac{5}{8} \times \frac{3}{32}$ to $8 \times 6 \times \frac{3}{4}$
American standard I beams, 3″ deep to 12″ deep
American standard channels, 3″ deep to 15″ deep
Wide-flange sections including H beams, 2″ deep × 2″ wide to 10″ deep × $5\frac{3}{4}$″ wide
Tees, 1″ flange × 1″ stem to 5″ flange × 3″ stem
Special tees, 6″ flange to 8″ flange and 3″ stem to 6″ stem
Zees, $1\frac{3}{4}$″ deep to 6″ deep
Bulb angles, $4 \times 3\frac{1}{2} \times \frac{3}{8}$ to $6 \times 3\frac{1}{2} \times 0.28$ to 0.31″ thick
Bulb angles, Army Navy Series, $1 \times \frac{3}{4}$ to $3\frac{1}{2} \times 2\frac{1}{2}$
Channels, Army Navy Series, 2″ deep to 7″ deep
Wide-flange sections, Army Navy Series, $2\frac{1}{2}$″ deep × 2″ wide to 5″ deep to 5″ wide
Tees, Army-Navy Series, flange 1.50″ to 4.00″, stem 1.25″ to 5.00″
Special channels, 2″ deep to 10″ deep
Wing channels, $3\frac{1}{2}$″ to $7\frac{1}{2}$″
Rectangular sections, $1 \times \frac{1}{8}$ to 72×1
Square bars, $\frac{3}{8}$″ to $5\frac{1}{2}$″
Round bars, $\frac{3}{8}$″ to 8″ ϕ

Note. Some of the very small angle sections are not practical sizes for most structural framing.

SOURCE: "Alcoa Structural Handbook," Aluminum Company of America.

It is generally assumed that the engineer responsible for the design of structures is fully familiar with the material and has selected the proper sizes for the work on which an estimate is required. Therefore the average estimator will not be particularly concerned with the selection of the shape or size of the material required.

As in the case of structural-steel rolling mills there are several large aluminum producers, and an estimator may obtain information from any of them regarding the sizes and type of shapes produced.

The Reynolds Metals Co. produces a line of structural shapes in the following range of sizes:

Equal-leg angles, $\frac{3}{4} \times \frac{3}{4} \times \frac{3}{32}$ in. to $8 \times 8 \times 1$ in.
Unequal-leg angles, $1\frac{1}{4} \times \frac{3}{4} \times \frac{3}{32}$ in. to $8 \times 6 \times \frac{3}{4}$ in.
Standard channels, 3 to 10 in.
Special channels, 3×2 in. to $10 \times 3\frac{5}{8}$ in.
I beams, 3 to 10 in.
H beams, 4 to 8 in.
Wide-flange beams, 6×4 in. to 8×8 in.
Tees, $1\frac{1}{2} \times 1\frac{1}{4} \times \frac{1}{4}$ in. to $4 \times 4 \times \frac{3}{8}$ in.
Zees, $3 \times 2\frac{11}{16} \times \frac{1}{4}$ in. to $5 \times 3\frac{1}{4} \times \frac{1}{2}$ in.

These sections are produced by rolling or are extruded. Reference to the Reynolds "Metals Catalog" will provide information regarding the

methods of producing each particular shape. Other necessary design data are included in the Reynolds tables.

In addition to the shapes which have been listed there may be obtained rounds, squares, hexagons, and flat plates or rectangular sections.

In order to clarify the references to rolled sections and extruded sections the following descriptions have been taken from the Reynolds Metals Co. publication, "The A-B-C's of Aluminum."

> Molten metal is cast into molds. If the metal is fluxed and skimmed (refined) before casting into molds it becomes primary aluminum ingot. Fluxing produces a cleaner metal with less foreign matter.
>
> When structural shapes like I beams, angles or channels are wanted the hot ingot is squeezed between rolls which have been cut out to give the metal the desired shape.
>
> In the extrusion process the hot billet is put in a huge hydraulic press and squeezed out through a die whose opening has the shape desired. It is possible to produce a bar of aluminum having almost any cross section desired.

Note that in connection with the lists of sizes produced it is very possible as the demand increases that the producers may expand or revise the line of shapes manufactured.

12-6. Comparison of Steel and Aluminum Sections. A comparison of some of the commoner steel sections with an approximate aluminum section is shown in Table 12-2. This table is included for reference only, as

Table 12-2. Approximate Comparisons of Steel and Aluminum Sections

Shape	Size	Wt aluminum, lb	Wt steel, lb
Angle	2 × 2 × ¼	1.11	3.19
	2½ × 2½ × ¼	1.40	4.1
	3 × 3 × ⅜	2.47	7.2
	4 × 4 × ½	4.41	12.8
	6 × 3½ × ⅜	4.04	11.7
	6 × 4 × ½	5.58	16.2
	8 × 8 × ½	9.14	26.4
I beam	6″	4.3	12.5
	7″	5.27	15.3
	8″	6.35	18.4
	10″	8.72	25.4 25 WF
	12″	10.99	31.8 31 WF
Channels	6″	2.83	8.2
	8″	4.25	11.5
	10″	5.28	15.3
	12″	7.41	20.7
	15″	11.71	33.9

the sizes shown are not always interchangeable because of certain mechanical or strength values required under a given design condition. An estimator is advised not to interchange a steel design to an aluminum design, or vice versa, unless all strength values are properly checked by a competent qualified engineer.

12-7. Stiffeners. The use of stiffening angles in connection with aluminum design is somewhat similar to the use of stiffener angles on steel design. Stiffeners are required to increase the buckling strength of the web plate.

It is normal practice in connection with the design to use vertical or horizontal stiffeners, and sometimes both are used on the same section. There are cases where the design includes several longitudinal stiffeners in one panel.

12-8. Fastening Materials. Sections of aluminum may be joined together with rivets or bolts, or, with the proper alloy, welding is used. In addition to these three there are special fasteners which may be indicated on the drawings.

The estimator is advised to note very carefully exactly the kind and sizes of the fastening materials which must be supplied. In the event that the proper description cannot be obtained from the specifications or plans it is well to consult with a representative of the buyer.

Connections may be made with steel or aluminum-alloy bolts. Bolts must fit tightly in the holes, and where these are a few thousandths of an inch clearance, the value of the bolt will be decreased. A common rule is to decrease the value of the bolt one-third when there is not a tight fit. Note that the normal clearance for bolts in steel (except turned bolts) is $\frac{1}{16}$ in. The clearance for turned bolts is usually $\frac{1}{50}$ in. It is evident that, should the design notes or specifications indicate a very close clearance between the bolt and the edge of the hole, the shopwork will be somewhat more expensive.

Bolts should be properly tightened, and it is recommended that a good lubricant be employed on the threads and on the bearing surfaces. A lubricant having a white lead base may be obtained for this use.

These items are presented here to indicate to the estimator that the costs for steel fabrication cannot be applied to aluminum fabrication. The procedures required for aluminum fabrication are similar in many ways to those for steel fabrication, but it will be necessary for a steel fabricator to accumulate a new set of cost figures for aluminum.

Riveted connections are quite common in aluminum construction, but of course, here again, the structural-steel techniques cannot be strictly followed. The selection of the kind of rivet is very important, and the strength variation is considerable among the several kinds of aluminum alloy which are used in the manufacture of the rivets. It follows that the

terials available from producers not mentioned by name that they contact these producers for definite information relating to their products.

A partial list of building products and also of other structural materials as produced by the Aluminum Company of America (Alcoa) follows:

Corrugated roofing and siding
V-beam roofing and siding
Ribbed roofing sheet
Sandwich wall
Perforated corrugated sheet
Field formed flashing
Highway railings
Hand railings
Extruded shapes
Traffic-control devices

Some of the structural materials (other than standard rolled structural shapes) and a partial list of building products as produced by the Reynolds Metal Co. follow:

Reynolds aluminum curtain-wall system
Aluminum master shingles
Aluminum windows
"Reyno Deck" roof decking
Copings and gravel stops
Bridge railings
Highway accessories
Architectural shapes

12-11. Aluminum Railings. An estimator is often obliged to include railings in an estimate. There are two kinds of railings which occur in construction work: highway railings for bridges and roadways, and pipe hand railings.

Note that railings may be required to be constructed of aluminum or of steel. Information relative to railings built with steel sections will be found in Sec. 13-8. Many designs are similar, and others are completely different.

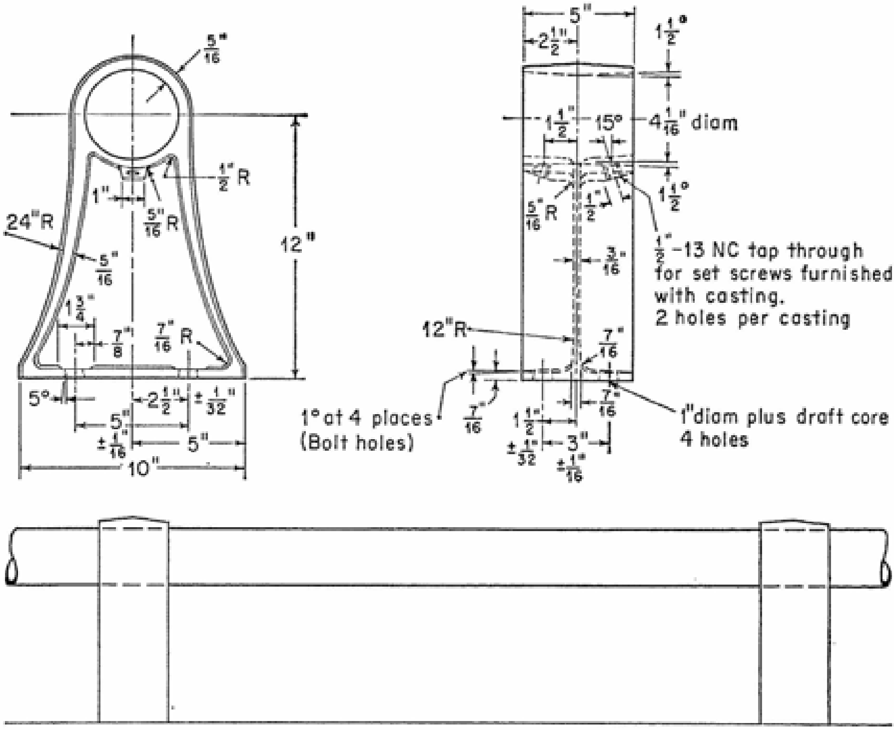
12-12. Highway Railings. Two very distinct types of highway railings are the parapet type and the panel type. As indicated by the designation, parapet-type railings are placed or set on top of concrete parapets. The top rails will be about 12 to around 30 in. from the top of the concrete. There is no set measurement for the height of the railing posts. It is the choice of the designer of the structure as to how high the parapet shall be, and this in turn establishes the elevation of the top rail.

The estimator will read and accept all dimensions as indicated on the estimating drawings, and of course all other figures are as shown.

