Fireproof Construction

A TECHNICAL SERIES ON BUILDING CONSTRUCTION

WALTER C. VOSS, *Editor*

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This series is dedicated to Ross Francis Tucker, whose interest in young men and construction left an indelible mark on the personnel of the industry.

PREFACE

In preparing the material for this book, the author has been fully cognizant of the many variations in method and details which can and have been used in the construction of fire-resisting buildings. Any attempt to catalog all of the presently used materials and methods not to mention any proposed current innovations would be cumbersome and perhaps repetitive. The objective sought has been to call attention to an accepted fundamental practice in each of the various matters discussed to supply a basis for extended discussion and innovations which do not violate basic practices.

The building industry is richly supplied with trade literature in the form of catalogs and industry magazines. This matter is an invaluable source of information on materials, equipment, service devices, and contemporary practice. A generous use of this information may well extend the usefulness of the book.

There will be readers who may wish to question some of the ideas given or who may know other methods to accomplish similar ends. The author hopes that they will inform him of such differences of opinion or alternates so he may profit thereby. It is certain that future editions of the book will be more valuable as a result of such reader cooperation.

W. C. V.

Cambridge, Mass.
January, 1948

ACKNOWLEDGMENTS

It is quite obvious that the preparation of a text of this kind dealing with so broad a subject would require the use of material and ideas from many sources. Where direct use of such material has been made, credit is given throughout the book. Many of the illustrations have been reproduced from "Architectural Construction," Volume I, by Voss and Henry (John Wiley and Sons, Inc.) and "Architectural Construction," Volume II, Book Two, by Voss and Varney (John Wiley and Sons, Inc.).

In preparing these illustrations, most of the work was done by Miss Alice Fowler and Mr. Leonard Goguen. Mr. Albert J. O'Neill rendered invaluable service in gathering much of the illustrative source material.

Miss Mary O'Donnell and Mr. Raymond Boyd worked patiently in the preparation of the typescript through its many revisions.

CONTENTS

CHAPTER 1

INTRODUCTION

1–1. Classification of Types

a. Several authorities classify buildings into groups based upon types of construction. The most important of these groups are the National Board of Fire Underwriters, the American Iron and Steel Institute and the Bureau of Standards. These authorities base their classification upon fire resistance as the major factor. There are other factors which control construction types but the essential differences are disclosed by the definitions given by these sources. In the past buildings were subdivided into three groups, named First Class, Second Class and Third Class. This classification has been discarded as not sufficiently descriptive and as lacking clarifying definition.

b. It will be interesting to compare these varying approaches, which illustrates their relative concurrence and as stated by the American Iron and Steel Institute:*

"It is questionable whether more than two, or possibly three, types of fire resistive construction need be recognized in a building code. If more types of fire resistive construction are established they serve no useful purpose in the code unless correspondingly fine differentiation is made in the scope of use permitted for each of the various types. Such procedure tends toward complications in the administration of the code, and narrows or reduces the range of scope within each of the several sub-types qualified for use; this in turn may adversely affect the rentability of such structures."

The two classifications which are here grouped as First Class and which are covered by this book are defined by the National Board of Fire Underwriters and the American Iron and Steel Institute as given under *c* and *d* below. It must be remembered that in reality there is no fireproof building and the best one may expect is a reasonable measure of fire resistance.

c. National Board of Fire Underwriters. Fireproof construction is construction in which the structural members are of approved noncombustible construction having the necessary strength and stability and having fire-resistance ratings of not less than four hours for exterior nonbearing walls, for wall panels, for columns, and for wall-supporting girders and trusses; and not less than three hours for floors, for roofs, for floor- and roof-supporting beams, girders, and trusses; and in which exterior

* Building Code Modernization—1946.

bearing walls and interior bearing walls, if any, are of approved masonry or of reinforced concrete.

d. Semi-fireproof construction is construction in which the structural members are of approved noncombustible construction having the necessary strength and stability and having fire-resistance ratings of not less than four hours for exterior non-bearing

Old Classification	National Board of Fire Underwriters	American Iron and Steel Institute	Bureau of Standards
First Class	Fireproof Construction Semi-Fireproof Construction	I Fireproof Construction II Fire Resistive Construction	I Fireproof Construction II Incombustible Construction
Second Class	Heavy Timber Construction Ordinary Construction Light Non-Combustible Construction Unprotected Metal Construction	III Heavy Timber Construction IV Non-Combustible Construction V Ordinary Construction	III Exterior Protected (Ordinary) Construction
Third Class	Frame Construction	VI Wood Frame Construction	IV Wood Construction

walls and for wall panels; not less than three hours for columns, and for wall-supporting girders and trusses; not less than two hours for floors, for roofs, and for floor- and roof-supporting beams, girders and trusses; and in which exterior bearing walls and interior bearing walls, if any, are of approved masonry or reinforced concrete.

e. American Iron and Steel Institute. Fireproof and fire-resistive construction shall be that in which exterior walls are of masonry or reinforced concrete, or of other approved materials or combinations of materials that provide fire resistance not less than required by Table 1-1 and in which all the structural members are of noncombustible materials.

1-2. Fire Tests and Resistance Ratings

a. Most of these definitions are based upon hourly fire-resistance ratings. These are defined as the time in hours that the materials or construction will withstand the standard fire exposure as determined by a fire test in conformity with the "Standard Methods of Fire Tests of Building Construction and Materials." The exact conditions under which construction and materials are tested and the hourly ratings which have been established are given in Appendices A and B of the 1943 Edition of the Building Code recommended by the National Board of Fire Underwriters.

1-3. Scope

a. The text of this book will be confined to a study of the sequence of erection, the proper handling of materials, variations in details to

TABLE 1–1*

FIRE PROTECTION REQUIREMENTS

Reduced Hours of Fire Resistance

Description	Type I Fireproof	Type II Fire Resistive	Type III Heavy Timber	Type IV Non-Combustible	Type V Ordinary	Type VI Wood Frame
Structural Members	Non-Combustible	Non-Combustible	Wood	Non-Combustible	Wood	Wood
Walls —Party Walls....	4 hrs.	4 hrs.	4 hrs.	4 hrs.	4 hrs.	4 hrs.
Exterior Bearing	4	3	4	Non-comb.	3	No Req.
" Non-Bearing	3	2	3	Non-comb.	2	No Req.
Inner Court....	3	2	3	Non-comb.	2	No Req.
Penthouse......				Non-comb.		No Req.
Fire Walls......	4	3	4	2	4	4
Partitions —Interior Bearing	4	3	3	Non-comb.		
" Non-Bearing						
Columns—Supporting masonry or bearing walls.......	4	3	2	2	2	1
Supporting roofs only...........	3	2	8″ x 8″ or 1 hr.	Non-comb.		No Req.
Other columns..	4	2	8″ x 8″ or 1 hr.	Non-comb.		No Req.
Trusses —Supporting masonry or bearing walls, columns, girders, trusses......	4	3	2	2	2	1
Supporting roofs only..........	2	1½	4″ x 4″ or 1 hr.	Non-comb.		No Req.
Other trusses..	2½	2	6″ x 6″ or 1 hr.	Non-comb.		No Req.
Girders —Supporting masonry or bearing walls, columns, girders, trusses.......	4	3	2	2	2	1
Supporting roofs only........	2	1	6″ x 8″ or 1 hr.	Non-comb.		No Req.
Other girders...	2½	1½	6″ x 10″ or 1 hr.	Non-comb.		No Req.
Beams —Supporting masonry or bearing walls, columns, girders, trusses.........	4	3	2	2	2	1
Supporting roofs only...........	1½	1	6″ x 6″ or 1 hr.	Non-comb.		No Req.
Other beams....	2½	1½	6″ x 8″ or 1 hr.	Non-comb.		No Req.
Floors —Deck construction...........	2½	1½		Non-comb.		No Req.
Roofs —Deck construction	1½	1		Non-comb.		No Req.
High above floor				Non-comb.		No Req.

* Adapted from Table 201—"Fire Protection through Modern Building Codes,"—Copyright 1945—American Iron and Steel Institute.

accomplish certain ends and the equipment and organization of the job insofar as it relates to the coordination of the various trades for First Class buildings which we have entitled "Fireproof Construction." The reader should make many references to existing literature, as no attempt will be made to include many of the alternate methods which have been and are used under conditions similar to those described.

CHAPTER 2

PRELIMINARY AND INCIDENTAL WORK

2–1. Inspection of Site

a. The contractor should always inspect the site upon which he has contracted to erect a building. Upon the thoroughness with which he conducts his survey will depend the ease with which he is later able to conduct his foundation work, and it often eliminates costly repairs for damage to adjacent streets and structures. Among the most general information he would seek would be:

(1) subsoil conditions,
(2) services available,
(3) condition and structure of adjacent buildings, and
(4) legal restrictions upon the occupancy of public ways.

b. Under subsoil conditions, the contractor would ask for or make borings so he may better understand his problems during excavation and foundation construction. He would want to know the elevation of the ground water table and whether he must deal with ledge. He should also consult the city building department to acquaint himself with any subsoil surveys which exist. If these are not available, he should try to find out from contractors who have built in the area, if indeed he has not himself, what difficulties they encountered.

c. The services which usually exist in all public ways should be thoroughly checked with the city authorities and with the public service companies. This will give him pertinent information which will aid him in protecting the services while shoring and excavating as well as inform him of the type of power available for use with his equipment. He should inquire as to what steps he must take and what expenses will be involved in making the connection to power sources so that the type of service he requires may be available.

d. In many cases the lot upon which he is to build will be adjoined by older buildings. In some cases he may have to go below the foundations of these buildings. A thorough inspection should be made of such structures so he may make his plans for their protection and support.

e. A careful survey of building code requirements, particularly with respect to excavation, shoring, sidewalk occupation, bridges and the like

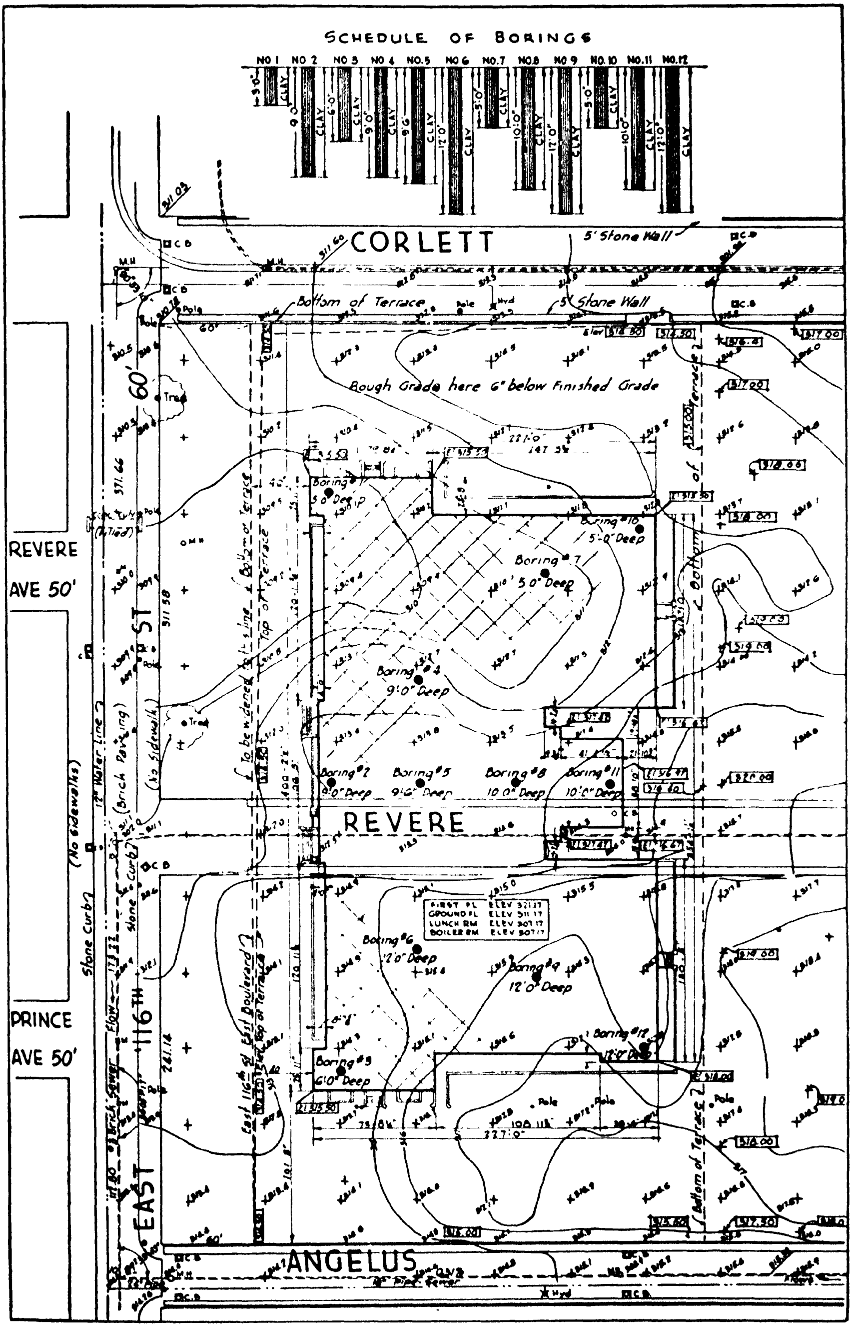


FIG. 2-1. Typical Plot Plan.

should always be made. The contractor should consult the police department as to the limitations which it may place upon him during construction, such as time that deliveries may be made, how much of the street may be occupied and for what interval of time, whether and under what conditions sidewalk bridges may be constructed and maintained, and whether police protection will be required by law at any particular times.

f. Much of the above information, particularly as it relates to the actual building will be found on the architect's plot plan, one of which is illustrated in Figure 2–1. This plan should be checked by the contractor against existing records in the building, street, sewer and water departments of the city. In short, any time and thought expended by a thorough examination of the site and the conditions which surround its use will help to avoid costly mistakes.

2–2. Protecting Site and Building

a. The protection of the site, which would indicate the adjacent sidewalks and streets and the adjacent buildings or structures, would only be undertaken after the contractor has been given the job. In addition to the information which he may have obtained in his original inspection before submitting his bid, it is always desirable to get photographs, properly notarized, of the exterior and interior condition of these buildings before he has done any work which could be construed as affecting the stability of such buildings. Such precautions may prove to be of no use, but should they be required it would be unfortunate if they were not available. The request for entrance made of the adjacent owner has the effect of inspiring confidence that protection will be afforded and is also a wise precaution as it will clearly indicate the original conditions of the walls and in what direction they are moving, if they move at all. Photographs of the condition of such walls, from time to time, properly notarized, are a wise additional precaution.

b. Any land owner, which includes the property of the city, such as sidewalks and streets, has the right to claim support and protection of his land or property in the condition which the contractor found it when he started his work on the new building. This right exists in every state of the union, as a common law protection. However, the right of lateral support pertains only to the land and does not preclude the protection of buildings which have imposed greater loads upon such land. Nevertheless, the fact that a building has increased the pressure on the soil is not always a safe defense when it can be proved that such a building has not contributed to any failure or injury.

c. It is the accepted responsibility of the contractor, and the owner for whom he builds, to excavate in a safe and skilful manner. The exact method by which he does this is not the concern of the adjoining owner. The main objective is to prevent the soil from sliding or falling out from beneath the existing building. It is always desirable for the contractor or his owner to notify the adjoining owner of his desire to excavate and the common law of "sic utere tuo ut alienum non laedus" will apply. This means that the excavating owner plans to use his property so as not to injure others. When the new excavation goes below the foundations of the existing building notice is usually required and it is wise to keep accurate records of the serving of such notice. In no case should the excavator promise to furnish protection unless he expects to be held liable for damage due to his actions.

d. The contractor should provide and maintain all legal or necessary guards, railings, lights, warning signs and watchmen during the execution of the work to protect fully all persons from loss, damage or injury occurring through the neglect, carelessness or incompetence of himself or his employes, or the condition of handling of his appliances. Temporary fences must be provided.

e. All excavations and the basement should be kept free of all water appearing from any cause during any stage of the work, until the building is completed. All excavations should be free from water before any concreting or other work is done in them. Ditches or pipe drains to keep water from flowing into abutting property should be provided.

f. The question of damage to streets, sidewalks, lawns and the building often results in many controversies. The contractor should be careful to read the specifications carefully in order to know what is expected of him. They usually require that the contractor should be held responsible for any damage caused by him or his workmen to the streets and sidewalks during the construction of the new building, and that he make good any such damage without cost to the owner.