12-13. Details of Parapet Railings. Certain standard-design railing components have been developed by the Aluminum Company of America. Complete details and data are contained in a booklet entitled "Alcoa Aluminum Highway Railings." Several of the designs and some data will be included here to present to the estimator points to be considered in estimating bridge railings.

As of 1957, Alcoa aluminum railings were in place in 42 states and Alaska. Thus aluminum railing occurs in many bridge designs and in almost any section of this country.

The material for a typical panel of a very simple parapet-type railing



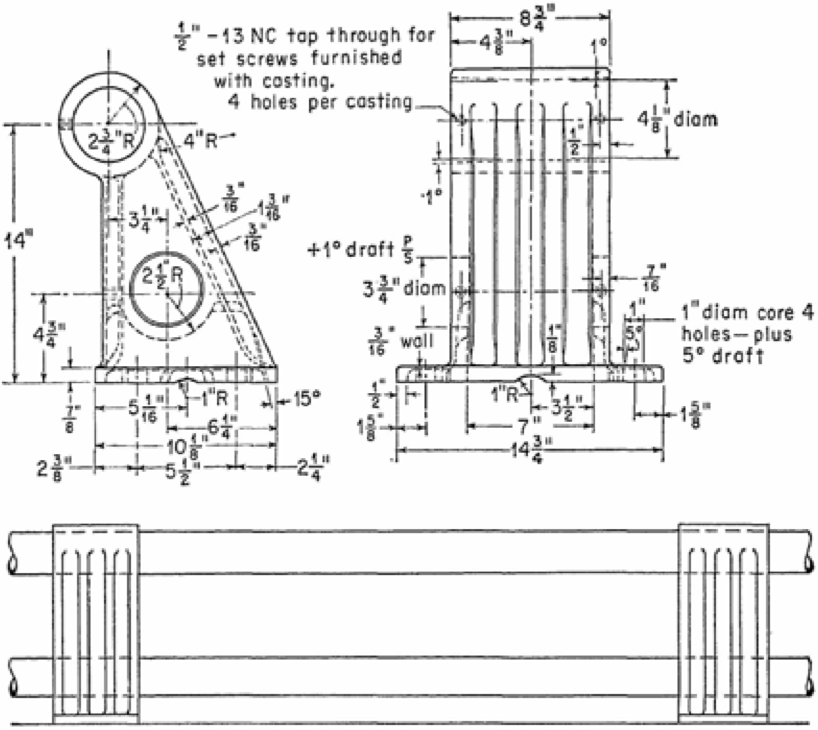
Material for typical panel

1 Rail	4" OD × $\frac{1}{8}$", 8'-11" long, 1.79 lb/ft	15.95 lb
1 Post	Alcoa 1001	11.20 lb
	Total weight	27.15 lb

FIG. 12-2. Panel of single-parapet railing.

is shown in Fig. 12-2. Except for the end of the run each panel consists of one post and one length of tube. The detail of the post casting is shown. The casting is a stock part, and it is not required that the estimator list other than one post per section with the part number identification. The length of the tube between posts will be taken as shown on the estimating plans. The estimating of railings of this type will then consist in counting and listing the total number of posts and listing of the length or lengths of tubing, plus the number of set screws and, if required, the number of anchor bolts. (The anchor bolts may have been included in another sec-

tion of the contract.) Finally, be sure to note the alloy number for the tubing, as there is a variation in cost among the several alloys in about the same range like the variation noted in structural steel among the several classes of steel.



Material for typical panel

1 Top rail 4" OD × ⅛", 8'-11" long, 1.79 lb/ft	15.95 lb
1 Bottom rail 3½" OD × ⅛", 8'-11" long, 1.56 lb/ft	13.90 lb
1 Post Alcoa 2005	28.20 lb
Total weight	58.05 lb

Fig. 12-3. Section of parapet railing.

The weights are 11.2 lb for each post and 1.79 lb per ft for the 4-in.-OD × ⅛-in. wall tube. Therefore each section of 8 ft 11 in. will be 27.15 lb total for the tube and post.

A section of railing of more elaborate type is shown in Fig. 12-3. This section consists of two rails. The top one is 4 in. OD × ⅛ in. and the bottom rail 3½ in. OD × ⅛ in. All sections are 8 ft 11 in.

The estimate per section is, for the post, 28.20 lb each, the 4-in. tube at 1.79 lb per ft, and the 3½-in. tube at 1.56 lb per ft. This will then be

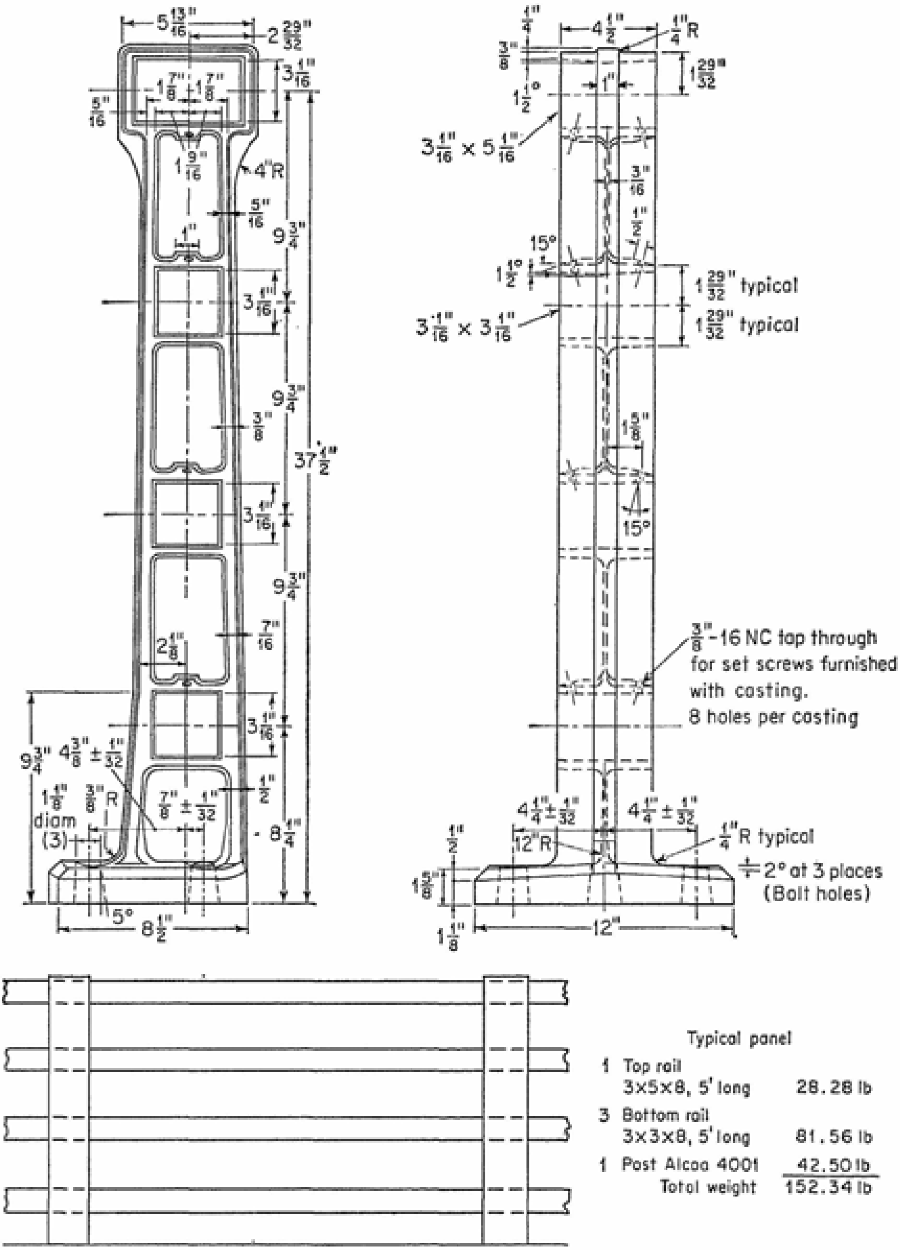
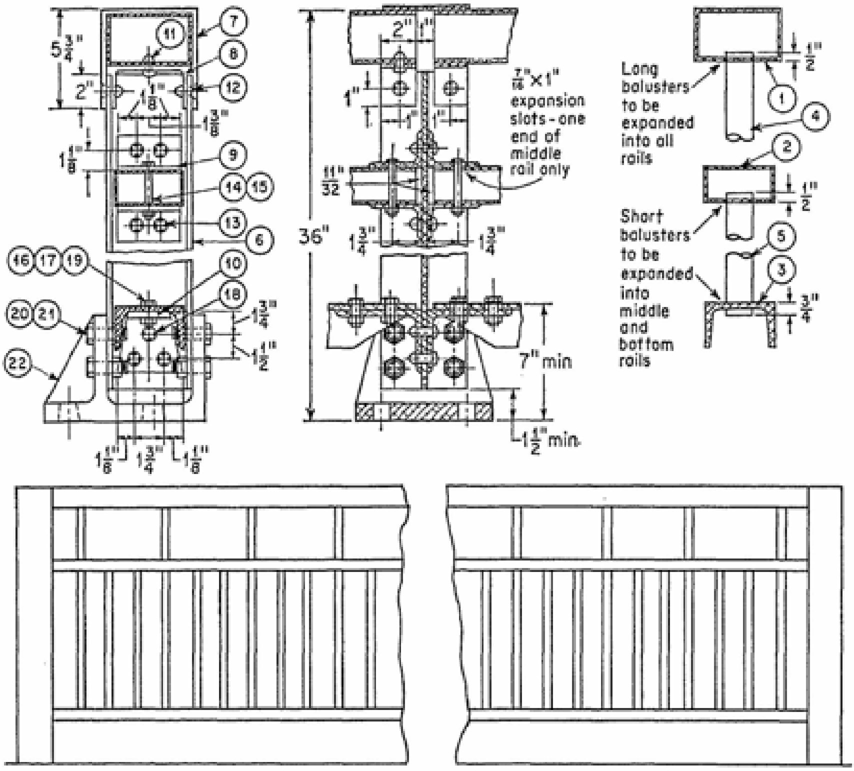


FIG. 12-4. Panel-type railing.

29.85 lb for the sections of tubing added to the weight of one post at 28.20 lb to obtain a total of 58.05 lb. This design of railing will therefore be more than twice the weight of that considered in Fig. 12-1.



Material for 10' panel

Item			Item		
1	Top rail 3×5, 9'-11" long	33.4 lb	9	Middle rail seat 4 required	1.7 lb
2	Middle rail 2×4	16.8 lb	10	Bottom rail seat 2 required	2.8 lb
3	Bottom rail 4"	33.0 lb	22	Post base 5766	13.0 lb
4	Long baluster $1\frac{1}{2}$" ϕ 9 required	7.3 lb	11, 12, 13, 18	Rivets	
5	Short baluster $1\frac{1}{2}$" ϕ 16 required	9.6 lb	14, 16, 20	Bolts	
6	Post 9430	14.1 lb	15, 17, 21	Nuts	
7	Post cap 65029	2.1 lb		Total weight of section	137.2 lb
8	Top rail seat 2 required	1.1 lb			
19	Washers				

FIG. 12-5. Additional design of panel-type railing.