2–3. Protecting Adjoining Buildings

a. In order to protect the adjoining buildings the new building owner for whom the excavating is being done should acquire permission for entry of adjacent premises through his contractor by agreement or contract. This is especially required when the new building goes below existing foundations, and where the contractor wishes to enter the existing buildings to arrange for their proper support. Such agreements should be carefully prepared to obviate any future trouble and to protect fully the new owner against unreasonable suits for damages. The adjoining owner is obligated to assist in the protection of his building, and if he neglects to take proper precautions after notice is given, the excavating owner is not liable unless it can be proved that the contractor was careless or negligent. If the adjoining owner refuses cooperation the contractor may go in and protect the old building at its owner's expense, but he is no longer bound by law to afford such protection. In some cities, a license or permit is required to allow the excavating owner to enter the adjoining building. When such permission has been granted, however, the excavating owner is thereafter liable for any damage resulting from the work. The only variation from this general concept occurs when the adjoining owner reserves the right of supervision on such work. In such a case he would be jointly liable. It is therefore quite expedient to consult the local laws pertaining to these matters and to be acquainted thoroughly with the legal implications.

2-4. Protecting New Buildings

a. The contractor should cover and protect all portions of the building when the work is not in progress and he should be responsible for damage from any cause. He should provide and set all temporary roofs. He should provide covers for doorways, sash for windows where required, boxing and cover planks, and any other materials necessary to protect all the work on the building whether set by him or any of his subcontractors. Any work damaged through lack of proper protection or from any other cause must be repaired or replaced without cost to the owner.

b. As soon as the main roof is on, the contractor should enclose the building, using cheese cloth on light wood frames to close all exterior windows and which can easily be taken down and put up. Under no condition should any wood sash be hung before the plastering is completed and the building dried out. Exterior doors should have temporary enclosures set out 4 feet from the building, so that work can be done on finished doors without removing the enclosure. Doors in the temporary enclosures are usually provided with sash or glass and covered with roofing felt. These enclosures are maintained as long as required and removed when directed by the architect.

c. No fires of any kind should be allowed inside the building at any time during the course of construction without special provision for supervision. A reliable watchman should be supplied both by day and night to keep the work free from trespassers from the beginning of the work until its acceptance and to care for all equipment necessary during the night. He should be a dependable, sober, able-bodied man, who shall be continuously attendant upon the building and premises at all times when workmen are not engaged in or about the building and he shall be in attendance until his services are no longer required because of substantial completion of the building.

d. Should freezing weather set in before the building is roofed over and enclosed, all work subject to injury should be stopped until seasonable weather returns or unless the building is properly closed in and heated to allow work without damage. The contractor should follow specifications for winter work very carefully to be sure that he will not be held liable for poor results if winter work is allowed by the specifications. Freezing will seriously affect concrete work, masons work, plastering, and other trades employing mortars. Snow should always be removed from the floors and roof of the building. Snow and water seriously affect roofing work and it is wise to be assured that winter conditions will not interfere with such work, either by delaying it or by particular precautions in the line of protective coverings.

e. Temporary stairways from the ground floor to the roof, erected from floor to floor, should be built as soon as practicable. These are usually kept in place until ordered removed by the architect, or when the permanent stairs are erected. In the building with steel stairs, the rough stairs are erected with the frame and serve as temporary stairs. These temporary stairways should not be less than 4 feet wide, capable of sustaining a load of 80 pounds per square foot and constructed of sound lumber with not less than 2 x 12 carriages, treads not less than 2″ thick; they may have open risers, and should have a rail on each side made of 2 x 4 lumber. The rise should not be more than 8″ and the treads not less than 10″.

f. The contractor or his subcontractors must, at his own expense, obtain all necessary permits, give all necessary notices, pay all legal fees and comply with all municipal laws, ordinances or regulations, also all state, building and sanitary laws relating to building and the preservation of the public health.

g. The contractor should do all bracing and shoring that may be necessary to insure the safety of the building, or to protect it from damage. He should temporarily brace all brickwork which is incorporated into high, unsupported walls, until the mortar has hardened sufficiently to insure lateral stability.

h. The contractor is held responsible for any loss or damage caused by him or his workmen to the property of the owner or to the work or material of the other contractors, and must make good any such loss, damage or injury without cost to the owner. In no case should lawns or gardens be used for storage or for the preparation of materials of any kind, nor should any carting be done over them. When the work is finished, the contractor should put the grounds in as good a condition as they were just before he started to use them. The contractor should never load nor permit any part of the structure to be loaded with a weight that will endanger its safety. This is a very important matter and should be watched carefully.

2–5. Removal of Old Structures

a. The removal of old buildings in the congested portions of large cities, and even elsewhere, is usually carried on by firms who are specialists as wreckers rather than building contractors. It is customary and quite necessary to provide a substantial bridge over the sidewalk of any public way during wrecking, and the materials, such as plaster, debris, old wood, brick and other parts that may be so handled, are forwarded to the street by means of a chute fitted with a weighted gate and placed high enough above the street to permit of direct loading into trucks for dumping. The building regulations of large cities impose definite restrictions upon the wrecking operation. The timber, structural steel, frames and sash, flooring, trim, piping and any portions of discarded equipment are carefully dismantled and lowered by derricks to trucks. These parts, if representative of any appreciable salvage value, are usually considered as part payment for the work of demolition and often defray a substantial portion of the cost. The salvage value of usual demolition is, however, less than the cost of the process, although it is always appraised in competitive bidding.

b. Where party walls separate the old building from an adjoining one on one or more sides, it is important to see that no damage is done to the neighboring structure by careless cutting or tearing out. These walls are held under joint ownership and each owner is responsible for their strength. If a tall building is going up in place of the one removed, it is usually impracticable and unsafe to bear upon this old wall. In this case the frame of the new building is entirely independent and is cut into chases in the old wall, but in no case should the new work encroach upon the adjoining property, and the line should be carefully observed. Figure 2–2 illustrates a plan through a party wall with a steel column and a concrete column in position. When these chases are cut, the beams which frame into the columns must also be let into horizontal chases as shown. It is always wise to allow a clearance under these beams so that any future settlement of the building will not cause any load on the old wall. This process eliminates the old wall as a means for supporting new work, but it serves the purpose of fireproofing and may often be used as a base for plastering. In order to remove an old party wall entirely, both owners must agree to the removal and the rebuilding. Most party walls are at at least 12″ thick, but more commonly 16″, as such a wall provides a space of 8″ between the ends of the old wood joists on each side, as shown. A minimum of 6″, if joists are staggered, will afford this protection. Where funds allow, and space as well, the wisest procedure is the building of independent walls, the vertical plane of the party line being scrupulously observed as the delimitation of all portions of the structure.

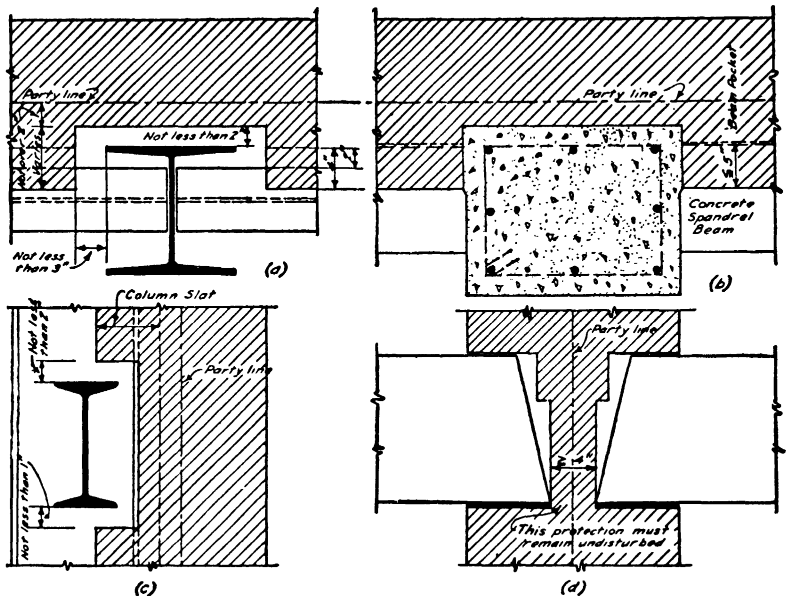


FIG. 2–2. Frames on Party Lines. (a) steel column; (b) reinforced concrete column; (c) steel spandrel beam; (d) wood joist position.

2–6. Shoring and Needling

a. In the construction of new buildings adjoining existing buildings, where it is found essential to carry the new footings below those of the existing structures, it is obviously necessary to support each old structure temporarily until provision may be made for its permanent stability. The owner of the new building should assume the responsibility for the safety of the old one and should include in his contract with his builder such clauses as will insure the adjoining structures against damage of any sort.

b. The most common methods used for such temporary support are shown diagrammatically in Figure 2–3. Shores are heavy timbers embedded in the walls of the building to be supported, and slope to a distributing crib or mud sill. In this way they provide the two components of the forces acting which tend to produce settlement and outward lateral movement. The minimum angle for such shores is usually

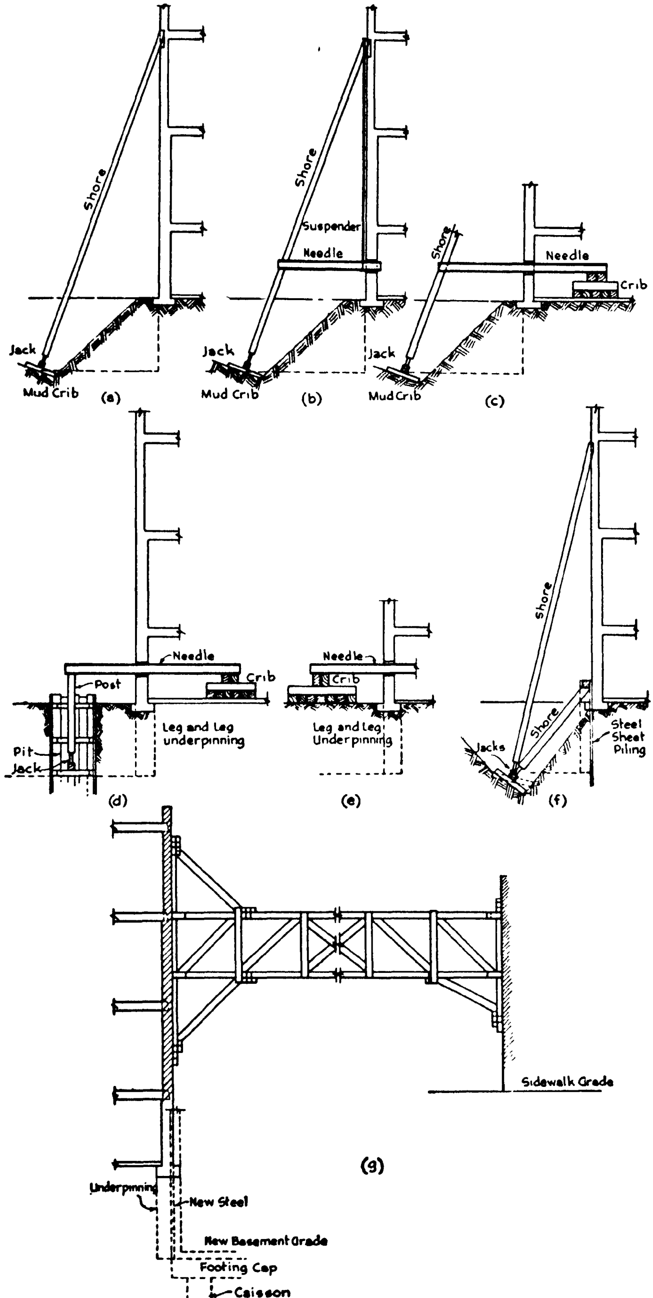


FIG. 2-3. Schemes for Shoring, Needling and Underpinning. (a) simple shore; (b) figure 4 shore; (c) shore, needles and interior crib; (d) post, crib and needles; (e) needles and double crib; (f) double shore and sheet piling; (g) cross-lot bracing.

about 70° with the horizontal. Needles are the horizontal beams which are built into openings cut into the existing wall and may be supported by a combination of hangers and cribbing, hangers and shores, or by posts and cribbing directly. When there are existing buildings on both sides of the lot for the new buildings and the width of the lot is not too large—less than 50 feet—cross-lot shoring may be used to provide the lateral components to stabilize both old walls. In this case, support for the vertical loads must be provided in addition. A combination of sheet piling and shores is also used. In this instance the braced sheet piling confines the supporting soil to carry the vertical load, while the shores prevent lateral movement and aid in carrying a part of the wall load.

c. The spacing of the shores is dependent upon the loads encountered, but 8 feet is a very common figure. The spread of the cribbing should be large enough to bring only a proportionately small unit load on the soil, as the problem is one of settlement rather than of actual bearing power. The amount to allow will, of course, depend upon the nature of the soil encountered. These shores are allowed to remain in place until the old footings are dropped to a new level consistent with the new building footings, and the intervening wall replaced, as shown. At least one pair of shores should remain in place while this work is going on and the work should be confined within the limits of the bracing. It is sometimes found desirable to shore the entire party wall at once, before the footings of the old building are completely exposed. This is especially true of old pile footings, the removal of the surrounding earth causing the old buildings to be disturbed very easily by vibrations. The heads of shores should be placed opposite a floor line to prevent rupture of the wall and to provide thrust resistance. The head of the shore should bear uniformly under the masonry of the wall. It is usually wise to provide a steel plate at the head of the shore so that steel wedges can be driven beside it to take up the load. These are sometimes grouted in with cement mortar to provide overall contact. Figure 2–4 shows some typical details at the head and foot of a shore, at the intersection of a needle with a shore and the hanger rods employed in the "figure four" shore.

d. In connection with needling it is very important that the wall impose as uniform a load over the area in contact with the needles as possible. To do this wood fillers are often placed above the beams. This softer material crushes to meet the contour of the face of the wall bearing bed. As for shores, the cribbing, mud sills or posts should be adequate in bearing areas on the soil, as minimum settlement is of paramount importance. The lateral stability of the needles to prevent them from buckling or turning over is important. This can be provided by steel web spacers or wood block separators. Under extreme conditions the needles under