12-14. Details of Panel-type Railings. A design of the posts for a panel-type railing is shown in Fig. 12.4. A section of this railing consists of a post as shown and four horizontal tube sections. The top rail is a tube

$3 \times 5 \times \frac{3}{16}$ in., and this weighs 3.36 lb per ft. The three remaining horizontal sections are $3 \times 3 \times \frac{1}{4}$-in. square tubes and weigh 3.23 lb each per foot. The weight of the post is 42.50 lb. An entire section of railing consisting of one post and the four rail sections has a total weight of 152.34 lb.

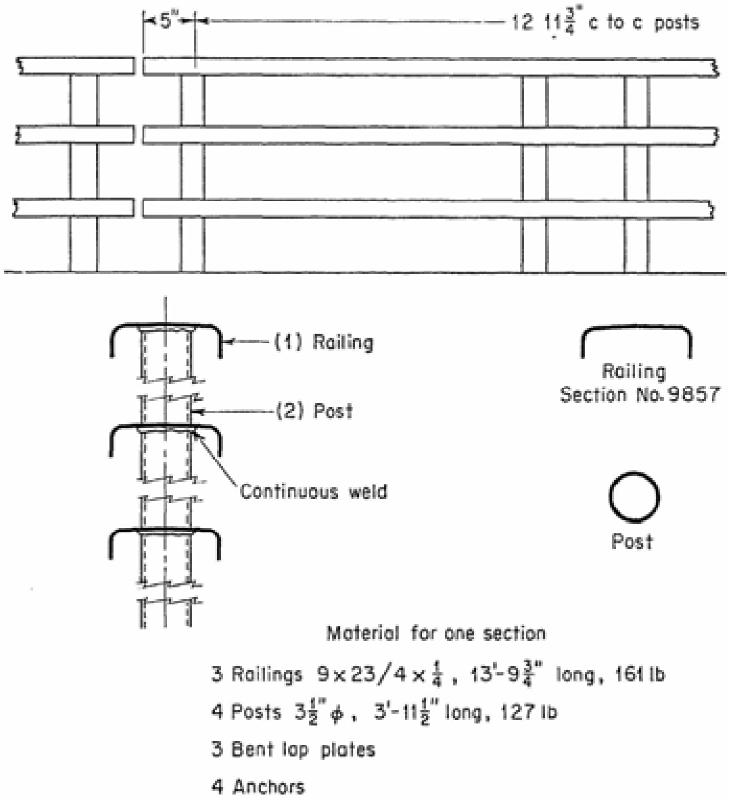


FIG. 12-6. Horizontal-type railing.

A very interesting design for a panel-type bridge railing is shown in Fig. 12-5. The details of the post are as seen looking from two directions, from the front and from the side. Each part has been identified by a number placed in a circle, and the material thus identified is listed at the bottom left of the drawing. The post, post cap, post base, and top rail seat are all standard castings and may be ordered from the supplier as designed, without tool charges. A little study of the figure should enable an estimator to visualize the several components which are required to build a section of railing. The figure includes all rivets, bolts, nuts, and

washers as required for the assembly at the posts. All the balusters are expanded into the horizontal rails.

Details of a type of horizontal railing are shown in Fig. 12-6, and de-

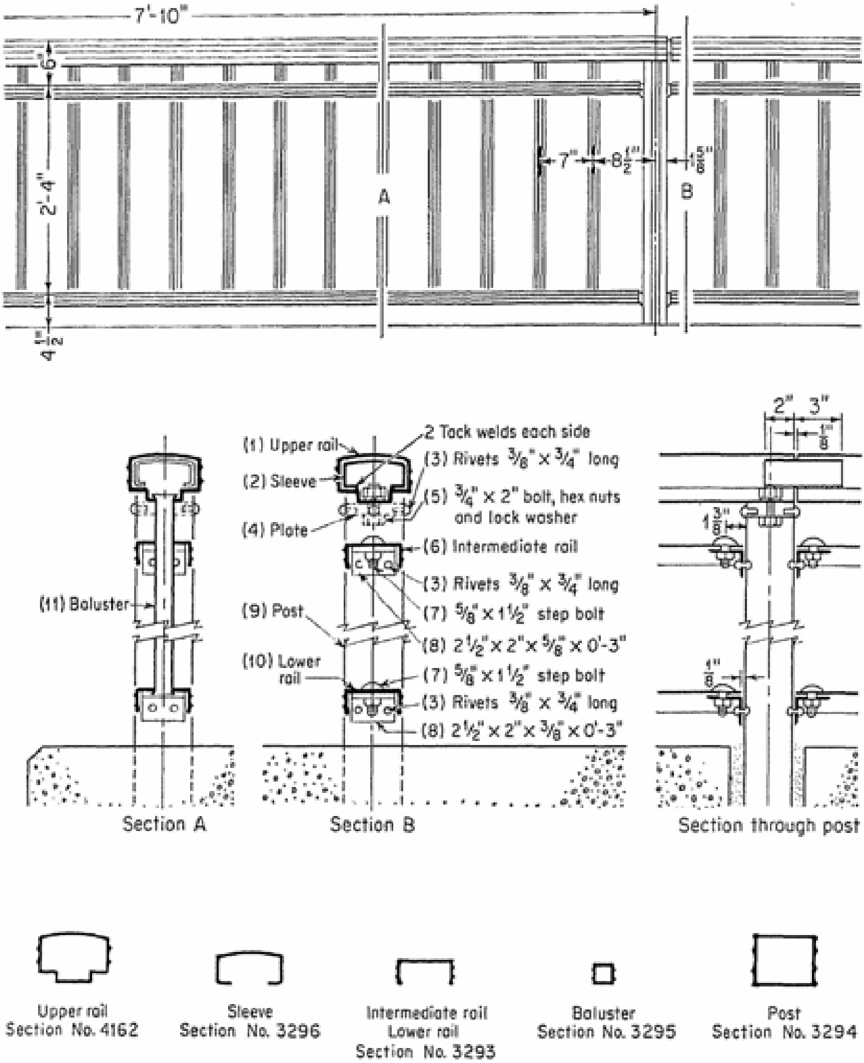


FIG. 12-7. Baluster-type railing.

tails of a vertical-type baluster railing are shown in Fig. 12-7. The horizontal railing (Fig. 12-6) is arranged in a quite long section, 12 ft $11\frac{3}{4}$ in. center to center of posts. There are four posts in each section of this design. Two posts are at the center of the section and one near each end

of each section. The posts are round, and the railing is a standard stock size. It is attached to the posts by welding as indicated. The vertical-type railing (Fig. 12-7) has 12 balusters, and the upper, intermediate, and bottom rails complete the design. A listing of the materials for a 7-ft 10-in. section has been made, as can be seen in Fig. 12-8. Each of the sections in this assembly is identified by a number in parentheses which appears in Fig. 12-7. Cross sections of the various members are also included in Fig. 12-7. Careful examination of the details will provide com-

Item	No.	Section	Wt, lb
1	1	Upper rail $3\frac{1}{4} \times 5$	27.0
2	1	Sleeve	
3	12	Rivets	
4	1	Aluminum plate	
5	2	Bolt nut and washers	
6	1	Intermediate rail	16.6
7	4	Step bolts	
8	4	Angles	
9	1	Post	16.4
10	1	Lower rail	16.6
11	12	Balusters	17.0
		One section = 7′-10″ c to c posts	

FIG. 12-8. Take-off of baluster-type railing.

plete information regarding the shopwork necessary to fabricate a section of railing.

It will have been noted from the series of figures which have been presented here that many different railing designs and patterns are feasible with the use of the great number of stock materials available. An arrangement is possible whereby a steel cable may be run through certain aluminum sections. This method will permit a much greater impact load. The cable may be run through one of the rail sections or through several. Mention is made of this possibility so that the estimator will be aware of this type of design and will include the extra material in the estimate.

12-15. Design Data for Railings. The Reynolds Metals Co. has prepared a booklet on bridge railing, *AIA File* 15-1955, which contains much information on aluminum bridge railings and fittings.

Railing may be constructed with the intermediate sections either ver-

tical or horizontal. The type with vertical members does not invite climbing but will usually require many more sections of materials.

Standard specifications for the design and construction of bridge railings have been prepared by the AASHO and should be consulted unless other specifications have been supplied.

12-16. Erection of Railings. The erection of railings whether of steel or of aluminum will require extra care. A railing in addition to its physical value is an important item in dressing up a structure. Therefore it is not unusual for the specifications to be extremely rigid and the inspection severe.

The erection costs will be high for the setting of most railings, particularly those on structures which follow a curve or a bend in the alignment of the structure. In cases where the shopwork has not been done with extreme care, the cost of erecting the railings will be very high because of the field corrections which may have to be made. It is not unusual for the erection cost to soar upward to a figure representing 1 hr of ironworker's or journeyman's time per foot of railing.

An estimator will have no way of knowing the proper costs to include for the erection of railing until a study is made of the costs of work which has been completed. Should no figures be available, then careful consideration must be made of the conditions and of the experience of the shopmen and of the erector. Naturally this is not a common situation, but it is one to be avoided by the proper shopwork and the planning of work.

12-17. Aluminum Hand Railings. To differentiate between bridge railings and hand railings, a hand railing is the type of railing provided at the edge of stairways or around or partially around openings in a floor. A major consideration in the selection of aluminum hand railing is the saving in maintenance costs, for aluminum withstands ordinary atmospheric corrosion and of course does not require painting.

In estimating railings it is quite usual practice to list the linear feet of the runs of rail. The information entered on the estimate will indicate the lengths of the straight runs and the length of sloping or stair runs. The size of pipe will be shown, as well as the number of rails in the section. The usual section of pipe railing consists of a top rail and an intermediate rail. As a point of interest, both rails are designed to withstand a concentrated load of 200 lb at mid-span.

Standard railing posts will be 3 ft high to 4 ft 6 in. The recommended spacing of posts (Aluminum Company of America hand-railings booklet) is 6 ft 4 in. for 1½-in. round pipe; for this diameter of pipe posts 3 ft high should be used. With 2-in. round pipe the recommended spacings for the posts are 7 ft 4 in. to 9 ft 8 in. The spacings between the posts will vary according to the height of the posts.

Many standard types of hand-rail fittings are shown in the previously

mentioned booklet. These fittings are made in a number of forms, and about 15 different arrangements are given for either the threaded or the flush type. The assembly of a railing may be completed by welding should this be preferred to the screw-type connections.

12-18. Other Aluminum Building Products. As previously mentioned, it is the practice of many fabricators to supply other building products in addition to steel or aluminum framing.