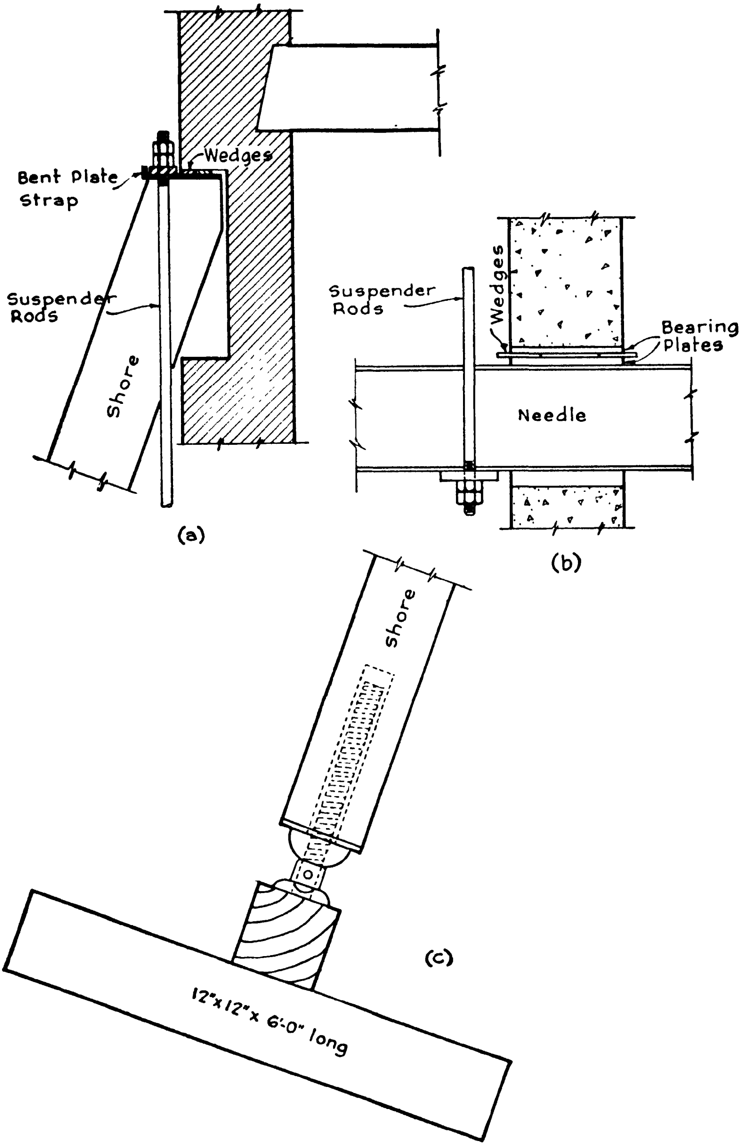


Fig. 2-4. Shore Details. (a) head, showing hanger rods of figure 4 shore; (b) hanger rods and needle; (c) foot of shore.

the wall pocket are sometimes concreted in place. This provides both adequate bearing and protection against buckling and side movement. Some of these details are shown in Figure 2-5.

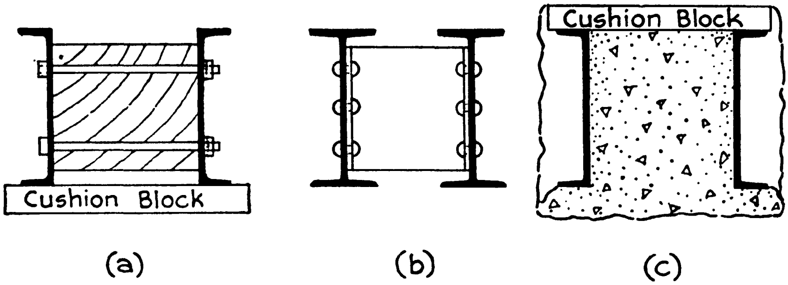


FIG. 2-5. Reinforcing Needles. (a) wood separator; (b) steel plate separator; (c) concrete separator.

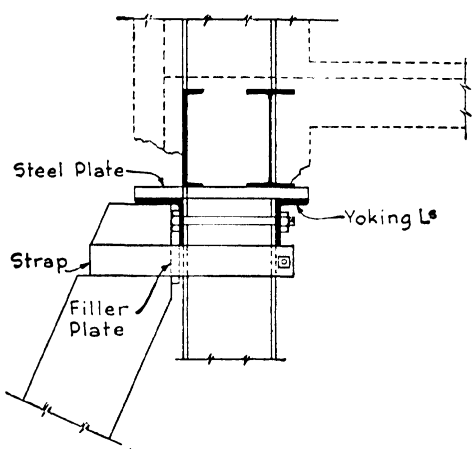


FIG. 2-6. Shore Yoke at Steel Column.

e. When the adjacent building has a full structural frame, either reinforced concrete or structural steel, it is possible to pick up the exterior wall columns on the shores, by yoking the column and the shore rigidly together as shown in Figure 2-6. This simplifies the vertical "pickup," but it is just as important to prevent lateral movement by the use of inclined shores with a horizontal thrust component.

2–7. Underpinning

a. Underpinning is the act of extending existing foundations to a lower level, usually deep enough to carry them to undisturbed soil or supports which will not be affected further by the new work. In the case of exterior bearing walls, one of the very common methods to carry down footings is called the "leg-and-leg" method. This simply means that pits from 4 to 6 feet long and of sufficient width and depth are dug below the existing foundation, and these are spaced so that it will necessitate from three to four successive operations to complete the

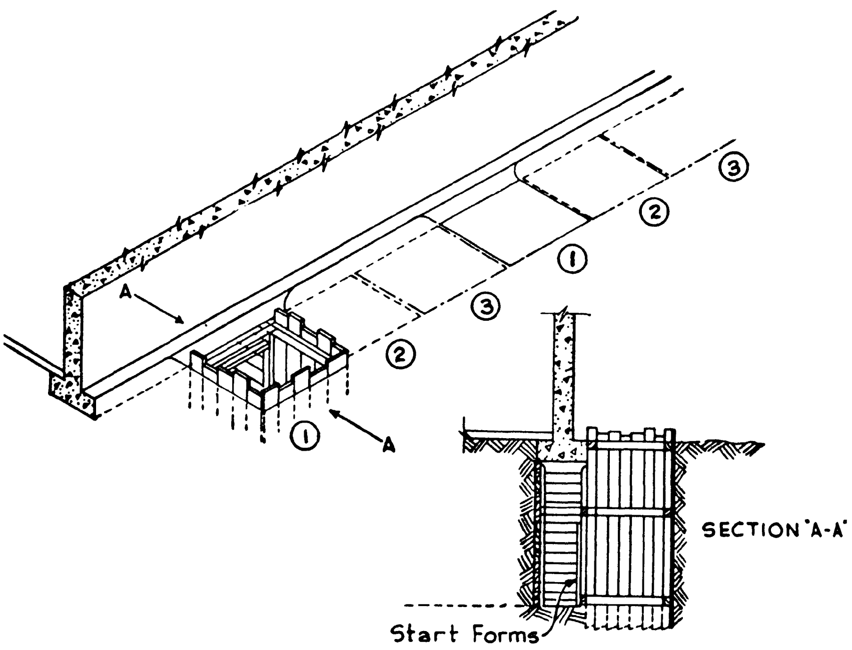


FIG. 2–7. Leg-and-leg Underpinning. Sequence of excavation, forming and casting— ① ② ③

underpinning. This is shown in Figure 2–7. When the fully framed building is underpinned it is necessary to extend the column footings to firm bearing and to provide extensions to the basement walls so that they too will be stabilized.

b. When casting the concrete for leg-and-leg underpinning it is advisable to place the new footing first and then build the forms for the remaining concrete so that when it is cast it will produce a head and the concrete can thus be brought into intimate contact with the old footing, as shown in Figure 2–8. The wall sections should be cast with V-shaped vertical keys to provide lateral alignment. The lip formed at the chute and that portion of the old footing which projects into the new lot can be cut off later.

c. There are occasions when it may be more economical to pick up the loads from an existing building on the footings for the new building.

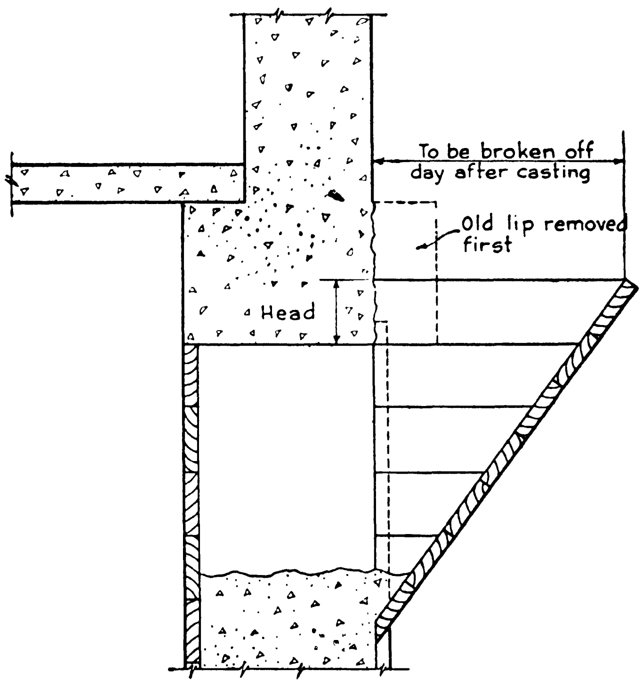


Fig. 2–8. Casting Underpinning with Head.

This is particularly applicable if the old building is not too heavy and where it is expected to use offset exterior wall caissons and combined cantilever beam footings to pick up the wall columns. The old wall can then be caught up by grade beams under the old wall which span between the ends of the cantilever beams, as shown in Figure 2–9. There are many other alternatives for underpinning and these should be studied by the reader as special cases. The important matters in all cases resolve themselves into two major considerations, namely,—safe support with the minimum of disturbance to the old structure and economy.

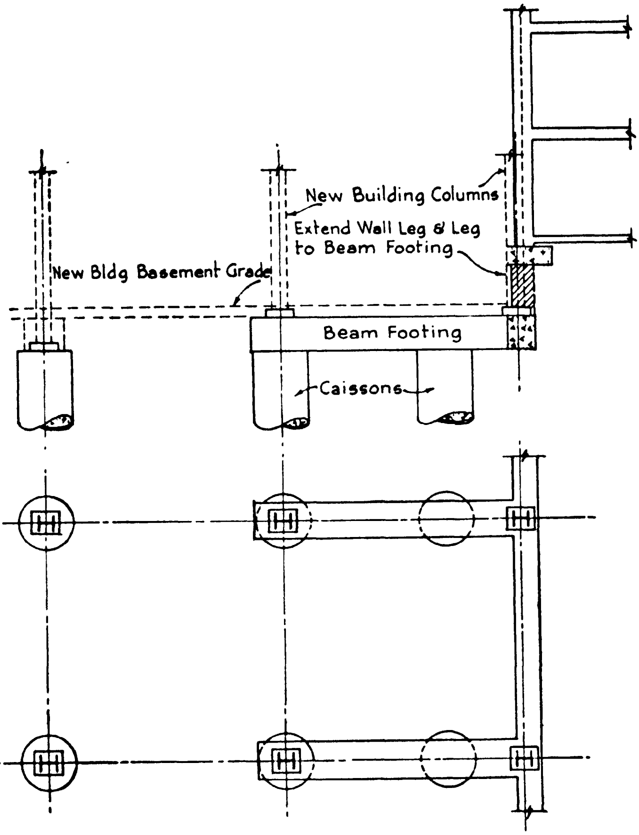


FIG. 2-9. Picking Up Old Wall with Cantilever Beam Footings.

2-8. Sidewalk Bridge

a. During the period of excavation and until the foundations have been built and the frame erected to grade, the site will be surrounded by a tight board fence. Most people are curious and failure to prevent their approach to the excavation constitutes a hazard that the prudent builder will eliminate. Consequently, the fence should be well constructed and high enough so that there will be no temptation for people to congregate to watch the proceedings. As soon as the frame reaches grade, which means the sidewalk grade, it will be necessary to erect a sidewalk bridge on all streets, to protect the public and also to afford a place for the storage of certain materials during the progress of the job. Each job has particular problems of its own. The intention is to protect the public, and the contractor should be equally anxious to prevent injury to either pedestrians or to property.

b. Structures analogous to the bridge are essential adjuncts to building operations in all large cities. In this connection it is interesting to quote from the Chicago Law bearing upon this element.

> 820. *(e) During the progress of building operations, a sidewalk not less than six feet in width shall be at all times kept open in front of such lot or lots. Such sidewalk shall, if there are excavations on either side of same, be protected by substantial railings which shall be built and maintained thereon so long as excavations continue to exist. It is not intended hereby to prohibit the maintenance of a driveway for delivery of material across such sidewalk from the curb line to the building site.*
>
> 821. *It shall be permitted for the purpose of delivering material to the basements of buildings in process of erection to erect elevated temporary sidewalks to a height of not exceeding four feet above the curb level of the street, and in case a sidewalk is so elevated it shall be provided with good, substantial steps or easy inclines on both ends of the same and shall have railings on both sides thereof.*
>
> 822. *When buildings are erected to a height greater than four stories and such buildings are near the street line, there shall be built over the adjoining sidewalk a roof having a framework composed of supports and stringers of three by twelve timbers not more than four feet from center to center, covered by two layers of two inch plank. Such roof and covering shall be maintained as long as material is being used or handled on such street front above the level of the sidewalk. Temporary sidewalks, their railings, approaches and roof over same, shall be made with regard to ease of approach, strength and safety, to the satisfaction of the Commissioner of Buildings.*

c. In general, however, a bridge should be:

(1) safe structurally,
(2) water-tight,
(3) convenient,
(4) well-lighted, and
(5) reasonably attractive.

The structural safety is a matter of design. One must remember that heavy materials are handled on this structure and it must be designed accordingly. Impact is involved. It must be watertight so that rains will not cause damage to pedestrians who too frequently are looking for a damage suit. The bridge must be planked so that slivers, holes, knots, or irregularities will not be a public menace. It must not be constructed to necessitate inconvenient traveling on the part of the public or to make the handling of materials uneconomical. As the bridge is usually in place quite a long while it must be lighted by night. Most builders now construct attractive bridges and the architects now spend considerable time

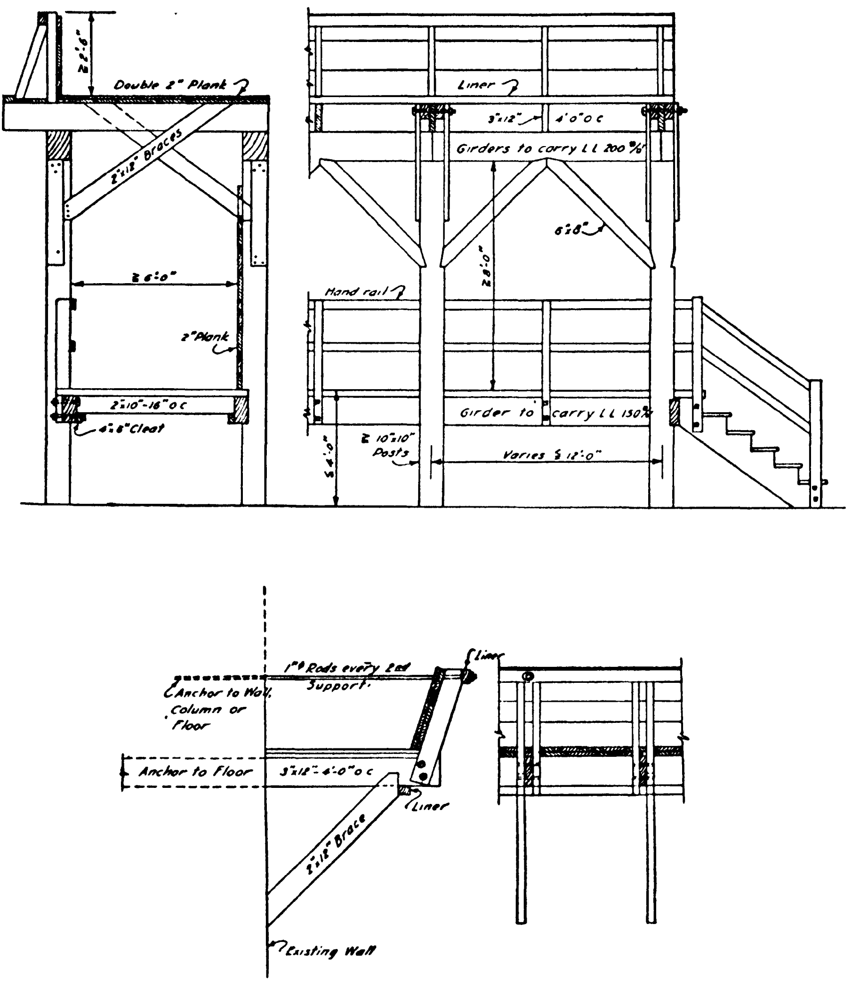


FIG. 2–10. Sidewalk Bridge and Overhead Roof.

making the bridge sightly. Figure 2–10 shows a section through such a bridge, and the protective roof which is usually erected where a building is being increased in height or remodeled above the level of the existing walls.

d. In the City of New York, particularly, and in some other progressive cities, great care is taken in the design of sidewalk bridges that they shall not only perform their temporary functions by providing accommodations and protection for the public but shall also present an agreeable looking exterior. In instances where such temporary structures may be in continuous use for many months the public is entitled to this much amelioration of the chaotic surroundings of usual building operations. Commercial houses are quick in their appreciation of the advertising value lying in orderly and attractive appearances during the, at best, awkward conditions attending building demolition and repair.

e. In considering the erection of a sidewalk bridge certain preliminary considerations are of importance. The first of these is the support which must be afforded the street. To "lose a street" by settlement, due to improper shoring, would be an expensive catastrophe and should be avoided in all instances by careful study. The street has in it sewers, conduits, water lines, gas mains and what not. A settlement will often cause a failure in one or more of these lines and result in no end of trouble, expense and even danger. A study should be made of these lines as they exist and steps should always be taken to protect them against failure. This is ordinarily effected by properly shoring existing curb or vault walls or by sheet piling to restrain soil thrust. The piling may be driven alongside of the curb, if the old curb wall must come out.

f. Another important consideration is the provision for foot traffic during the erection of the bridge. This is usually provided by a plank wall on the street adjacent to the curb, which should be set high enough above the street to allow unimpeded gutter drainage to take place to avoid steps up or down to the walks on either side. The walk should have a railing both on the lot side and the street side and should not be less than 5 feet wide, if that much space can be spared in the width of the street. A permit for such work must be obtained from the city and the contractor should, in addition, cover himself by public liability insurance during its use, and it will be found wise to carry such insurance throughout the life of the job.

g. The construction and design of the bridge is directly dependent upon the means which will be used for material delivery and the location of such storage. In large cities on congested streets the usual practice is to allow for storage of materials under the walk of the bridge and in such an instance the bridge walk is raised high enough above the sidewalk or curb grade to permit of direct delivery from trucks to the site. In some instances a driveway is left directly into the lot, in which case the bridge sidewalk must end with a stairs providing sufficient distance clear of the driveway to avoid danger by trucking to pedestrians. At any rate these conditions must be the subject of study, and a plan for materials delivery should be evolved which will be expeditious and consequently economical.

h. The sidewalk construction should be such as to sustain a live load of 150 pounds per square foot. This is usually excessive, but building codes will control. The planking should run longitudinally, if possible, and the planks should be dressed and of a lumber which will not easily "sliver." This means the use of pine, spruce, or oak, the first being most commonly employed. If the area beneath the walk is to be used to store perishable materials such as lime, cement, plaster, and the like, provision should be made to line the walk with a waterproof building paper or felt and then the wearing surface of the bridge is often ¾″ matched lumber. The sidewalk should be protected by railings at the curb line and the stairs at either end should be substantially constructed and of easy rise and run, with rails.

i. The roof of the bridge is used for the temporary storage, after delivery, of steel, cut stone, lumber, frames, and the like. In this case, the live load used in the design of the roof should be 250 pounds per square foot. The roof covering should always be in two thicknesses of lumber to provide an intermediate layer of waterproof paper or felt. The curb edge of the roof should be provided with a battered parapet to facilitate deliveries and to give as much additional width to the bridge as possible. This wall should be solid and should be lined on the bridge side with planking.

j. The selection of the kind of timber enters directly into the design of the bridge members. The usual material for this work is yellow pine or fir but second grade, or sound, pine is common. Other lumbers may be used, in which case the allowable stresses for various kinds of conditions should be established. Temporary structures of this type should be designed for flexure as the matter of deflection is unimportant. Planking will be found to be excessive under the usual conditions, as wide spacing of beams or joists will result in unwieldy joist sections. In no case should less than 2″ planking be employed regardless of the actual values obtained by design. The common timber sizes should be used.

k. The bridge should be lighted each night so as to emulate the illumination effected by the usual street lights. Too much light cannot be provided, as the brighter the obstruction the less opportunity for accident. Lighting, if well conceived, also adds to the appearance of the bridge and when this is coupled with some care to make the bridge presentable will greatly offset the ugliness which usually surrounds building operations.

l. Generous bracing of beams to posts in both directions is not an unwise precaution and such added lateral stability will often materially decrease the effective joist or beam spans, thereby saving in their size. This bracing is usually double, one on each face of a column, and is made of 2″ plank spiked or bolted to the posts and beams.

m. For access to the site and to the building the fence should be provided with a suitable gate, and the bridge should be constructed so that trucks may enter at the street grade, steps or ramps being provided for the convenience of pedestrians.

n. Just inside of the gate should be the watchman's shanty, and a watchman should be on duty there at all times, and it should be his business not only to know every one who enters, but also to prevent any one entering who has no business on the job. Obviously, it is desirable that there should be a single entrance.

o. It is good job management to keep all visitors off of the job, and when it is desirable to admit them, to require them to sign a waiver against claims for damages, in case they are injured while on the operation. The superintendent should have a supply of such waivers on hand and should insist upon their being signed by any visitors whom he admits to the job.

p. Within recent years a new form of bridge has been developed, wherein pipes of various sizes are used for the supports. In many cities there are firms which supply these on a rental basis, which will include the cost both of erection and removal. They will often save the builder a lot of bother, and are likely to be more economical than timber bridges, and likewise they will be likely to comply with local reguations and building laws.

CHAPTER 3

ROCK EXCAVATION

3–1. General Types of Excavation

a. The materials to be excavated vary considerably from site to site and often within a single site. Generally, they may be classed as:

(1) sand or silt,
(2) clay, or
(3) rock.

Previous to the major operation of excavation, the humous soil, or loam, must be stripped and piled on the site where directed. The handling of sandy and clay soils involves many considerations which do not apply to rock excavation, and it is with rock excavation that we are here concerned.

3–2. Water Removal

a. Perhaps one of the most important matters which a contractor should consider is that of disposing of water in the excavation. The usual specification states:

> *"The Contractor shall do all necessary pumping to keep the excavation and building free of water at all times."*

This involves the expenditure of considerable sums of money in many instances. The contractor should therefore study the site for water-table elevation, springs and other discharges, and also the borings to determine the necessity for pumping and the scope of such work. Where the site is underlain with rock the collection of water upon the ledge may cause considerable accumulations of water and this should be carried off by a series of trenches to a sump pit from which it may be pumped into the city storm-water sewers.

3–3. Geological Aspects

a. The interior rock structure has considerable effect on blasting methods. Thus we classify rocks as

(1) igneous,
(2) sedimentary, and
(3) metamorphic.

The igneous rock may be fine-grained or coarse-grained and contain or be without quartz in its composition. The finer the grain, particularly if it contains quartz, the tougher the rock and the harder it is to excavate. In these rocks we have interlocking crystals which add greatly to its strength and toughness. Diabase is just such a tough rock. Feldspar diabases are tough and have spars with a black mineral filling. The true granites are much harder as they contain a preponderance of quartz. Trap rock is a granite diabase and thus combines the characteristics of both structures. A porphyry is an igneous rock composed of large crystals of one kind or another surrounded by a fine-grained mass. The large particles are called phenocrysts and the filler is called the ground mass. This rock is hard and dense, drills hard, but blasts very well. A shattering blow renders a prophyry ideal for removal. The igneous rocks aid the blaster inasmuch as the internal stresses which exist in them assist in their further cracking.

b. Sedimentary rocks are laid down by the action of water or by wind, as in the case of loess. In either case the mass rests on a base of igneous rock in layers or strata. These beds are held together by a cement composed of calcium carbonate and/or silica. The cement can fill the voids to any degree and the small grains form a ground mass or filler for the cementing action. The strength of these rocks will depend upon the strength of the cementing material. The small-grained interfaces are most common and are the stronger. Sandstones are sedimentary rocks with quartz grains and they are hard on drill bits. Bluestone, another sedimentary rock, has a siliceous cement and is jointed and bedded. For this reason it blasts well. Shales are made from clay or mud deposits and are laminated in their structure. They break in lens-shaped chips with thousands of parallel joints which cause the chips to swell up under the action of water. These characteristics may cause binding during the drilling operation. Shales make a good bearing material but the likelihood of slippage necessitates great care in shoring operations. They also require extra blasting because of their capacity to dissipate energy and because of the care required to prevent slippage. This means a greater number of smaller charges. Limestones are sedimentary rocks laid down either by direct deposition of calcareous sand with lime carbonate cement, or by the chemical action common to limestone dissolution and redeposition. They are usually quite dense, are hard to drill, and when they have clay joints may cause occasional slides.

c. Metamorphic rocks are crystalline rocks reformed from igneous or sedimentary deposits. Among the most common are slates, schists, gneisses and marbles. Slates do not swell like shales but do have the habit of sliding. Schists are rocks with a preponderance of mica in thin layers. They dull drill bits and the bedding often deflects the drill and causes binding. They are jointed and blast well. Injected schists are those into whose voids and joints molten siliceous minerals have flowed. This brings in quartz and feldspar. Thus the drilling of these rocks is about as difficult as drilling in granite. They blast well and the released internal stresses cause them to burst during blasting. Gneiss is formed by the absorption of schists, which results in a fine-grained, streaky granitic structure. The gneisses are irregularly jointed and blast much more readily than true granites. Marbles, which are formed by the reconstitution and crystallization of limestones are relatively soft and tough. They cause a powder cushion during drilling and thereby slow down the operation considerably.

d. Externally, rock blasting may be affected by:

(1) joints, and
(2) faults.

Joints are found in every known rock and may be vertical, horizontal, or irregular and oblique at all angles. Ground water follows these joints easily and in blasting the energy is materially dissipated at such discontinuities. Faults are found at all conceivable angles in almost all rock. These are caused by slides or mass movement and the breaks are exactly matching fissures at the crystal faces. It is commonly true that where one main fault exists there will be others at intervals on either side, roughly parallel. Faults will often be filled with gouge which has the composition of granite gneiss. This material assists in causing drill-hole plugging and slippage.

3-4. Minor Rock Excavation and Leveling

a. Beside creating the necessary space for the basement and for footings the purpose of blasting is to expose firm rock strata and to level any inclined planes or other impediments so as to make direct horizontal bearing possible. In no case would a shattering charge of explosive be used, but, rather a slow-acting, lifting charge. Shattering charges tend to destroy the base or induce treacherous fissures in lower strata. It is important that firm rock be used for founding a structure.

b. Inclined rock strata should be leveled as shown in Figure 3-1 and stepped areas are proportioned to provide proper resistance to sliding. If a fissure or depression is encountered, it should be cleaned out carefully, and then filled to a proper level with plain concrete. If the rock strata dip obliquely, water tends to flow along the layers, so common in inclined rock formations. This water should be carried off by means of one or more permanent drains. This is especially essential if springs or some other form of continuous flow are present. Water, occurring even in small quantities, if it completely envelops the foundation, may develop formidable pressures unless provided with a suitable outlet.

c. When it is probable that rock outcroppings, or extensive surface or subsoil boulders, will be encountered it is customary to specify that the contractor submit a unit price per cubic yard for general blasting and another unit price per cubic yard for trench blasting. In order to afford