Many of these products may be obtained in both steel and aluminum, but in this chapter only the aluminum products are being considered. Some of the building materials will be suitable for mill-type buildings and others for beam-and-column or tier buildings. No attempt will be made here to keep the descriptions of materials suitable, or used for, one type of structure separate from those adaptable to other structures.

12-19. Covering Materials. Covering materials include those materials used for roofing and siding. The first of these to be considered is corrugated aluminum roofing and siding sheets. Before describing the covering materials in further detail, it should be noted that a basic unit is one square, which equals 100 sq ft.

In preparing an estimate, the work usually included will be as follows: Furnish all materials and labor to install complete the roofing and siding (either or both as specified), all as indicated on the drawings furnished for estimating. Flashing and fasteners will be included with the materials supplied; also calking, calking materials, priming, back painting, and paint, all as required.

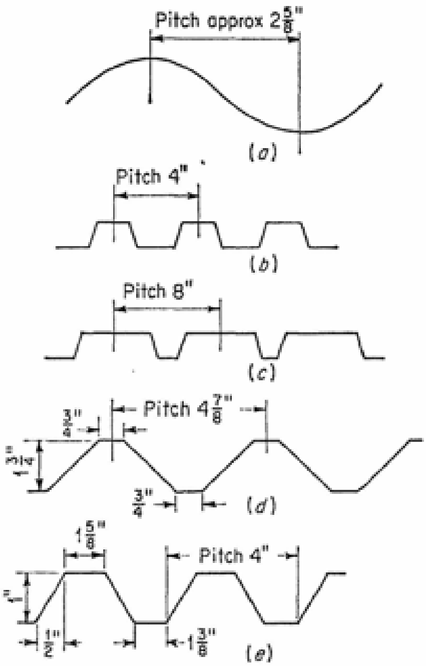


FIG. 12-9. Siding and roofing sheets.

Sections of several types of sheets are shown in Fig. 12-9. The corrugated industrial sheet (Fig. 12-9*a*) is one of the materials in most common use.

Normal over-all widths and standard lengths are indicated in Table 12-4. Other widths may be obtained; the variation in stock lengths is from 5 to 12 ft. Specifications will indicate the amount for allowance for side laps.

As an example, the width of 48⅓ in. will result in a 45⅓-in. coverage. As a further example, the approximate number of sheets per square (100 sq ft) is 3.10 for sheets 8 ft 0 in. long and 48⅓ in. wide. As still another example, the same-width sheets will require 4.13 per square for sheets 6 ft long and 2.07 sheets per square for 12-ft sheets.

Table 12-4. Roofing and Siding Sizes

Symbol	Type	Normal over-all width	Length	Wt, lb/100 sq ft
R (a)	Industrial corrugation	48⅓″	Up to 12′	55.2
R (a)	Corrugated	43	Up to 12′	41.4
R (b)	4″ ribbed	41⅝″	22′-5″	58.0
R (c)	8″ ribbed	41⅝″	22′-5″	51.8
A (a)	Corrugated industrial	48⅓″	5′ to 12′	41.4 or 55.2
A (d)	V-beam roofing	41⅛″	5′ to 12′	75 or 93.6
A (e)	Industrial siding sheet	41½″	5′ to 30′	58

R = from Reynolds Metals Co. booklet, *AIA File* 12-C.
A = from Aluminum Company of America, *AIA File* 12-C.

Complete details may be obtained from catalogues supplied by the aluminum manufacturers. These catalogues should be in the estimating-department files when it is the practice of the fabricator to supply and erect roofing and siding. Some of the basic data may be found, for instance, in tables which can be obtained from the Aluminum Company of America and also from other producers. Some of the items are:

Weight per sheet for different thicknesses
Square feet per sheet
Approximate number of sheets per square
Purlin spacing and maximum safe loads

Fasteners are available which may be installed from the weather side, or exterior, of the buildings without workmen inside to assist. One type is a self-tapping screw which has a hexagon head and is supplied with a neoprene washer. Matching holes are drilled through the sheet and the purlin. The screws are installed with a power nut runner, tapping threads as they enter and sealing the hole in the sheet with the neoprene washer. A weldable stud may be obtained from the Nelson Stud Welding Division of Gregory Industries, Inc., Lorain, Ohio. Studs may be installed in advance of the sheeting and are welded to the supporting steel with an arc gun. Sheets are laid over the studs and are impaled with a rubber hammer. An aluminum burr is applied to the shank of each stud and the shank is

headed or flattened, drawing the sheet tight. Other fasteners are the Widman fastener (George D. Widman, Inc., Gardena, Calif.), the Nelson Setlock fastener (Nelson Stud Welding Division, Gregory Industries), the strap-and-bolt type, double purlin nails, roofing nails, and tinner's rivets.

Should no kind be specified, an estimator is usually advised by his employer of the type of fastener preferred. When the type is indicated in the specifications, this is what will be used unless an exception can be obtained from the buyer of the work.

Up to this point the roofing and siding material described has been the corrugated industrial sheet. Several other forms of covering materials have been shown in section in Fig. 12-9. In connection with these reference may also be made to Table 12-4. The two types of sheets shown in Fig. 12-9*b* and *c* are described in the Reynolds Metals Co. booklet, *AIA File* 12-C, as 4-in. ribbed embossed and 8-in. ribbed embossed. Embossing gives a decorative effect which lends a finished appearance to the structure. Either of these two types, as shown in Table 12-4, may be had in lengths up to 22 ft 5 in.; this makes it possible to construct a moderately high side wall without the necessity of lapping the sheets. Thus the final appearance is improved, and the cost of erection may be moderately reduced. It may be observed from the table that the weights of the sections are about 52 to 58 lb per 100 sq ft of formed sheet.

Alcoa aluminum V-beam roofing and siding are shown in section in Fig. 12-9*d*. These sheets may be had in lengths of 5 to 30 ft. The standard sheets are 41⅛ in. wide and have a coverage of 39 in. with one V overlap. A complete table of the weights and coverage may be found in the Alcoa aluminum industrial-building-products catalogue. A base figure has been used for 75 lb per square (100 sq ft). For example, it will require two sheets each 14½ ft in length per square. Each of the sheets will weigh a fraction over 37 lb.

Suggested specifications for fasteners are self-tapping screws. Also, V-beam closures may be specified in either aluminum or rubber. Rubber preformed closures are supplied by several producers. Self-tapping screws require the steel and aluminum sheet to be drilled, but they will cut threads in the steel, and the hole in the sheet will be sealed with the neoprene washer.

Alcoa aluminum ribbed industrial siding sheet as shown in section in Fig. 12-9*e* does not require any detailed explanation here, as all conditions of use are about as described for the other types. These sheets may be had in lighter weight than the V-beam roofing sheet.

12-20. Flashing and Closures. In order to provide a finish and a complete closure, it is necessary to use flashing material and, when conditions require, the formed rubber, neoprene, or contoured aluminum closure

strips. The different types of flashing may be purchased from suppliers in the finished forms, or it may be desirable to locate a bending brake at the site of the work and there bend the flat sheets to suit each condition. Details of several types of formed flashing may be seen in Fig. 12-10.

Figure 12-11 shows the locations of some of the flashings on a typical mill structure. Of course, different arrangements of flashings and closings will be required for structures of other design.

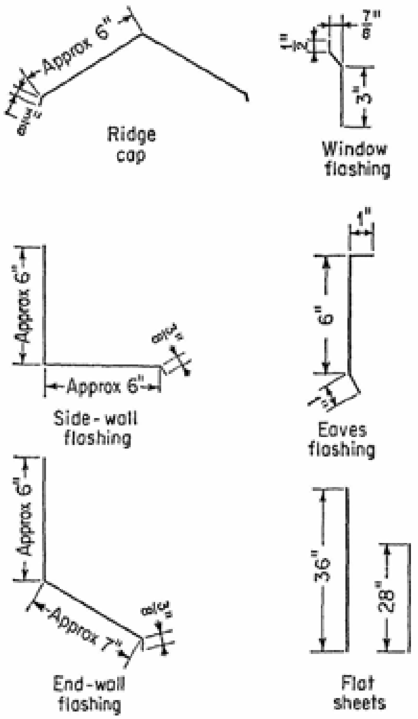


Fig. 12-10. Forms of flashings.

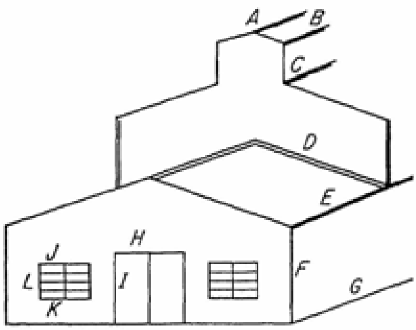


Fig. 12-11. Locations of flashings.

An estimator will obtain current prices for the formed material or, in the event that the flat sheets are used, will add the necessary labor costs to either the shop-cost estimate or the estimate for the field work.

12-21. Sandwich Walls. The sandwich wall as manufactured by the Aluminum Company of America is called Alcoa aluminum industrial sandwich wall. A similar type of wall by the Reynolds Metals Co. is listed as Reyconowall. The word "sandwich" very well describes the construction of these types of walls which consist of two aluminum sheets, between which is placed glass-fiber board or glass-fiber insulating material.

A selection from the several kinds of aluminum sheets may be made. The Reynolds Metals Co. indicates in its booklet these several arrangements:

A. 4-in. ribbed embossed sheet
   1-in.-thick glass-fiber board
   0.032 industrial corrugated sheet
B. 8-in. ribbed embossed sheet

1-in.-thick glass-fiber board
0.032 industrial corrugated sheet

C. 0.032 industrial corrugated sheets both sides

Note that 0.024 industrial corrugated sheets may be substituted for the 0.032 thickness should the designing engineers wish to do so. As a further option the Reynolds perforated corrugated sheets may be used as the interior wall material for acoustical treatment.

The use of similar sheets is indicated in the Aluminum Company of America catalogue.

A. Corrugated siding either 0.032 or 0.024
1- or 1½-in. insulation
Corrugated siding or perforated corrugated sheets

B. V-beam siding 0.040 or 0.051
1- or 1½-in. insulation
Corrugated or perforated corrugated sheets

C. Ribbed siding 0.032 or 0.040
1- or 1½-in. insulation
Corrugated or perforated corrugated sheets

The term sandwich walls will indicate to the estimator that double the number of aluminum sheets will be required for the work. The special fastening materials will be estimated as indicated on the drawings or described in the specifications.

12-22. Aluminum Roof Deck. An estimator may be required to include roof-decking material in the estimate. This material as supplied by the Reynolds Metals Co. may be obtained in lengths up to 14 ft. 6 in. and 25 in. wide.

Note that there are other aluminum producers in addition to those mentioned here, and similar items may be obtained from them.