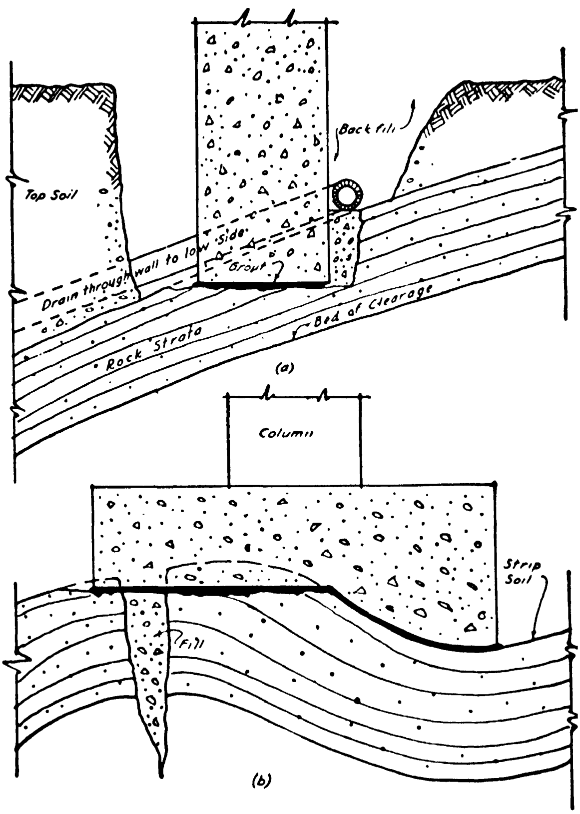
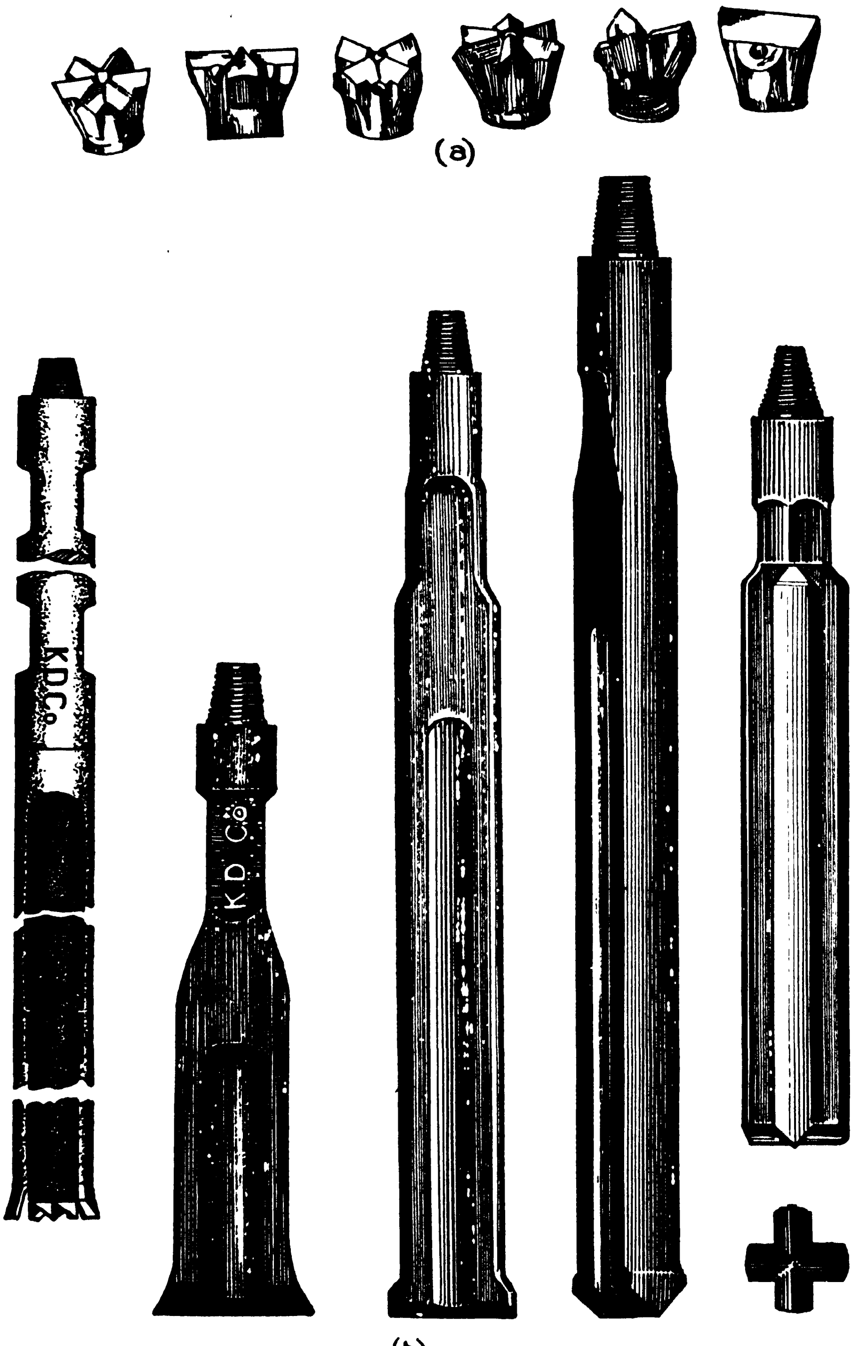


FIG. 3-1. Rock Foundation Beds. (a) inclined stratum and drain; (b) fissures and depressions.

fairness in estimating the amount of such rock excavation, a careful survey of the quantity should be made by the engineer after the loose excavation has been completed and the rock surface exposed. The settlement with the contractor can then be determined by this measurement multiplied by his stipulated unit price per cubic yard.



(b)

FIG. 3-2. Drill Bits. (a) rosettes; (b) well drill points.

3–5. Rock Drilling

a. Rock may be drilled by hand or by machines. When hand drilling is used it is usually done by:

(1) rotary drill or auger,
(2) hammer drill, or
(3) churn drill.

The rotary drill or auger is used only in soft material such as peat, shale or coal. The hammer and churn drills are used in limestone, trap, sandstone and granite. Hammer drills are made of steel rods from ¾″ to 1½″ in diameter, with specially formed cutting points which are from ⅜″ to ½″ larger than the rod, to prevent binding during the drilling operations. The type of point depends upon the type of drilling to be done. The chisel bit is very commonly used, but star- and rose-shaped bits are especially well adapted for drilling into brickwork and concrete. Some of these bits are shown in Figure 3–2. Hammer drills up to ⅞″ in diameter can be operated by one man. For larger sizes, one man holds and turns the drill while two or more strikers do the striking. When one man does the drilling he usually uses a hammer weighing from 4 to 5 pounds. When a crew of three or more men is used the sledges weigh 8 to 10 pounds. One-man drilling is usually confined to shallow holes, usually not over 3 feet deep, or where drilling must be done in constricted areas. Many light blows in quick succession are much more effective than heavy, intermittent blows in either one-man or crew drilling. Pouring water into the drill hole holds the powdered rock in suspension as a sludge and aids in drilling. The hole is cleaned from time to time by using a spoon rod to remove the paste. Where compressed air is available the holes may be blown out.

b. Churn drilling is done by raising and dropping a drill rod of considerable weight in a hole already well started in some other way. The impact of these drops, together with the twists involved, fractures and pulverizes the rock. Many details for constructing the shank of the churn drill and for weighting it to produce sharp impacts are used. One of these is where the pipe or rod shank is welded to the drill bit. When short shanks are desirable, but weight must be provided, an iron ball is welded to the shank. The drill is then called a "ball" drill. Churn drilling is more economical than hammer drilling for cutting vertical holes.

c. It will aid in giving an idea of the difficulty of drilling to review some of the speeds of drilling as established. With the hammer drill cutting a 1½″ hole, with one man holding and two men striking, drilling of a 6 foot hole proceeded at about the following rates:

Granite	8½″	per hour
Trap	13″	per hour
Limestone	19″	per hour

Churn drilling in soft rock such as shale or sandstone, with a hole from 1½″ to 2¾″ in diameter, can be done at the rate of 12″ per hour. As the hardness of the rock increases, the speed is reduced, so that for granite the rate would be reduced to about 8½″ per hour and to about 4¾″ for porphyry. It must always be remembered that the rate of drilling depends upon the diameter of the hole, condition of the hole as regards water and cracks in the rock, the angle at which the hole is driven, the method used, type and condition of the drill used, and the skill in handling the drill.

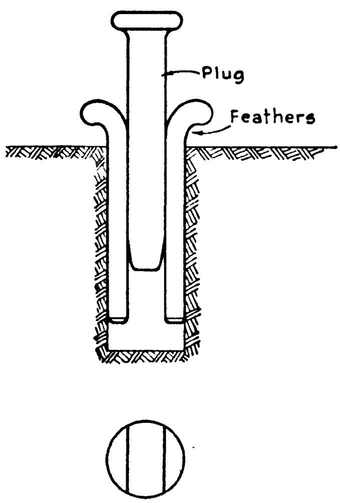


FIG. 3-3. Plug and Feathers.

d. When it is necessary to excavate ledge rock or remove old concrete machine foundations where the use of explosives is impracticable, the use of "plugs and feathers" is advisable. These are shown in Figure 3-3. The feathers are made from half round steel so as to conform to the contour of the drill hole and the upper ends are curved to prevent them from falling into the hole. The plug is driven between the inner flat faces of the feathers which aid in splitting the rock. A row of holes with several sets of "plugs and feathers" are usually used.

e. Power drills are classified as to the kind of power used in their operation. They are classified as:

(1) Steam Drill
- (a) piston
- (b) cable
- (c) rotary

(2) Compressed Air Drill
- (a) piston
- (b) hammer

(3) Electric Drill
- (a) piston
- (b) hammer
- (c) rotary

The drills most commonly used in rock excavation are the piston, hammer and cable drill. The kind of power may be varied with any of these types.

f. The hammer drill is efficient for light and rapid work where portability and quick action are feasible. Holes up to 12 feet deep can be drilled with the equipment held in the hands of the operator. It is, however, more common to have the drill mounted. The mounting may be a tripod or post and clamp as shown in Figure 3–4. The commonly used hammer drills are operated by either steam or compressed air.

FIG. 3–4. Rock Drilling Rigs. (a) hand; (b) tripod; (c) post and clamp. (*Courtesy E. I. du Pont de Nemours & Co., Inc.*)

Although electric and gasoline operated drills can be secured, by far the most work is done with compressed air. The differentiation between drills of competitive manufacture is principally confined to valve control and the mechanism used to rotate the drill steel. The rate at which a drill hole may be put down will be illustrated by the following data based upon a 3⅛″ machine, using compressed air or steam at 70 pounds per square inch, with a starting bit of 2¾″ and finishing with a bit of 1½″.

Soft sandstone, limestones and shales	4″ per minute
Medium sandstone, limestones and shales	3″ per minute
Hard granites, sandstones and limestones	2¼″ per minute
Very hard granites, traps, etc.	1½″ per minute
Soft rocks that sludge rapidly	1¼″ per minute

g. The piston or percussion drill is a self-contained mechanism. A U-bolt chuck is attached to the piston rod of the machine. This chuck is used to clamp the drill steel. These drills are usually of the tripod type and are used in deep holes, hard rock and where high pressures are available. They may be operated by either compressed air or steam. Air is preferred as it is cool and produces no clouds destroying visibility. When air is used it is of course necessary to have an air compressor operated by either steam, gasoline or electric power. The smaller, hand air drills which will handle ⅞″ to 1″ drill steels, which drill 1½″ to 2½″ holes, require a compressor of about 100 cubic feet capacity per minute. The larger air drills using up to a 3¼″ drill steel will require from 150 to 200 cubic feet of compressed air per minute at a pressure of 90 pounds per square inch.

h. Cable drills are almost always confined to the type of drilling known as churn or well drilling. These handle cable drilling tools consisting of a heavy bar from 3″ to 5″ in diameter and in lengths varying up to 25 feet. The drill steel is operated from a cable which is attached to a mechanism which gives reciprocating motion. Such machines can make from 45 to 60 strokes per minute. They will drill a 6″ hole in a solid bed of limestone at rates from 5 to 12 feet per hour. In trap rock and granite this is reduced to 10″ to 16″ per hour. Holes may be sunk to 200 feet.

i. In nearly all drilling the hole is started with a short drill steel, longer steels being inserted as the hole gets deeper. It is preferable to drill holes downward or with a downward slope so that water may be poured into it. When holes are drilled upward they are therefore known as "dry holes."

j. The bits used are either a high grade alloy steel or a good carbon steel. As the former requires low heats and great care in forging or sharpening the latter is very commonly employed for ordinary work. The drill steel bits are either round, hexagon or octagon in section and most of them are cored to allow the compressed air to blow out the hole.

3–6. Blasting Methods

a. All blasting should be supervised by an experienced blaster and done by a licensed powder man. The handling and storage of explosives is usually controlled by state statutes and local laws. The amounts of explosive used will determine the degree to which the rock is shattered and broken. Such matters will be considered later.

b. There are six general methods used for rock excavation by the use of explosive charges. Thus we recognize:

(1) benching,
(2) snakeholing,
(3) well drilling,
(4) tunneling,
(5) random blasting, and
(6) line drilling.

Figure 3–5 gives the general terms applied to benching. It will be noted that the height of the face is called the bench, the distance from the drill-hole line to the open face is called the burden, and the horizontal distance between holes in the direction of the face is called the spacing. Snakeholing consists of drilling horizontal holes at the bottom of a mass of rock or boulder as shown in Figure 3–6(a). Well drilling is used for the blasting of large quantities of rock as shown in Figure 3–7. Tunneling is also used for large mass blasts. When of limited extent it is called a

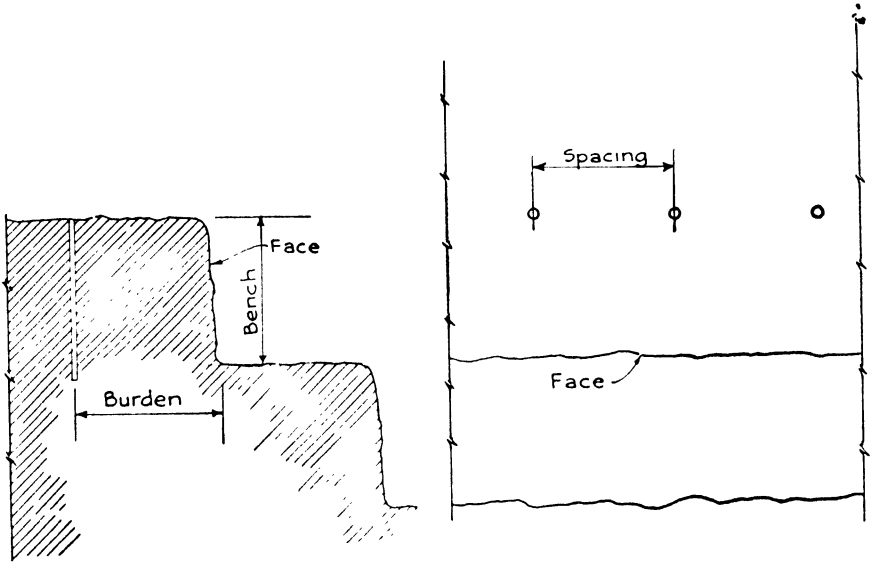


Fig. 3–5. Blasting Terminology.

"coyote" hole. If a snake hole is of sufficient size to accommodate a man, but with no cross tunnels, it is called a "gopher" hole. Random blasting, as the name implies, is used where no definite plan of drilling can be employed due to irregularities of rock formation, faults, seams and cracks. In such cases the particular problem should dictate the most advantageous method of applying the energy of the explosive. Line drilling consists in sinking small holes from 2″ to 6″ on center. In this way small blasts can trim back the rock to within 8″ to 12″ of an adjoining structure. The remaining rock can then be excavated by the use of plugs and feathers.

c. When large boulders or ledge outcroppings are encountered, mud-capping, blockholing or snakeholing may be used. In the first case the charge is placed upon the boulder and capped with mud as shown in

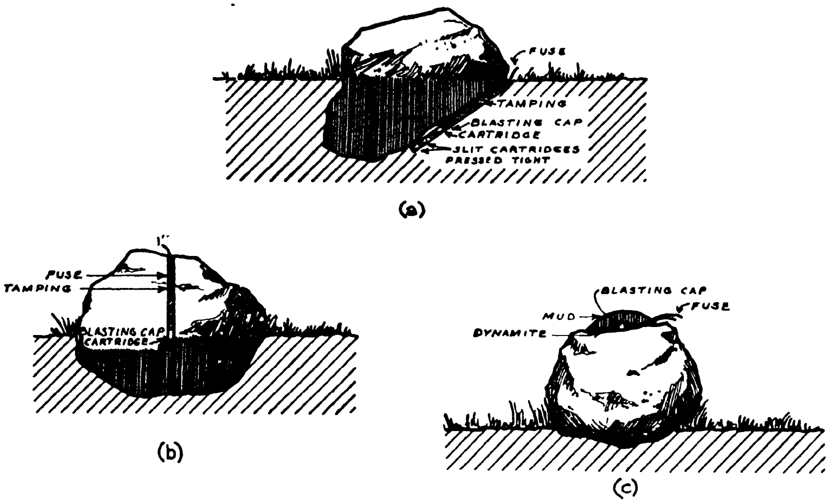


FIG. 3–6. Blasting Methods. (a) snake-holing; (b) block-holing; (c) mudcapping. (*Courtesy E. I. du Pont de Nemours & Co., Inc.*)

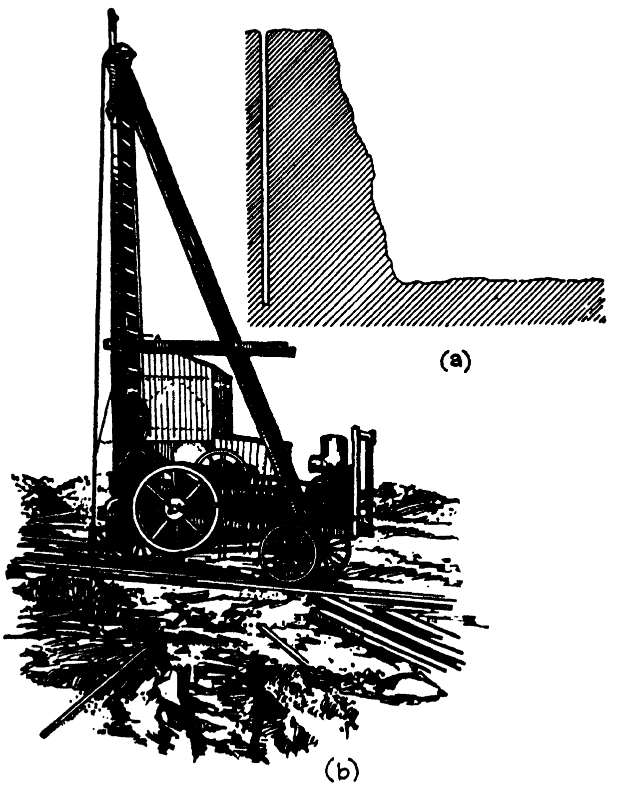


FIG. 3–7. Well Drilling. (a) section of drill hole; (b) drilling rig.

Figure 3–6(c). Blockholing consists of drilling a vertical hole in the boulder or ledge as shown in Figure 3–6(b) and using this for a tamped charge.

d. In making the inspection of a site the contractor should investigate the test borings carefully. At times such borings may not justify the conclusions of extensive rock but merely boulders. In most large cities subsurface surveys will help in establishing the extent of underlying rock strata.

3–7. Explosives

a. The explosives which are customarily used are:

(1) straight nitroglycerine dynamite,
(2) extra ammonia dynamite,
(3) gelatin dynamite,
(4) permissible ammonium nitrate powder,
(5) high count ammonium nitrate powder,
(6) blasting powder, varied granulation, and
(7) trinitrotoluene (TNT).

In selecting explosives the blaster must decide whether he wishes to employ the action of deflagrating explosives such as powders or the action of detonating explosives such as the common dynamites. The deflagrating explosives are slower acting than the detonating explosives, but both depend upon the sudden evolution of gases which create the pressures of disruption.

b. Blasting powders are black, granular materials. They are fired by ignition which accounts for the progressive generation of gas and the relative slowness of the blast. Powders are manufactured in two general grades. One of these, sometimes known as "A" powder, is a mixture of sulphur, charcoal and potassium nitrate or "saltpeter." The other, known as "B" powder, is a mixture of sulphur, charcoal and sodium nitrate. As the "A" powders are more expensive than the "B" powders, they are usually only used for difficult blasting, as in quarrying fine dimension stone. "B" powders are the commonly used type in general construction work, if deflagrating explosives are wanted for the work. Both "A" and "B" powders are made in various grain sizes. The "A" powders are classified as C, FF, FFFF, FFFFF, FFFFFFF, and dust; the "B" powders are classified as C, CC, CCC, F, FF, FFF and FFFF. These powders are packed in 25 pound kegs.

c. High explosives include all of the dynamites such as straight, extra, and gelatin, permissible explosives, and the "low" powders. The principal characteristics are strength, velocity or smashing effect, water resistance, density, fumes, temperature of freezing, and length and duration of flame. The dynamites are composed of nitroglycerine which impregnates a filler, usually cellulose. The proportion of nitroglycerine by weight establishes the strength percentage of the dynamite. Thus a 50% dynamite contains 50% nitroglycerine.

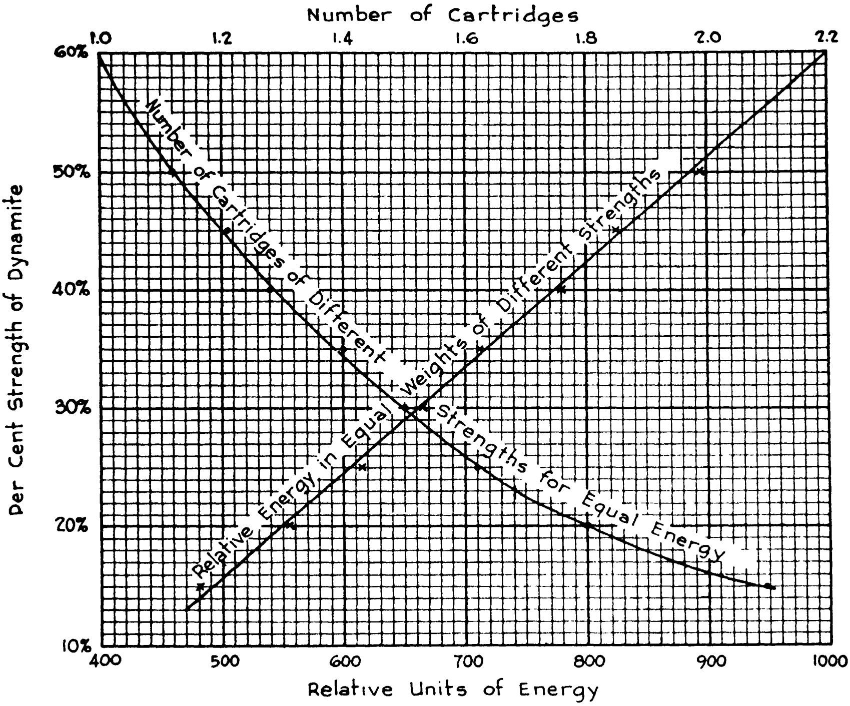


FIG. 3–8. Relative energy of Dynamite. (*Courtesy E. I. du Pont de Nemours & Co., Inc.*)

d. The relative energy of different dynamites is generally misunderstood. Careful laboratory tests by the manufacturers of dynamites have shown a relation which is indicated in Figure 3–8. Thus to compare the energy devolped by 30% and 60% dynamite, one would move horizontally from the 30% ordinate to the intersection with the line labeled "Relative energy in equal weights of different strengths." This point establishes the abscissa indicating 665 relative units of energy. Similarly, the 60% ordinate establishes the abscissa indicating 400 relative units of energy. Thus, instead of the 60% dynamite being two times as strong as 30% dynamite, as is often supposed, the ratio is 1.66. A comparison of cartridge strength is also indicated. Thus, a single 60% dynamite cartridge with 1000 relative units of energy has the same strength as 1.29 cartridges of 40% dynamite. This would be proved by multiplying the relative units of energy of 40% dynamite by 1.29, which is approximately 1000 relative units of energy.

e. As the velocity of a dynamite is closely allied to its strength and density, these three characteristics should be considered together when chosing the explosive. Some dynamites are more bulky than others. The bulky ones will therefore fill a greater volume of the drill hole. This may be an advantage in providing a greater spread of the action at a lower intensity, but in small drill holes, extremely bulky explosives are troublesome. In cases where the spread of energy is desirable, it is possible to spring the bottom of the hole as shown in Figure 3–9 to afford a greater volume of explosive.

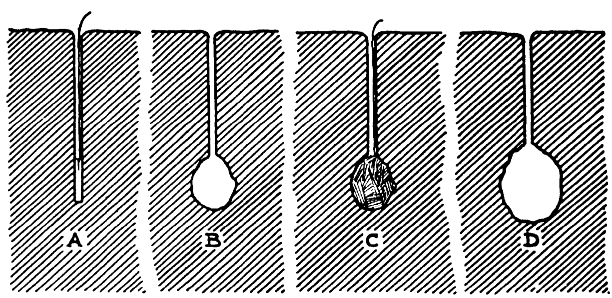


FIG. 3–9. Chambering and Springing. A—drill hole with springing charge; B—sprung hole; C—chambering charge; D—chambered hole.

f. Water resistance is often a critical characteristic in certain cases. If the blast is fired soon after loading, an explosive with intermediate water resistance is satisfactory. Thus, extra ammonia dynamites can be fired in drill holes which contain water, providing the firing is done soon after loading. If any time must elapse between loading and firing, a gelatin dynamite should be employed.

g. One of the extremely important matters which must be considered when using dynamites, or even powders, is the generation of fumes. In open work, such as foundation rock excavation, the nature of these gases is relatively unimportant, but for underground or pit work the fumes are important. In this connection, gelatin dynamite gives off the least quantity of poisonous fume. All others, including the ammonia dynamites, give better results but only with fair ventilation. Burning dynamite emits poisonous fumes. The more completely dynamite is detonated, the less dangerous the fumes. Confinement of the explosive aids in reducing the effects of fumes because complete detonation is effected.

h. Nearly all high explosives except blasting gelatin are low freezing.

This is an important recent improvement in dynamite and avoids the handling of frozen dynamite. While frozen, the process of thawing must be carefully done and should be handled only by experienced blasters.

i. In the extra ammonia dynamites about half of the nitroglycerine is replaced by ammonium nitrate. It is slower in action, is suited for soft rock or in hard rock where shattering is not required, and in sand, clay and earth excavation. The fumes are less objectionable than those of straight dynamite. They are usually low freezing.

j. The gelatin dynamites are commonly made in the form of a waterproof jelly which carries nitro-cotton dissolved in nitroglycerine. They are usually dense, waterproof and plastic. The fumes from these dynamites are least objectionable of all deflagrating explosives. They have a high velocity and pack densely because of their plasticity, thus confining the charge. Their water resistance is excellent and they are low freezing.

k. Explosives are listed as permissible after being tested by the United States Bureau of Mines and passed as safe for blasting in gaseous and dusty mines under specified conditions. They give the smallest flame of shortest duration. These explosives are of two principal classes. One contains nitroglycerine as its principal ingredient and the other contains ammonium nitrate. The former are similar to low, straight dynamites in their action. The latter are made in several grades and are used especially in coal mines to produce several degrees of shattering. These also find considerable use where a slow, "pushing" action is wanted and thus are employed in dimension stone quarrying.

l. The blasting powders are slow burning and contain from 70 to 75% sodium nitrate, 10 to 15% charcoal and 10 to 15% of sulphur.

m. All of the above explosives are listed in Table 3–1, which gives the general data adapted from information by the E. I. du Pont de Nemours & Company.

3–8. Determination of Charges (Figure 3–10)

a. For general purposes it may be assumed that one pound of 50% dynamite, with an energy content of about 2,250,000 foot pounds, will, if properly tamped and placed, dislodge and shatter about 11 tons of rock. To determine the weight of the rock for use in this general rule, the following weights per cubic foot for various rock are typical:

Granite	175
Gneiss	160
Quartzite	165
Dolomite	180
Marble	165
Trap	185

TABLE 3-1

PROPERTIES OF DYNAMITES OTHER THAN PERMISSIBLES

Grade	Strength		Density Ctgs per 50 lb 1¼"x8" (1)	Velocity Ft per Sec	Water Resistance	Fumes (2)
	Weight	Bulk				
Du Pont Straight......	15–35% 40–50% 60%	15–35% 40–50% 60%	102 102–104 106	8,200–12,800 13,800–16,100 18,200	Poor Good Excellent	Fair Very Poor Very Poor
"Red Cross Extra"....	15–35% 40–60%	11–29% 35–55%	110 110	7,400– 9,600 10,400–12,800	Fair Good	Fair Fair
Du Pont "Extra".....	A to D E to H C-1 to G-1	55–40% 35–20% 45–25%	115–135 142–172 128–162	10,800– 9,500 9,300– 8,800 7,700– 6,500	Fair Poor Poor	Good (3) Good (3) Good (3)
Du Pont Gelatin......	20–60% 75–90%	30–59% 67–79%	85–96 101–107	10,500–19,700 (4) 20,600–22,300 (4)	Excellent Excellent	Excellent Very Poor
"Hi-Velocity" Gelatin..	50–80%	41–56%	100–120	18,000–21,600	Excellent	Very Poor
Blasting Gelatin.......	100%	100%	110	23,600	Excellent	Poor
Special Gelatin........	30–80% 90%	35–70% 79%	88–107 109	13,100–17,100 (4) 19,700 (4)	Excellent Excellent	Excellent Poor
Seismograph Gelatins..	60%	48–55%	100–107	17,100 (4)–19,700	Excellent	Very Poor
"Gelex".............	No. 1 & No. 2	60 & 45%	110–122	14,100–12,600	Very Good	Excellent

NOTES: (1) Subject to a variation of plus or minus 3% from standard.
(2) Grades rated with "Very Poor" fumes are not recommended for underground use.
(3) This fume rating for the du Pont "Extra" dynamites applies only to special wrappers; in standard wrappers the fume rating is "Fair."
(4) The velocities shown for these gelatin dynamites are the high values developed when detonated unconfined with a straight dynamite primer.

Thus, for a spacing of 6 feet, a bench of 4 feet and a burden of 6 feet, the volume of rock to remove is 144 cubic feet. If the rock is dolomite the weight of this rock is 25,920 pounds. This would require 1.18 pounds of 50% dynamite. As the drill holes would be 1 foot deeper than the bench height, they would be 5 feet deep. As holes are not loaded to over half

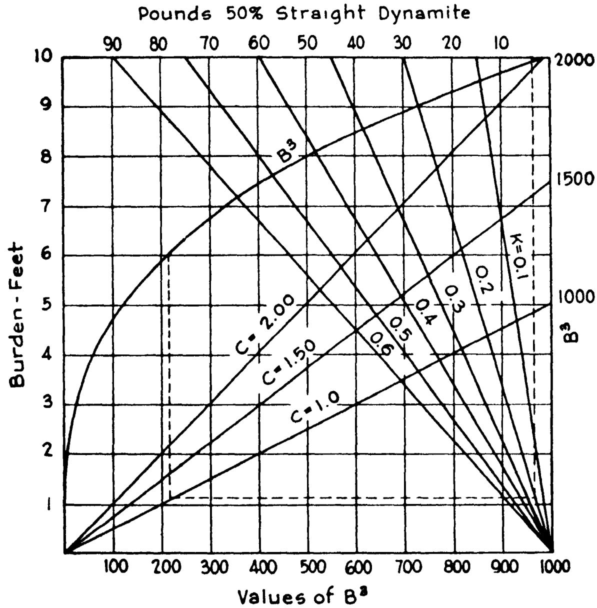


FIG. 3–10. Blasting Charges. To use curves, select burden, move to B^3 line, drop to proper value of "c" (Hard Tamped—1.0; Medium Tamped—1.5; Loose Tamped—2.0) and move to proper value of "k" as given in tabulation. Pounds of dynamite given vertically above the intersection so located and as shown by dotted lines for 6′–0″ burden.

their depth this weight must be packed into 2½ feet of hole. As the standard cartridge is 1¼″ in diameter and 8″ long and weighs 0.48 pound, it would take about 2½ sticks occupying 20″ of the hole. As discussed in Art. 3–7, if 40% dynamite had been used it would have taken 1.14 x 2.5 sticks or 2.85 sticks occupying about 23″ of the hole.

b. It must be remembered that the device of an expert blaster should always be sought by the engineer who is confronted with a blasting problem. The reader can find much additional information on this matter in the literature. The density figures are reflected in the number of cartridges for the standard 50 pound case. The number of cartridges for