12-23. Aluminum Curtain Walls. The term "curtain wall" is generally used in reference to the material round the perimeter of a structure such as an office building or an apartment house. Aluminum curtain walls may be obtained in many types. Such walls consist of aluminum panels, the window material, mullions, sash, and glass.

The average structural estimator may not be required to include curtain-wall material in the structural estimate. Because of this fact and because of the new designs of wall sections which are appearing, it is not practical to describe wall systems here. Suggestion is made to obtain up-to-date catalogues from the several producers of wall systems.

12-24. Cost of Extras for Aluminum Structurals. The mill cost of aluminum structurals is quoted at a base figure which may be increased under certain ordering conditions. It is advisable for an estimator to have a copy of the current extra charges in the office files. If a copy is not on hand,

figures must be checked with the suppliers so as to include all necessary costs in the final estimate figure.

The basic units on which there are extras are quantity, length, and alloy. These units do not change too frequently, but the money values will change from time to time as the costs of manufacture increase or decrease.

In reference to quantity, 30,000 lb or more will be billed at the base price of the material as far as weight is concerned. The maximum extra charge will be for a quantity of 500 lb, and this decreases by stages until the 30,000-lb figure is reached.

Standard mill lengths are 15 ft minimum to a maximum varying from 25 to 40 ft. There is no extra charge for cutting within this range, but there will be an extra for lengths of 5 to 10 ft and also a different charge for lengths between 10 and 15 ft.

There may also be a temper differential required, depending upon the specifications.

As with structural steel, it is important that an estimator check carefully to ensure the inclusion of all costs which the fabricator may be required to pay for every item of material which is purchased.

CHAPTER 13

Material Supplementary to the Structural Frame

13-1. Introduction. The items included in fabricators' contracts vary widely. Many fabricators furnish the material only for the structural frame, the erection being performed by independent erectors. Others contract for the structural frame erected in place but do not include material other than that necessary to complete the structural frame.

From these minimums it will be found that the practice of many other fabricators is to include many of the supplementary or so-called miscellaneous materials.

Some of the materials are purchased in final finished form from other suppliers. Other items are made up by the fabricator.

13-2. Lally Columns. The Lally column derives its name from the patentee John Lally and is basically a section of pipe or of tubing filled with concrete.

At present genuine Lally columns are available in four types, which are a development of the original round sections. These types are:

Heavyweight round, fabricated from steel pipe
Rectangular, from seamless steel tubing or welded hot-rolled steel plates or structural shapes
Square, of the same kind of material as the rectangular
Lightweight, of steel tubing

In general, Lally columns are included in the column schedule for the structure, or they may be indicated in a separate section of the column schedule. The designing engineer decides on the method of listing or showing these columns. Sometimes the columns are indicated on the floor plans. However, the estimator should have no trouble locating and making a proper take-off of these columns. A separate section of the estimate may be devoted to the listing of these columns, as they will be purchased from the manufacturers and may be shipped directly to the site of construction.

Lally columns are identified by symbols, as follows:

SHW Standard heavyweight columns range in size from 3½ to 20 in. OD. The weights are 15 lb per ft for the lighter sections to 370 lb per ft for the heaviest sections. These weights are for the entire column material, steel plus concrete.

XHW Extra heavyweight columns come in sizes of 4 to 12¾ in. OD, the weights ranging from 21 to 178 lb per ft.

XXHW Double extra heavyweight columns may be obtained in sizes of 4 to 8⅝ in., all OD dimensions.

RS This designates rectangular columns. The range of sizes for these columns is 3 × 3 × 3/16 in. at 14 lb per ft to 6 × 6 × ¼ in. at 50 lb per ft.

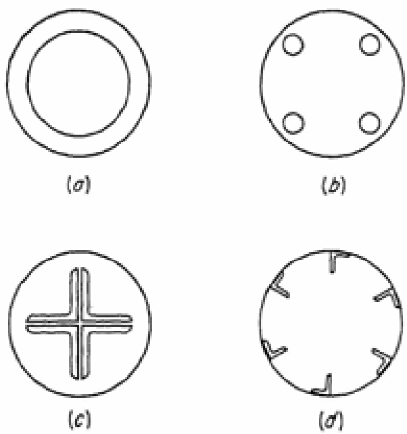


Fig. 13-1. Lally-column reinforcement.

LW Lightweight columns are mainly produced for use in residential construction and are rarely found in any other kind of structure. These sections have a diameter of either 3½ or 4 in. and the weight of 12 or 15 lb per ft.

Note that, while the standard range of sizes is given here, special sections may also be obtained.

The column schedules and the take-off should indicate the columns thus: 6 × 6 × ¼ in. × 50 lb RS. This designates the size and weight of the section and also the type, in this case rectangular section.

There are several methods of reinforcement which may be used where the diameter of the column must be limited. Figure 13-1 shows four methods of reinforcement. The section of Fig. 13-1*a* shows reinforcement consisting of a second section of pipe within the outside pipe section. The diameter of the inside pipe must be less than that of the outside pipe by not more than 4 in. The reinforcement shown in Fig. 13-1*b* is composed of four sections of solid round steel. In Fig. 13-1*c* a group of four angles is used. In Fig. 13-1*d*, which is a reinforced shell column, there are six angles 1 × 1 × ¼ in. welded to the pipe shell.

13-3. Lally-column Take-off. The take-off of Lally columns is quite simple and consists in a listing of the lengths, sizes, and type, all as indicated on the estimating plans. This information is forwarded to the manufacturer for a quotation. Besides this figure, which is to be included in the estimate, handling costs to be incurred by the fabricator and the erection costs are added. The structural fabricator by whom the estimator

is employed may add other charges to compensate for his temporary investment or other expense in connection with the Lally columns before payment is made him by the buyer of the structure.

A typical connection of beams to columns is shown in Fig. 13-2*a*. The structural-steel cap and base are welded to the shell of the column and will be included in the Lally-column quotation but must be noted by the

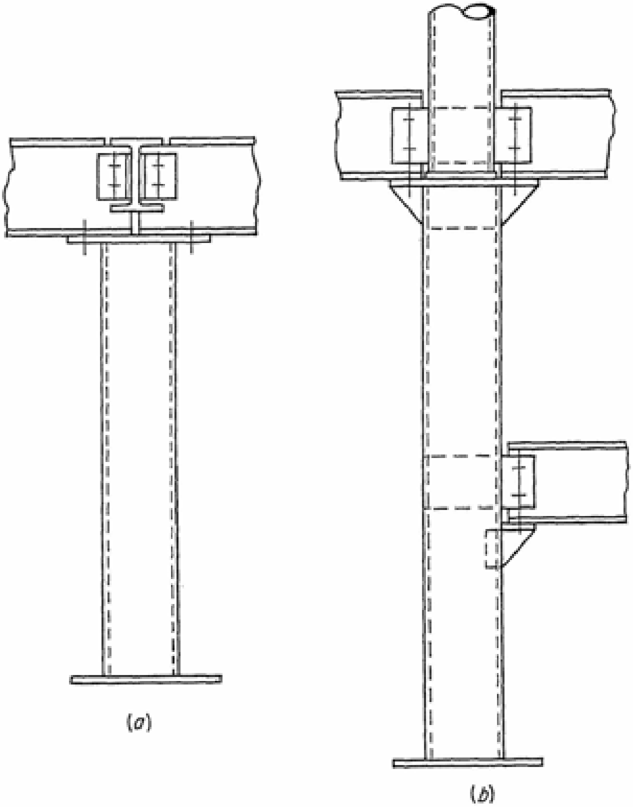


FIG. 13-2. Lally-column details.

estimator in the request for a quotation. The balance of the shopwork in this case to the beams will be included in the regular shop costs. This shopwork will be the preparation of the clip angles, the punching of the beams as indicated, and the coping of the top flanges.

The arrangement of Fig. 13-2*b* shows one of the methods used in multistory framing. The caps, bases, side brackets, and web tie plates are all welded to the shell and will be supplied as required from the manufacturer of the columns, but, as before, all necessary information must be

included in the request for a quotation from the Lally Column Co. A minimum of shopwork is required for the beams of Fig. 13-2*b*, consisting only of punching the webs or flanges as shown.

The detail of Fig. 13-3 is of a connection to a through web plate. As shown, the column shell is slotted and the web plate run through and then welded to the shell. Here again the remaining work is the punching of the beams. The holes in the through web plate are made by the column manufacturer.

It has been the practice of the Lally Column Co., wherever conditions permit, to arrange to make a take-off from the estimating plans and to supply the information for the erector's use, that is, the total weight and the number of pieces to be erected. The estimator, when required to include this type of framing, may contact one of this company's offices.

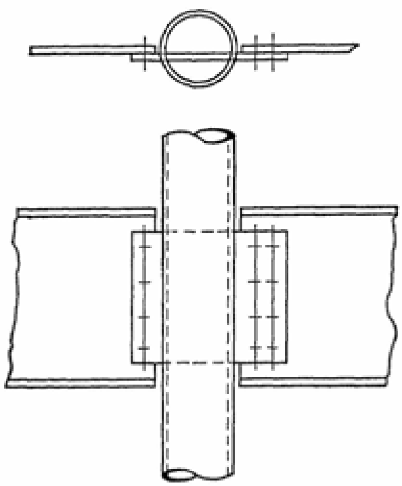


Fig. 13-3. Lally-column details.

Note. Stainless steel may be indicated for an outside shell. This must be clearly noted on the take-off because of the much higher cost of this material.

13-4. Stairs. The average structural-steel estimator will not be required to include the more elaborate kinds of stairs. On the other hand, he frequently will be obliged to include the more common stair framing in, for instance, a powerhouse or an industrial building.

The very simple type of stair framing consists of the stringers and treads, and sometimes but not always the risers. Stair stringers are the supporting members and in most cases are in pairs, though there are cases where a single stringer is used. The bearing of the tread at the edge opposite the stringer may be on the masonry of the wall of the building. Stringers most often consist of channel sections, though also there are special rolled stringer sections. One method of supporting the treads is to attach short lengths of angles at approximately the elevation of the treads. There are other methods of attaching the treads, one of which is to weld them directly to the stringers.

Stringers may have clips or angles at either end to secure them either to the floor or to the framing of the structure. The fabrication of a stringer costs more than a simple beam of channel because of the fact that it is a sloping member and may require cutting at one or both ends, in addi-

tion to the work of preparing and attaching the angles which will support the treads.

Treads are designed in many forms and types. The estimator will carefully indicate on the take-off the kind of tread used, including all dimensions and other data. A few of the many types of stair treads are grating, solid nonslip, raised-pattern steel plate, pan type, in which is placed masonry or concrete, and certain masonry or stone slabs. Several different widths are used. Also, it is common practice to require nosings on some types of tread. Most tread material is purchased ready to incorporate with the stringers, although some fabricators may fabricate or form some of the tread items.