VALUES OF K IN B^3KC

Material	Max. Burden (Feet)	Breaching or Springing Shattering	Breaking and Moving
Granite	<3	.63	.32
Gneiss	3-5	.50	.25
Quartzite	5-7	.44	.22
Trap	>7	.38	.19
Bedded	<3	.49	.25
Limestone	3-5	.38	.19
Dolomite	5-7	.34	.17
	>7	.29	.15
Medium Strat.	<3	.39	.20
Limestone	3-5	.31	.16
Sandstone	5-7	.27	.14
	>7	.24	.12
Thin Strat.	<3	.27	.14
Limestone	3-5	.22	.11
Med. Shale	5-7	.19	.10
	>7	.17	.09

the various cartridge strengths is given below for the standard 1¼″ by 8″ sticks:

Cartridge Strength	55	50	45	40	35	30	25	20
No. Cartridges per Box	115	120	126	132	142	152	162	172

3-9. Loading and Firing

a. Figure 3-11 shows the section of a drill hole with the charge in place. The cartridges which are slightly smaller than the drill holes, are slit lengthwise and pressed into the hole with a wooden ramming stick. The last cartridge is equipped with a fuse cap or electric detonator as shown in Figure 3-12. This cartridge is then called the primer and is lowered into the hole and the lead wires are carried out and above the hole. The hole is then tamped with paper followed by moist clay or sand. The lead wires are then led to the firing machine or blasting battery. This machine is a hand operated magneto which generates an electric current which, when transmitted across the gap in the detonator, explodes the primer and through it the entire charge.

b. There are four general means of setting off a charge. These are fuses, squibs, blasting caps, and electric blasting caps. Fuses are cores of black powder wrapped with hemp or cotton threads or with tape. They burn at the rate of about 2 feet per minute. Squibs are paper tubes filled with a

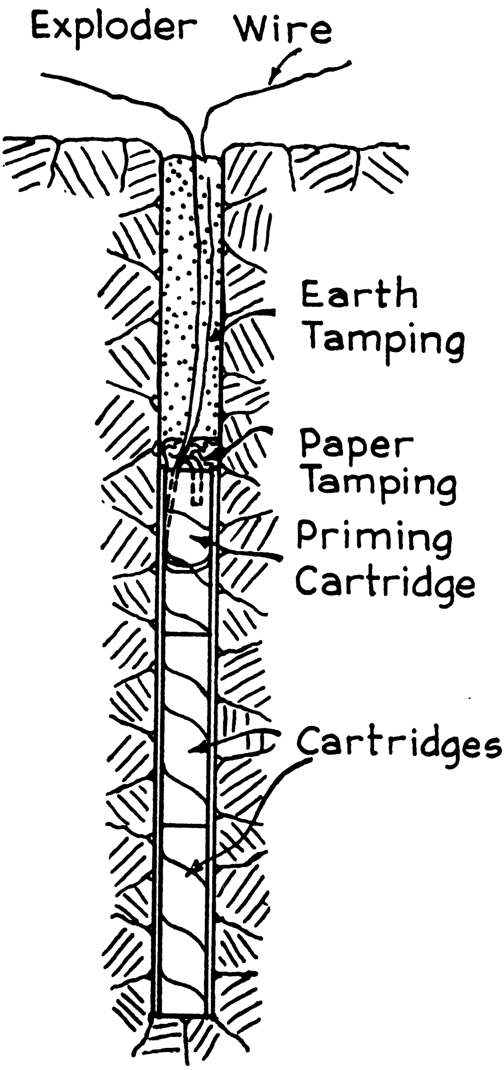


Fig. 3-11. Section of Drill Hole With Charge in Place.

powder composition which, when lighted at one end, burn for a few seconds and then ignite the powder composition and shoots like a rocket through the bore hole into the charge of blasting powder which it ignites.

The blasting cap is a copper shell closed at one end, containing a charge of a detonating compound which is ignited from the spark of a fuse and is used for detonating high explosives. Electric blasting caps consist of a cap in which is buried a fine platinum wire stretched across two copper wires which are held in a plug of sulphur composition. The resistance heating of the platinum wire bridge ignites the explosive charge which, in turn, detonates the high explosive. Electric devices can, of course, be used with squibs and fuses, if desired.

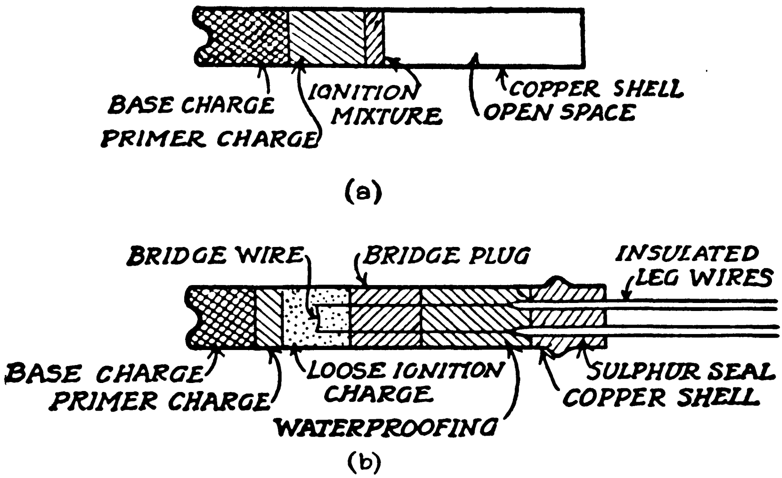


FIG. 3-12. Blasting Caps. (a) fuse; (b) electric detonator. (*Courtesy E. I. du Pont de Nemours & Co., Inc.*)

c. When blasting is done in the neighborhood of existing buildings where many men are always working, great care must be taken to protect them, the property and the equipment. The loaded holes should be protected with a chain or hemp cord mat. Logs and chains are also used and these are tied together to form a flexible, yet heavy, restraining cover. The blaster should always face the blast and with his back to the sun. Preceding the firing of the blast a careful inspection should be made to see that everything is safe. Roads should be patrolled if necessary. The wires should not be connected to the blasting machine or electric switch until everything is checked along the line. Misfires when using electric blasting caps are not as dangerous to investigate as misfires when fuses or blasting caps are used. With these primers considerable time should elapse before approaching the drill holes.

d. The approach to the adjoining building lines always presents a problem. If the rock is bedded horizontally, closely spaced drill holes and plugs and feathers will gradually break the rock out. If the beds are nearly vertical this process is very desirable. If the bedding is inclined, particularly if the rock is badly cracked, care to prevent the sliding of the rock should be taken. In no case should such sliding remove the support from the adjacent building. If the rock is solidly bedded and not broken up, a light trimming charge may be used with safety. This merely cracks the rock so that bars and wedges can be employed to effect the rest of the removal.

3-10. Rock Removal

a. The degree to which blasted rock is reduced in size will be determined by the caution which must be exercised in the blasting and the equipment which will be necessary or available in the particular case. Close spacing of holes, small burdens, and "pushing" charges will produce pieces of rock small enough to permit them to be shoveled by hand and loaded into trucks, or will make the loading by means of steam or gas shovels simple and speedy. In most cases, however, caution will dictate the use of much smaller charges with the result that large pieces will require crowbar work and heavy lifting. Such pieces can be handled by the means of chain slings in connection with the shovel or derrick or can be skidded on stone sleds and dragged out of the excavation. Inasmuch as a derrick is used on all large building operations, it may be advisable to get it on to the job early and to use it with skips with which to lift the stones to the trucks, which may be in the excavation or on the public way. The largest pieces can be drilled and split by the use of plugs and feathers or broken up with the stone sledge.

CHAPTER 4

FOUNDATIONS

4–1. Loads and Foundation Types

a. The degree of concentration of loads and the exact nature of the substrata materially affect the selection of foundation type. The load concentrations may be light, such as are encountered in buildings up to three or four stories in height. Beyond this height and perhaps up to ten or twelve stories with moderate floor loads the concentration would be medium. In the skyscraper, the concentrations of load may reach or even surpass 1000 kips. The subsoil conditions may provide rock strata at or near the column bases, or the rock may be 100 feet below the surface. The various combinations which may exist in any case will dictate the foundation type which is the most economically and structurally sound.

b. Light buildings may be founded upon compressible soils such as clay or upon incompressible soils such as sand. In either case the spread of the footings is not excessive and the soil bearing power need not be large. In buildings which impose medium concentrations of load on compressible soils, piles, Gow caissons or raft foundation mats are often used with satisfactory results. Where the loads are highly concentrated it is necessary to use grillages to spread the load over rock strata near the column bases, sink caissons to bed rock, if it is far below the column bases, or use steel piles driven to bed rock, if the rock is not too far down to be reached in this way, but too far down to allow the bedding of grillages directly upon the rock.

4–2. Stepped and Spread Footings

a. First-class buildings are not always multi-story structures or skyscrapers. When the loads are not great enough to require heavy foundation structures the footings may be spread over the compressible soil. In these cases the stepped or spread footing may be used as they would be in second-class buildings under similar load conditions.

4–3. Grillage Footings

a. The term "grillage" is applied to successive tiers of structural units, each tier consisting of one or more units and reversed as to direction of length so that the units of one tier usually cross those of the tiers above and below at right angles. Steel beams are most commonly used and the beams in each tier are tied together by the means of separators and bolts. The separators may be of cast iron, bent steel plates or of pipe. The tiers are usually bolted to each other, if the total weight of the assembly is not too great to be handled on the job. Such bolts are for alignment and erection only and do not come into play structurally when the grillage is finally set. A typical grillage is shown in Figure 4–1.

b. Grillage footings are used when the load concentration is high and where the resistance of the medium supporting this load is such as to require a substantial expansion of bearing area. They usually function well in distributing the loads over rock and over concrete cappings. Although they may at times be used under heavy walls it usually is found to be economical to bear such walls directly on the rock or upon extended piers to rock. Where the spread required is less than 3 feet, rolled steel slabs should be used instead of rolled beam sections. Thus, we may use grillages upon compressible soils, upon concrete piers, caissons, or mats and upon the rock strata directly.

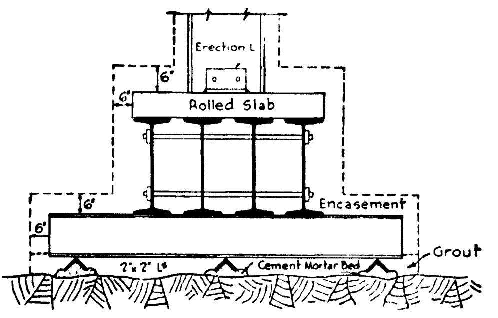


Fig. 4–1. Typical Grillage on Rock.

c. Grillages are made up of two or more tiers of rolled steel beam sections, each of which crosses the tier immediately below it. Each succeeding tier consists of a smaller number of deeper beams but each tier has approximately the same total section modulus. Thus, in Figure 4–1 we find a group of seven 10″ beams forming the lower tier and four 15″ beams forming the second tier. The rolled steel slab is then placed upon this final upper tier to take the structural steel column. In the usual case a double tier is used, particularly when the grillage rests upon a material such as concrete or bed rock, where the allowable resistance may be as high as 30 tons per square foot.

d. When grillages are bedded in compressible soils and are parts of a large footing, it is desirable to cast a 6″ to 12″ slab of concrete upon the soil first, as shown in Figure 4–2. The grillage, which is bolted together, tier to tier, and beam to beam by using separators and through bolts, is then set upon this concrete mat and centered by the job engineer. It should be brought to level by using steel wedges and, when it is in its correct position, may be encased in concrete. It is often more desirable to level grillages and rolled steel slabs by using light angles, usually 2 x 2 x ½, with their heels up. This method is shown in Figure 4–2. The angles are bedded in a stiff cement mortar, as shown, and when this has hardened the grillages are set and the angles and lower flanges of the lower tier are grouted in. Edge and end thicknesses of at least 3″ for protection should be provided. It should also be noted that the flanges of

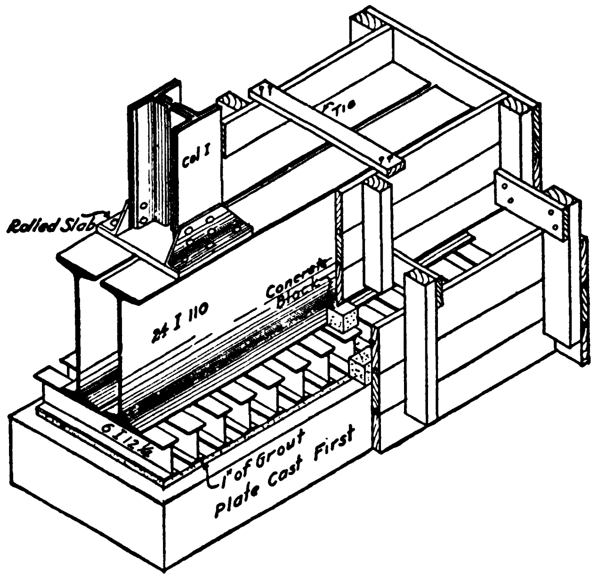


FIG. 4–2. Forming a Grillage Footing.

adjacent beams should be spread sufficiently to allow the concrete to fall into the space between the beams without too much difficulty. This would mean a clearance of at least 2″ in the usual case. Figure 4–2 also shows the usual method of forming the encasing concrete. The spreaders, which keep the edge and end distances true and ample should be made of precast concrete blocks, never of wood or absorptive units such as brick.

4–4. Column Bases

a. As the detail of the column base affects the grillage details the common methods used will be of interest. There are four general types, two of which provide a spread at the end of the column so as not to exceed the compressive value of the concrete upon which it rests. To effect a proper spread over rock or over a grillage, the rolled steel slab is used. The built-up base made of structural plates and sections is shown in Figure 4–3(a) and the common cast steel base is shown in Figure 4–3(b). When the rolled steel slab is used it is set in a manner similar to the grillage, as shown in Figure 7–6. Where the slabs are used in connection with grillages they are grouted directly upon the upper tier and checked for grade and alignment.

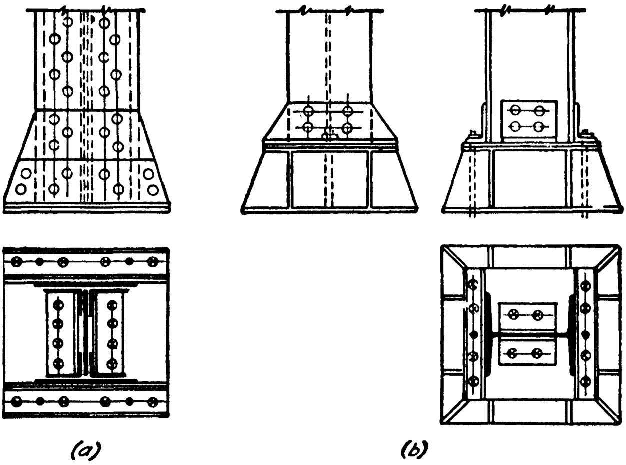


FIG. 4–3. Column Bases. (a) built-up steel; (b) cast steel.