When stairs are furnished for a contract, it is quite usual to include the railing. The general type of railing used is pipe except in the more elaborate structures. If it is required to make a complete estimate of pipe railing, include full information on the size and kind of pipe, which may be wrought iron, steel, or aluminum. In the case of iron or steel pipe, the pipe may be required to be painted or galvanized. The complete lengths of all the pipe required for the work must be included and also a complete listing given of all fittings and details.

When the railing is a buy-out (purchased from a supplier), it may be required to give only a general description, such as the number of rails high, the diameter and kind of pipe, the lengths of straight sections, the length of sloping sections, and the height of the posts.

13-5. Grating. Grating, or grid flooring, is used in many applications, from the floor material in a structure to that used on bridges. It follows therefore that many kinds of grating are on the market. It is not advisable here to describe only one or two types and possibly fail to mention a type which may be very important to some fabricator. As with some of the other materials, it is advisable to have a number of catalogues in the office files. These may be obtained from any of the manufacturers.

In making a take-off it is necessary to separate the straight rectangular runs from the areas which require cutting and forming for the irregular spaces. List this information carefully and also all other data specified or indicated on the drawings.

Some contracts may require a very light type of grating, while others require grating constructed from heavy bar sections. For instance, where raw material such as coal or ore is discharged from the cars into hoppers, the grating may be built from bars 6×1 in.

The materials used for the manufacture of gratings are either steel or aluminum. Steel gratings may be required to be either painted or galvanized. A usual method of painting is by dipping the assembled work into a container of paint. When grating is shipped from suppliers, there may be a charge for banding, which will be included in the estimate.

13-6. Reinforcing Rods. In cases where the concrete reinforcing rods are to be furnished by the fabricator, the usual work to be done is the cutting and the bending of the rods. Some area labor agreements will not permit the mechanical bending of the rods in the shop; instead, all bending is done at the site of the structure. Under these conditions the rods may be cut to length in the shop and assembled into bundles of like sizes, then tagged for identification and shipped to the site for the bending. Otherwise the rods may be prepared in the shop and shipped to the field ready to be incorporated in the structure.

13-7. Door and Window Material. These items may include the doors, door jambs, door heads, rolling doors, and large doors required for aircraft hangars. Many estimating plans include complete listings of doors as to type, location, and quantity. When this is the case, it is a very simple matter to transfer the information to the estimate sheet. In other cases it is necessary to read all the elevations and sections to locate and list the doors.

Hangar doors were mentioned in an earlier chapter (Sec. 9-38). These doors are usually very large and cannot be sent to the site completely assembled but must have the several sections matched and marked in the shop to avoid any trouble in erection. Both hangar doors and rolling doors may have mechanical operating equipment. This may be furnished to the fabricator for installation as the doors are assembled or during the course of erection.

Window framing may be very simple and easy to locate and list, although there are many cases where the entire outside of a structure is composed of window framing.

13-8. Steel Bridge Railings. In the previous chapter numerous data were given on aluminum bridge railings. There are also many arrangements for steel bridge railings, a few of which will be described here. It must be noted that many arrangements of railing are possible with the rolled structural shapes and plates.

One type of horizontal railing consists of an angle for the top rail and also the intermediate rail. These two angles are joined to an H-section post by means of clip angles. A special post cap welded to the top of the H section completes the material required for this railing. Other bridge railings consist of rectangular steel tubing which is welded to a post. The post is also a section of square tubing. Still another type may have two intermediate rails composed of channels and a top rail of a half section of steel pipe. The post for this railing may be a beam section or an H section. The channels may connect to the posts with clip angles, and the top rail may be welded to a bent plate, which also serves as a post cap.

A vertical bridge railing may consist of channel sections top and bottom, with square bars welded to the channels. The lower channel may be

punched out to permit the passage of the bars, which then can be welded on the inside of the channels.

13-9. Bar, or Open-web, Joists. There are many producers or manufacturers of bar joists, or open-web joists, and it follows that there are many different designs.

Several fabricators manufacture open-web joists and many others will supply the joists in addition to the structural steel. Many light manufacturing buildings and one-story warehouses are constructed of beam framing at the column centers and open-web joists for the balance of the roof-supporting material.

There are many architectural reasons for the use of bar joists, and thus the estimator will frequently encounter this kind of construction. Usually the design or floor plan will not show each joist in place; an estimator must be alert to this fact. Each panel or section between four columns will contain a mark or symbol indicating the type of joist and the number of joists in that particular panel. This will continue for the balance of the floor framing.

The size and spacing of the bridging should be indicated in the specifications. If not, the estimator should obtain the necessary data from the engineers or from the ultimate purchaser. Bridging is the supporting material applied across the joists to hold them in place and also supply some lateral support. Should it be left out of the estimate, it would involve a costly error.

Open-web joists may be obtained in very long spans. Such joists very closely resemble trusses.

13-10. Corrugated Sheets. Corrugated sheets which are made from sheet steel are very similar to those made of aluminum (Chap. 12), except, of course, in the case of the base material. The application and size of these sheets are much like what has been described for aluminum.

The use of galvanized corrugated sheets has proved very practical. Many jobs will have this kind of sheet specified.

Glossary

Abutment End support of masonry on which a bridge rests

Alloy steel Steel which has elements other than carbon added to give greater strength; silicon, manganese, and nickel are examples of the added elements

Anchor bolts Bolts used to secure columns or beams to masonry

Assembling To put component parts together to form girders, trusses, etc.

Bar The designation of rectangular rolled sections about 6 in. in width or less (on occasion the rolling mills will determine the widths included in this classification)

Bascule bridge A vertical lift bridge

Batten plates Tie plates to connect component parts of a member

Bay A section of an area marked off by columns or beams

Bearings Steel supports at the ends of girders, trusses, or beams

Bent Two columns and a connecting cross beam or girder to support longitudinal framing

Blocking Material, either wood or steel, used to raise an assembly from the floor of a car or truck or to support work during the course of fabrication or assembly in either the shop or the field

Block-out A section cut out to provide clearance for another member

Bracing system Struts and diagonals placed between main members

Bracket A projecting connection or support

Bridge crane A traveling crane which bridges the span between two adjacent craneways

Bull riveter A pressure rivet-driving machine constructed in the form of a large yoke which clamps the hot rivet and forms the second head when air pressure is applied

Bull stick The long timber or pipe passed through brackets attached to the mast at the bottom section of the guy derrick, the purpose being to supply the leverage to turn the derrick

Bull wheel Circular steel sections attached at the bottom of derrick masts. Cables are run from the bull wheel to drums on the hoist, and this provides power for turning the derrick instead of by use of the bull stick

Butt joint Where two parts bear against each other; usually held in place by splice plates or welds

Butt weld The welding together of two sections which butt against each other

Camber A flat vertical curve placed in a beam or truss or girder to counteract the deflection caused by loading

Cantilever Projecting beam supported at one end

Carriage The section of a bridge crane which travels transversely and spots the lifting hook over the work to be lifted

Cats The metal treads on either side of a tractor crane

Checkered plate Steel plates with raised ribs or patterns to prevent slipping

Chord member Main members of trusses as distinguished from diagonals, and main members of plate girders except webs

Clevis Forging with a forked end the other end threaded to receive a rod. The forked ends are flattened and drilled to receive a pin

Clips Small connection angles

Column cap Angles with or without a plate at the top of columns

Continuous beams and girders Members which are supported on more than two supports

Cope To cut a flange section in order to avoid interference with other sections

Cross bracing Bracing with intersecting diagonals

Cross frames Vertical cross bracing between girders or trusses

Cross section The view of a member or section cut by an imaginary plane

Dead load The load on a structure due to its own weight, that is, the material of which it is composed

Diagonal The members of a truss as distinguished from the chords or the inclined members of a bracing system

Driftpin A type of pin driven through holes to draw members into alignment

Drilled holes Holes which are required to be made with the use of drills rather than those which are punched in the metal

Driving nut A temporary nut screwed on a pin to protect the pin during the time it is being driven into position

Duplicator A machine for duplicating or copying work during the fabrication

Eave strut A member, or section, at the eaves of a building, connecting tops of columns

Expansion bearings Bearings placed under the ends of bridge girders to permit movement under moving loads or movement due to temperature changes

Expansion bolts A bolt with split sleeve which expands in masonry when the bolt is tightened

Extrude To push, or force, out

Fabrication The assembly of two or more rolled sections

Face To machine or smooth a surface

Falsework Temporary supports for a structure during erection

Field The site, or location, where work on a structure is being done

Field connections The connections of members which are to be made in the field

Fillet The metal at the junction of the flange and the web of a beam or channel; also, at the junction of the legs of angles and other structural sections

Fillet weld A weld of approximately triangular cross sections joining two surfaces approximately at right angles to each other in a lap joint, tee joint, or corner joint

Flame-clean To clean the surface of metal by the use of flame, preparatory to the application of paint

Flame-cut To cut sections of metal by the use of an oxyacetylene-burning torch, in place of sawing or shearing

Flange The two horizontal surfaces of a beam or girder when in a vertical position, as distinguished from the web. The web is the section joining the two flanges

Floor slab The reinforced-concrete floor supported by beams or girders

Forge A furnace for the heating of metal or rivets. It may be portable for use on construction

Friction saw Machine for cutting steel by use of a blade revolving at high speed

Gable The vertical triangular portion of the end of the building

Gage (gauge) A uniform standard of size, thickness, or distance of measurement

Gantry crane A self-propelled crane supported by bents or legs and traveling on rails; also a frame in the shop supporting equipment

Generator A machine which will produce electrical energy of selected characteristics when driven by another power source, which may be a gasoline engine, diesel engine, or electric motor

Girts Horizontal side or end members of a mill building or similar structure, to support siding materials

Government anchor A short bent rod inserted through a hole in the end of a wall-bearing beam to serve as a masonry tie

Ground wire The wire which is connected to the work in a welding operation to complete the circuit

Grout Thin mortar which will pour readily, used to fill the open spaces between the concrete piers and the base plates or slabs

Gusset plate The plate which connects members of a truss to each other

Hangar A shelter or building for housing aircraft

Hanger The vertical member from which a horizontal member hangs or is supported

Hooked bolts Bent bolts having thread and nut on one end and hooks over a crane beam to secure railroad rails. The railroad rails are drilled through the webs for inserting the ends of the bolts

Lag screw Large wood screw with square head, suitable for use with a wrench for turning

Lateral Directed toward or coming from the side or at right angles to the axis

Laterals Diagonal members and lateral bracing

Lattice and lacing Crossed flat bars or angles to hold main members in fixed positions

Lattice girder A parallel chord member with diagonal web members instead of solid web plates, similar to a truss

Lead wire The electric cable which carries the electric current to the welding-rod holder and thence to the welding rod

Lean-to A section of a building leaning against the main structure, the roof sloping away from the other building

Lift bridge A bascule, or leaf, bridge or span which is lifted readily between two towers

Lintels Angles or other sections, singly or in combination, used to support masonry over openings

Louvers Bent metal assemblies arranged to provide ventilation but to exclude rain or snow

Lump sum Full, or complete, price for a quotation on work

Masonry plate Plates under the ends of steel sections to help distribute the load to the masonry

Mill To plane the ends of members by means of a milling machine

Mitered joint Joint formed by pieces matched and united on a line bisecting the angle of junction

Monitor A raised structure above the roof of a mill building, usually through the center section, for the purpose of giving additional light or ventilation

Multiple drill A drilling unit which will provide for the drilling of several holes simultaneously

Multiple punch A machine which will punch several holes at one time

Outlooker A support for the end or edge of a roof, usually an angle fastened to the end of a purlin

Oxyacetylene The mixture of oxygen and acetylene which when ignited at the extreme end of a torch will provide the temperature for melting through steel

Panel A portion of frame structure; a section of a truss between panel points

Pedestal A built-up or cast-steel stool for support of a bridge girder

Pier Intermediate support for the adjacent ends of two bridge spans

Pilot nut Tapered nuts screwed on the end of a bridge pin to guide it while being driven to position

Pitch A slope or degree of slope as the ratio of the height of a truss to the span. The distance between adjacent rivets longitudinally

Plunger Small solid cylinder of hard steel which is inserted in the air-hammer barrel and which supplies the striking action on the rivet set

Portal bracing Bracing between the end posts of a bridge

Posts A supporting member or small column

Pound price Bid basis for contract, based on price per pound for each pound of structure delivered. May be calculated either from details or from weight on scales

Punch A tool for various uses, as a center punch, hole punch, etc.; or a machine which is employed to punch holes in materials, steel, aluminum, and other metals

Purlin The horizontal member supporting the roof which is supported by the trusses or rafters

Rafters A sloping member of a roof in place of a truss and often in the ends of a building

Rail clamp Clamp to fasten crane rails to the flanges of crane beams or girders

Ream To enlarge a hole which has been punched or drilled to smaller diameter

Reamer Tool to be fitted to machine for enlarging holes. Also a designation for the machine

Reinforcing bar Steel bar used in connection with concrete construction

Ridge strut Strut along the peak of a roof

Rivet set A die inserted in the outer end of a riveting tool for forming the rivet head

Rocker Bridge bearing which will distribute pressure from the stringers or girders to the masonry even though deflection occurs from moving loads or otherwise

Rolling mill The producing mill for shapes which are sold to fabricators for further working. The rolling mill is where the slabs or billets are passed through special rolls for forming the structural shapes

Sag rods Rods supporting girts or purlins against sagging

Sandblast Method of cleaning the surface of steel to obtain a smooth, clean surface before painting

Saw-tooth roof Roof arrangement of a series of vertical and sloping sections to obtain greater daylight

Section A cut across a member or area to show more clearly the various sections of a part of an assembly

Separator Material used to hold two or more sections a fixed distance apart. May be either long bolts with pipe separators or a plate with angles between the webs of beams

Shank The part of a rivet beyond the head

Shear A machine used to cut steel plates and other sections

Sheared plate A plate which has the edges sheared to obtain the required width

Sheet The thinner steel plates, usually less than ⅛ or $\frac{3}{16}$ in. thick

Shoe Bearing material at the ends of bridge girders or stringers

Shot blast Method of cleaning the surface of steel before painting. Small round pellets are forced by air pressure to strike the surface of the metal

Single-punch To punch only one hole at a time

Skew bridge A bridge which does not cross at right angles to a road or stream

Skids Same as blocking, that is, wooden or steel sections spread or placed on the floor to raise the work to convenient working height

Slab A heavy steel plate generally used under a column at the top of the piers

Sleeve nut A long nut having both right- and left-hand threads, used to join two rods

Slot weld Weld made through a slot in one member

Slotted hole Long hole with rounded ends and straight sides

Sole plate Small plate at the end of a girder which bears on the masonry plate

Spiking piece Strip of wood bolted to the top of a purlin to which planking is nailed

Spindle An arbor which applies motion to the work by the attachment of accessories, drills, or reamers. The spindle in turn is connected to the driving motor or unit

Staggered rivets Rivets spaced alternately on parallel lines

Stiffener Angle or plate used to reinforce a beam or girder web, usually at concentrated loads

Stitch rivets Rivets placed quite wide apart

Stringer Longitudinal main member of a bridge

Strut A light column or post

Subpunch A small hole punched in material which is subsequently reamed to larger size, usually after the assembly of several pieces

Substructure The foundations of a structure, such as piers and abutments of a bridge

Superstructure The main steel work of a structure above the substructure

Swage bolt A type of anchor bolt with depressions in the shank for developing bond with masonry

Sway bracing Bracing in a vertical plane between trusses or columns

Tack weld Small weld to secure parts before placing the service welds

Template Full-sized layout in cardboard or wood to be used in locating holes and cuts in the steel members

Tie plate Plate for holding members at proper locations

Tier building Multistory building, for instance, an office building

Tie rod Rod which ties beams or columns together, somewhat in the same way as a tie plate

Tractor crane A crane which travels on cats or continuous treads under its own power

Transformer Electrical apparatus for changing the electrical potential, for instance, to decrease the voltage of the incoming power supply

Traveler A moving erection platform on which derricks are mounted, frequently used in bridge construction

Turn buckle A forging with right and left threads at opposite ends which can be rotated by insertion of a bar through the center open section

U bolt Bent rod with nuts at each end bent in the shape of the letter U, often used to support piping

UM plate Universal Mill plate which has edges formed by vertical rolls, the forming mills having both horizontal and vertical rolls

Upset To enlarge the end of a bar or rod so that the diameter of the root of the thread is about the same as the unthreaded bar

Wind bracing Bracing required to resist wind stresses

Appendix: Complete Estimates for an Office Building and a Highway Bridge

The estimates which follow are complete examples of all the operations necessary to produce a figure for quotation to an owner or other buyer. These examples are for moderately simple work. In many cases work required to be estimated will be similar or will involve only an expansion of the tonnage and dimensions here considered.

The sample estimates are based on the present base and extras quoted by the mills. These costs may be brought up to date by reference to quotations in any of the trade magazines. The *Engineering News-Record* publishes average material costs several times yearly, as well as much other valuable information such as labor and insurance rates in various localities.

Unit costs used here are \$5.50 per hundredweight for material, \$2.25 per hour average shop rate, and an average field rate of \$4 an hour for ironworkers.

The final costs may appear quite high, but this is partly due to the comparatively low tonnages used. The erection costs will be considerably lower per ton when some of the base or plant costs are spread over a greater tonnage.

Office Building Page 1

Column Base Plates

No.	Material	Length	Wt, lb/ft	Total wt, lb
4	12 × 1	1′-6″	40.8	245
4	12 × ¾	1′-2″	30.6	143
4	12 × 1½	1′-6″	61.2	367
4	12 × 1	1′-2″	40.8	190

Setting Plates

8	12 × ¼	1′-6″	10.2	122
8	12 × ¼	1′-2″	10.2	95

Shims

256	3 × ¼	0′-3″	2.6	166

Anchor Bolts, Bent End and One Nut

32	⅞ φ	2′-0″	2.04	130
32	Nuts	....	0.23 ea	7
				1,465

Subsummary of Cost of Material Extras

Material	Wt, lb	Extra cost for width and thickness	Extra cost for length	Extra cost for quantity (wt)	Total extra cost for item
12 × ¼	217	$1.65	None	$1.50	$3.15
12 × ¾	143	1.10	$0.20	1.50	2.80
12 × 1	435	1.10	0.05	1.50	2.65
12 × 1½	367	1.10	0.10	1.50	2.70
3 × ¼	166	1.65	None	1.50	3.15
	1,328				

Office Building Page 2

Columns

No.	Material	Length	Total wt, lb
8	10 WF 45	30′-1″	10,832
8	10 WF 49	30′-4″	11,888
16	10 WF 33	22′-8″	11,968
16	Splices		
	46-lb plates	......	736
	12-lb rivets	......	192
			35,616

Subsummary of Cost of Material Extras

Material	Wt, lb	Extra cost for section	Extra cost for length	Extra cost for quantity (wt)	Total extra cost for item
10 WF 33	11,968	\$0.45	\$0.20	None	\$ 0.65
10 WF 45	10,832	0.45	0.10	None	0.55
10 WF 49	11,888	0.40	0.10	None	0.50
Splice plates (cut multiple)	736	1.10	0.10	\$1.50	2.70
Rivets (average cost base plus extras)	192	....	....	....	14.00
	35,616				

Office Building Page 3

Beams, Floors 1 to 4

No.	Classification	Material	Length	Wt, 1 floor, lb	Wt, 4 floors, lb
4	P	16 WF 36	14′-8″	2,112	8,448
6	CF	8 WF 17	7′-3″	740	2,960
8	P	14 WF 34	14′-8″	3,989	15,956
2	F	14 WF 34	19′-10″	1,349	5,396
4	F	14 WF 30	19′-10″	2,380	9,520
2	CF	14 WF 30	20′-8″	1,240	4,960
4	F	12 WF 27	19′-10″	2,142	8,568
4	CF	12 WF 27	20′-8″	2,232	8,928
1	F	14 WF 34	20′-2″	686	2,744
1	F	14 WF 30	20′-2″	605	2,420
1	F	14 WF 30	21′-0″	630	2,520
2	F	12 WF 27	20′-2″	1,089	4,356
2	CF	12 WF 27	21′-0″	1,134	4,536
1	F	14 WF 30	20′-2″	605	2,430
		Connections, 6½%	......	1,366	5,464
					89,198
		Bolts	......	.....	384
		Rivets	......	.....	1,436

Subsummary of Cost of Material Extras

Material	Wt, lb	Extra cost for section	Extra cost for length	Extra cost for quantity (wt)	Total extra cost for item
8 WF 17	2,960	\$0.80	\$0.50	\$0.25	\$1.55
12 WF 27	8,568	0.50	0.35	None	0.85
12 WF 27	17,820	0.50	0.20	None	0.70
14 WF 30	9,520	0.45	0.35	None	0.80
14 WF 30	12,320	0.45	0.20	None	0.65
14 WF 34	21,352	0.45	0.35	None	0.80
14 WF 34	2,744	0.45	0.20	None	0.65
16 WF 36	8,448	0.45	0.36	None	0.80
Connections	5,464	0.70	0.10	None	0.80
	89,196				

Office Building Page 4

Roof

No.	Material	Length	Wt, lb
12	12 WF 27	14′-8″	4,752
2	14 WF 34	19′-10″	1,349
1	14 WF 34	20′-2″	686
4	12 WF 27	19′-10″	2,142
2	12 WF 27	20′-2″	1,089
12	10 WF 21	20′-8″	5,208
4	10 WF 21	19′-10″	1,666
6	10 WF 21	21′-0″	2,646
2	10 WF 21	20′-2″	847
			20,385
	Connections, 6½%	......	1,324
			21,709
	Bolts	......	96
	Rivets	......	357

Subsummary of Cost of Material Extras

Material	Wt, lb	Extra cost for section	Extra cost for length	Extra cost for quantity (wt)	Total extra cost for item
10 WF 21	1,666	$0.65	$0.35	None	$1.00
10 WF 21	8,701	0.65	0.20	None	0.85
12 WF 27	6,894	0.50	0.35	None	0.85
12 WF 27	1,089	0.50	0.20	None	0.70
14 WF 34	1,349	0.45	0.35	$0.25	1.05
14 WF 34	686	0.45	0.20	0.25	0.90
Connections	1,324	0.70	0.10	None	0.80
	21,709				

Office Building Page 5

Extension of Costs of Extras from Pages 1 to 4, Inclusive

Item	Wt, lb	Extras per cwt	Actual cost	Rounded-out cost
		Base Material		
12 × ¼	217	$3.15	$ 6.83	$ 7
12 × ¾	143	2.80	4.00	4
12 × 1	435	2.65	11.52	12
12 × 1½	367	2.70	9.90	10
3 × ¼	166	3.15	5.23	5
	1,328			$ 38
		Columns and Splices		
10 WF 33	11,968	$0.65	$ 77.79	$ 78
10 WF 45	10,832	0.55	59.58	60
10 WF 49	11,888	0.50	59.40	59
Splice plates	736	2.70	19.87	20
	35,424			$217
		Floors 1 to 4		
8 WF 17	2,960	$1.55	$ 45.88	$ 46
12 WF 27	8,568	0.85	72.83	73
12 WF 27	17,820	0.70	124.74	125
14 WF 30	9,520	0.80	76.16	76
14 WF 30	12,320	0.65	80.08	80
14 WF 34	21,352	0.80	170.81	171
14 WF 34	2,744	0.65	17.83	18
16 WF 36	8,448	0.80	67.58	68
Connections	5,464	0.80	43.71	44
	89,196			$701
		Roof		
10 WF 21	1,666	$1.00	$ 16.66	$ 17
10 WF 21	8,701	0.85	73.96	74
12 WF 27	6,894	0.85	58.59	59
12 WF 27	1,089	0.70	7.62	8
14 WF 34	1,349	1.05	14.16	14
14 WF 34	686	0.90	6.17	6
Connections	1,324	0.80	10.59	11
	21,709			$189

Office Building Page 6

Mill Extra Charges

Material	Wt, lb	Cost of extras
Base plates	1,328	$ 38
Columns and Splices	35,424	217
Floors 1 to 4	89,196	701
Roof	21,709	189
	147,657	$1,145

Summary of Cost of All Materials

Material base cost	147,657 lb @ $5.50 cwt	$ 8,121
Mill extras (see above)		1,145
Rods	130 lb @ $8 cwt	10
Nuts	7 lb @ $30 cwt	2
Rivets	1,985 lb @ $14 cwt	278
Bolts	480 lb @ $25 cwt	120
Material totals	150,259 lb	$ 9,676
Freight to shop	75 tons @ $10	750
Paint	40 gal @ $ 6	240
Total for material and freight		$10,666

Office Building Page 7

Fabrication

32 anchor bolts @ $0.40	$ 13
32 base and setting plates @ $1.50	48
17.7 tons of columns @ $40	708
14.6 tons of beams punched @ $15	219
40.9 tons of beams framed @ $28	1,145
	$2,133
75 tons of painting @ $4	300
75 tons of loading @ $4	300
Taxes, etc.	200
Total fabricating cost	$2,933
100% overhead and insurance	2,933
	$5,866
75 tons of drawings (including supplies and prints) @ $30	$2,250
75 tons of freight (variable as to destination) @ $15	$1,125

Summary

Material	$10,666
Fabrication	5,866
Drawings	2,250
Freight	1,125
Total, f.o.b. cars at destination	$19,907

Office Building Page 8

Erection Estimate

Erection expense	*Labor cost*	*Erection misc. expenses*
Yard loading and unloading equipment		$100
Railroad freight or trucking of tools, compressor, etc.		100
Railroad freight or trucking of derrick, hoist, cranes		300
Supplies, gasoline, oil, oxygen, acetylene, wiring		40
Petty cash		...
Foremen's expense		...
Board and transportation of men		...
Rental of equipment		...
Erection labor		
Superintendent civil engineer timekeeper	$ 550	
Setting, removing plant	100	
Derrick moves	.....	
Crane moves	100	
Setting grillage or bases	50	
Unloading steel	150	
Sorting and setting	750	
Plumbing and fitting	200	
Planking	150	
Bolting 600 bolts @ $0.25	150	
Riveting 1,750 rivets @ $1	1,750	
Wages while traveling	.....	
Taxes	100	
	$4,050	$540
Insurance 25%	1,013	135
Overhead 50%	2,025	270
	$7,088	$945

Total erection cost

Erection labor	$7,088
Misc. expense	945
Field painting	400
Unloading and hauling	250
	$8,683

Office Building Page 9

Summary of Structure Erected in Place

Shop.............	$19,907
Erection..........	8,683
Total	$28,590
Profit 6%	1,715
Bid	$30,305

Description of Work

Office building, 4 floors and roof approximately 45′ × 63′ by 54′ high
Total No. pieces: 277
Wt heaviest piece: 1,600 lb
Longest piece: 30′-4″
Average wt pieces: 500 lb
Field rivets per ton: 23
Field bolts per ton: 8

Highway Bridge Page 1

Stringers

No.	Material	Length	Wt, lb/ft	Total wt, lb	Note
2	33 WF 130	68′-9″	.....	17,875	Camber
6	36 WF 150	68′-9″	.....	61,875	Camber
2	14 × 1	45′-0″	47.6	4,284	
6	14 × 1¼	45′-0″	59.5	16,065	

Diaphragms

42	18 channels, 42.7	6′-9″	.....	12,105	

Connection Angles

12	7 × 4 × ⅜	2′-6″	13.6	408	
72	7 × 4 × ⅜	2′-4″	13.6	2,284	
372	⅞ shop rivets		.....	372	
672	⅞ HSB and washers		.....	1,075	HSB = high-strength bolts

Bearings

8	8 × 1¾	1′-1″	47.6	413	Fixed bearing
8	10 × 3	1′-1″	102.0	884	Fixed bearing
8	8 × 2	1′-1″	54.4	472	Expansion bearing
8	10 × 3	1′-1″	102.0	884	Expansion bearing
8	8 × 5⁄16	1′-1″		(78)	Bronze

Swedge Bolts

32	1″ ϕ	1′-4″	2.7	115	
32	1″ nuts	.....	0.35 each	11	
				119,122	

Highway Bridge Page 2

Subsummary of Cost of Material Extras

Material	Wt, lb	Extra cost for section	Extra cost for length	Extra cost for camber	Extra cost for quantity (wt)	Total extra cost for item
33 WF 130	17,875	\$0.40	\$0.20	\$0.60	None	\$1.20
36 WF 150	61,875	0.40	0.20	0.60	None	1.20
18 WF 42.7	12,105	0.60	0.50	....	None	1.10
7 × 4 × 3/8	2,692	\$0.55	\$0.10	....	\$0.25	\$0.90
14 × 1	4,284	1.05	None	\$0.20	0.20	1.45
14 × 1¼	16,065	1.05	None	0.20	None	1.25
8 × 1¾	413	1.85	0.50		1.50	3.85
8 × 2	472	1.85	0.50		1.50	3.85
10 × 3	1,768	1.85	0.50		1.00	3.35
	117,549					

Extension of Costs of Extras

Item	Extras per cwt	Wt, lb	Rounded-out cost
33 WF 130	\$1.20	17,875	\$ 215
36 WF 150	1.20	61,875	743
18 WF 42.7	1.10	12,105	133
7 × 4 × 3/8	0.90	2,692	24
14 × 1	1.45	4,284	62
14 × 1¼	1.25	16,065	201
8 × 1¾	3.85	413	16
8 × 2	3.85	472	18
10 × 3	3.35	1,768	59
		117,549	\$1,471

Highway Bridge Page 3

Summary of Cost of All Materials

Material base cost (shapes and plates)	117,549 lb @ $5.50 cwt	$6,465
Extras from page 2		1,471
Rods (anchor bolt)	115 lb @ $8 cwt	9
Nuts	11 lb @ $30 cwt	3
Rivets	372 lb @ $14 cwt	52
HSB and washers	1,075 lb @ $65 cwt	699
Total for steel	119,122 lb	$8,699
Freight to shop	60 tons @ $10 per ton	$ 600
Extra freight length	@ $5 per ton	300
Paint	35 gal @ $6	210
Bronze	78 lb @ $2 per lb	156
Total for all materials		$9,965

Highway Bridge Page 4

Fabrication

32 swage bolts @ $0.40	$ 13
8 expansion bearings @ $25	200
8 fixed bearings @ $20	160
50 tons of bridge stringers with cover plates on bottom flanges, welded, @ $70	3,500
7.4 tons of channel diaphragms @ $22	163
	$4,036
60 tons of painting @ $3.50	$ 210
60 tons of loading and blocking @ $6	360
Taxes, etc.	200
Total fabricating cost	$4,806
100% overhead and insurance	4,806
Total for fabrication	$9,612
60 tons of drawings (including supplies and prints) @ $20	$1,200
60 tons of freight (variable as to destination) @ $20	1,200

Summary

Material	$ 9,965
Fabrication	9,612
Drawings	1,200
Freight	1,200
Total, f.o.b. cars at destination	$21,977

Highway Bridge Page 5

Erection Estimate

Erection expense	*Labor cost*	*Erection expense*
Yard loading and unloading equipment		$ 100
Railroad freight or trucking of tools, compressor, etc.		100
Railroad freight or trucking of derrick, hoist, cranes		500
Supplies, gasoline, oil, oxygen, acetylene, wiring		30
Petty cash		10
Board and transportation of men		150
Rental of equipment		...
Foremen's expense		50
Erection labor		
Foremen, civil engineer, timekeeper	$ 550	
Setting, removing plant	100	
Derrick moves	...	
Crane moves	50	
Setting grillage or bases	35	
Unloading steel, $2 a ton	120	
Sorting and setting, $6 a ton	360	
Plumbing and fitting	50	
Planking	...	
Bolting 672 bolts @ $0.50	336	
Rivets	...	
Wages while traveling	...	
Taxes	200	
Total	$1,801	$ 940
Insurance 25%	450	235
Overhead 50%	900	470
	$3,151	$1,645

Total erection cost

Erection labor	$3,151
Erection expense	1,645
Field paint	500
Unloading and hauling from cars	480
	$5,776

Highway Bridge Page 6

Summary of Structure Erected in Place

Shop	$21,977
Erection	5,776
Total	$27,753
Profit 6%	1,665
Bid	$29,418

Description of Work

Highway grade separation structure, 67′-3″ center to center of bearings
Tons: 60
Pieces: 66
Longest piece: 68′-9″
Heaviest piece: 13,000 lb
High-strength bolts per ton: 11

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