4–5. Rolled Steel Slabs

a. Rolled steel slabs are more economical and reliable than cast iron, and more economical than cast steel bases. Column ends are milled and the bearing surface of the slab is also machined. Slabs may be had up to 12″ in thickness, but 6″ is the usual practical and economical optimum. The American Bridge Company has established certain engineering standards in connection with rolled steel slabs. Rolled steel slabs should be used instead of grillages where the required length of beam is 3 feet or less. Preference should be given to slabs bearing directly on the concrete or rock if the loads are such as to make this possible. Four inch slabs may be straightened true and smooth in a hydraulic press. Slabs larger than 4″ must be planed.

4–6. Combined Footings

a. When a new building adjoins an existing one, and if it is to have footings separate from the old, the support of the party wall foundations involves the use of either combined or cantilever footings. The first type involves the conjunctive action of the wall columns with one or more of the interior columns by a mat of such shape as to bring the center of

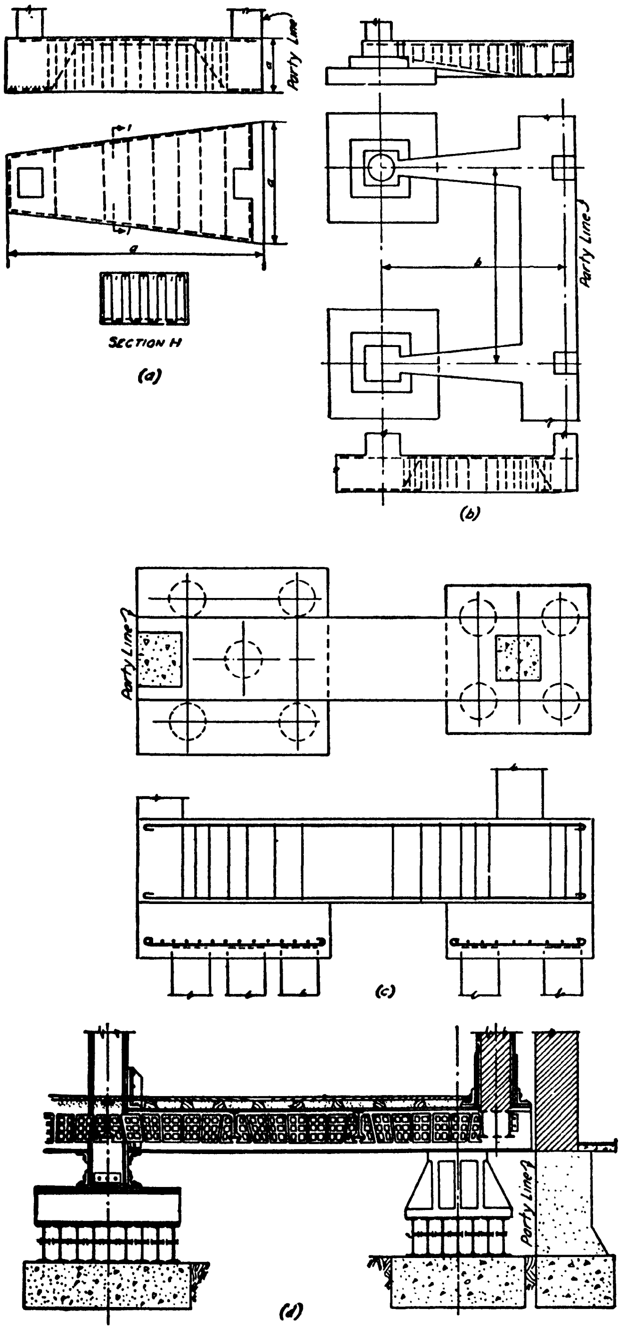


FIG. 4-4. Combined and Cantilever Footings. (a) spread mat; (b) beam and mat; (c) beam and pile caps; (d) eccentric steel grillage and cantilever beam.

the loads over the center of soil pressure and the bearing area large enough to support the combined loads of both columns and the mat, as shown in Figure 4–4. The cantilever footing is, of necessity, a combined one but involves the use of a beam cap which carries the loads to symmetrical mats, usually at two convenient points for excavation and work, as shown. These footings may be either reinforced concrete or grillages. They are used for either the reinforced concrete frame or the structural steel frame. When a new building abuts public ways it is possible, under the laws of some cities, to place the wall footings over the building lines, thus simplifying the construction.

b. Sometimes a single, continuous footing is used to support a row of columns. Such footings are usually of reinforced concrete. Where continuous exterior walls of concrete are used, they may be made a structural part of a continuous footing.

4–7. Raft Foundations

a. Raft foundations are used where the bearing power of the soil is low and are nearly always of reinforced concrete covering the entire site and may be one of three types. The first of these is the solid mat which may be as thick as 8 feet, a common thickness being 5 feet. Such mats are reinforced with bars running in both directions in both the upper and lower faces and about 6″ from the outside face. These mats are cast in one continuous operation to avoid the use of construction joints. This means keeping the workmen on the job in three shifts, if necessary, to complete the job. The second of these is formed by a series of continuous beams intersecting under the columns and acting as a series of inverted T-beams. This scheme may have the slab in its structurally correct position, that is, at the bottom of the beams, or it may be cast at the top of the beams. In the first of these variations the space between the beam stems is filled with cinders, rolled into a compact fill. In the latter of these variations it is necessary to have a stable soil which will bank well and require no backfill and which will trench well to provide a substitute for the forms for the beam stems. Usually, when such a soil is available, its bearing power would be such to make spread footings possible. The third of these is the use of the standard inverted flat slab design which requires careful excavation to provide undisturbed soil for bearing and usually is thickened under the columns to simulate the drop-panel of flat slab construction. The flat slab and beam types are shown in Figure 4–5. The bearing power of the soil may be so low that piles are used to support the raft slab. In using this alternative the engineer should be sure that the piles do increase the bearing power, as there are times when pile clusters do not behave as accumulations of single piles as far as individual bearing capacity is concerned.

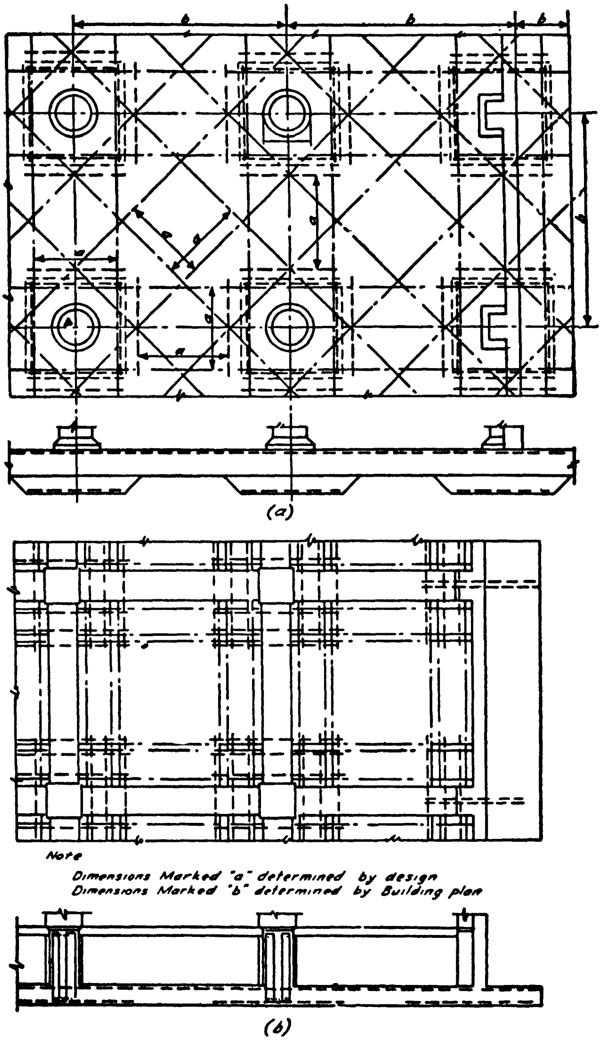


FIG. 4-5. Raft Foundations. (a) flat slab; (b) beam and slab.

4-8. Caissons

a. Strictly defined–the word which comes from the French word "caisse," meaning box–caissons were steel, wood or concrete hollow units which were sunk by the gradual excavation of soil from their lower cutting edges, as shown in Figure 4–6. Caissons are of three kinds,

(1) box caissons,
(2) open caissons, and
(3) pneumatic caissons.

The box caisson is open at the top and closed at the bottom; the open caisson is open at both ends; and the pneumatic caisson is closed at both

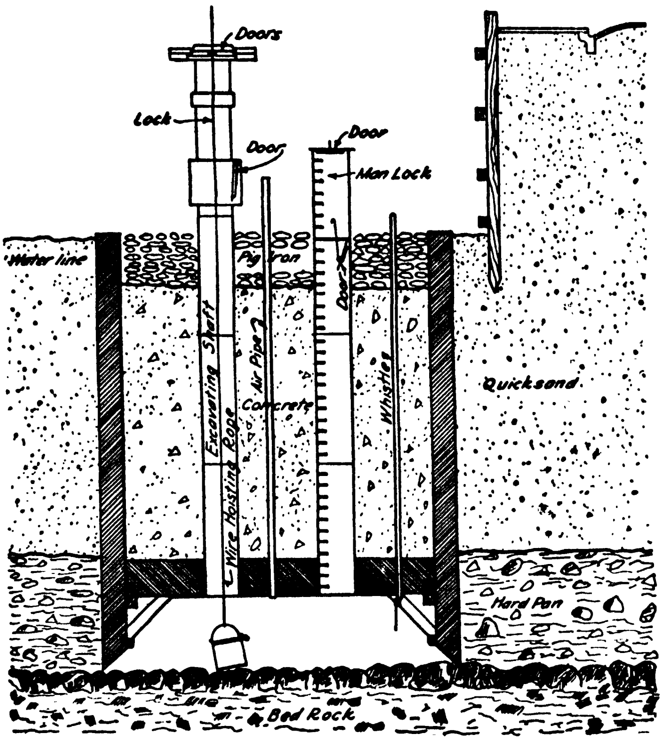


FIG. 4–6. Typical Caisson Box.

ends in order to provide pressure controls. The box caisson is used where it can be sunk, usually under water, without extensive excavation other than preparing a bed for the caisson. These, of course, are not applicable to buildings unless such a structure is based on foundations in shallow waters.

b. Open caissons are used where it is necessary to go deeply into the soil, or even to rock itself, to get a bearing power capable of sustaining the loads which are imposed by tall buildings. Open caissons may often be belled out at their bottom in order to distribute the loads over a larger area than the main shaft area would provide. In these cases, bedrock is so far below the surface of the ground that it is impracticable to go to rock. The sides of such extensions in area are at an angle of 60 degrees with the horizontal. The lower section is usually made at least 12″ deep, all as shown in Figure 4–7. In each of these cases the load from the steel columns is distributed over the pier cap of the caisson by means of grillage beams or a rolled steel slab so that the compressive strength of the concrete is not exceeded.

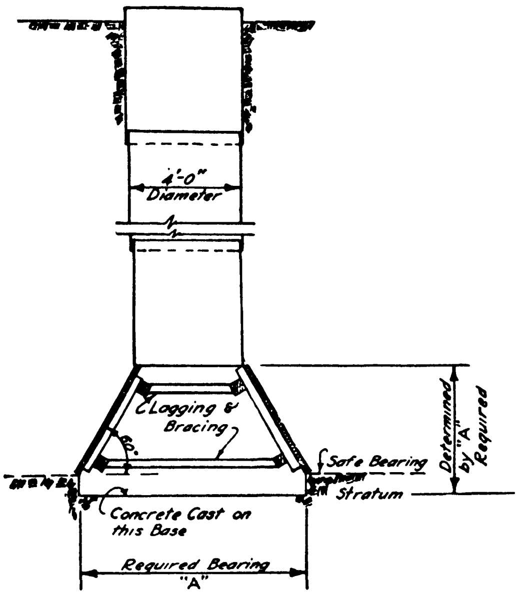


FIG. 4–7. Open Well Gow Caisson.

c. The open well caissons are sunk by excavating cylindrical holes about 5 to 8 feet deep and inserting steel cylinders or wood lagging, or by driving the steel shells first and then excavating the soil within the shell. The cylinders vary in diameter by increments of 2″, the largest shell being driven first, while the smallest shell is at the base of the caisson. Figure 4–8 shows the steel and wood-lagged caisson. The method of sinking the latter is commonly referred to as the "Chicago poling method." Excavation is done by hand and the excavated soil is raised to the surface by means of buckets. These buckets are raised and lowered from a tripod fitted with pulleys and obtaining power from spools or "niggerheads" which are all lined up on a column center line so that the spools may be driven by a single engine for each line. By tightening a slip rope over the driven spools the loads are raised by simple means. The accumulated excavated material is dumped into small trucks which, in turn, may run on to a ramp and be emptied into a bin for truck loading. A typical setup of this kind is shown diagrammatically in Figure 4–9(a).

d. In the "Chicago poling method" the excavation is usually carried down about 5′–4″ and 3″ beveled lagging is put in place and held there by the use of split rings which are driven to a tight fit. The ends are bolted and the lagging wedged tightly to the soil by means of wedges. By such successive steps the caisson is carried to its assigned grade. This setup is shown in Figure 4–8(b).

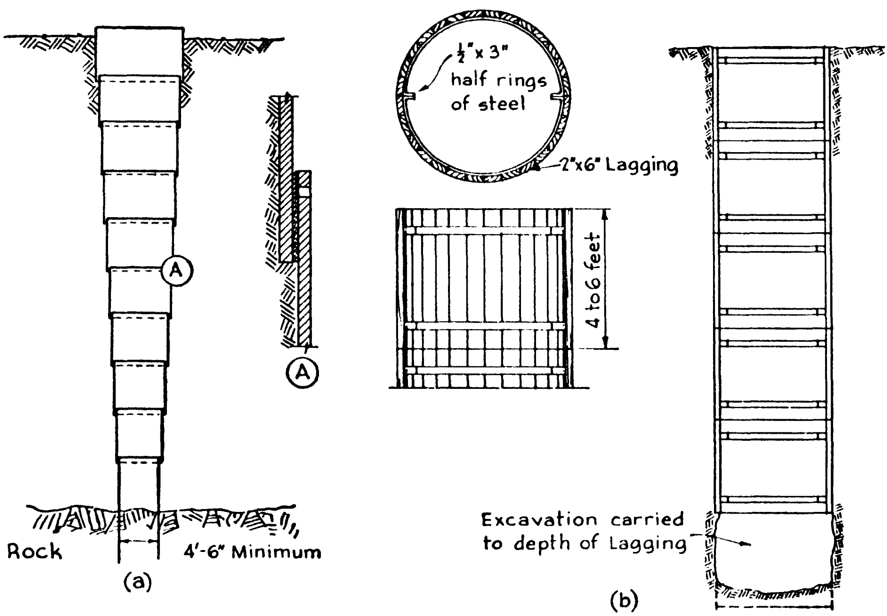


FIG. 4–8. Open Well Caissons. (a) steel shell; (b) Chicago "poling."

e. As water is encountered to a lesser or greater degree in all excavation which is carried to great depths, pumping or other water removal is necessary. It is therefore customary to carry hoses down with the caisson so that steam, gasoline or pulsometer pumps can be used to keep the caisson clear. When sand strata carrying considerable amounts of water are encountered, and if this stratum is sealed between two clay layers, it is customary to bell out the caisson just before reaching the sand layer to provide room for driving a continuous shell or wood sheet piling through the sand layer, as shown in Figure 4–9(c). When this is accom-

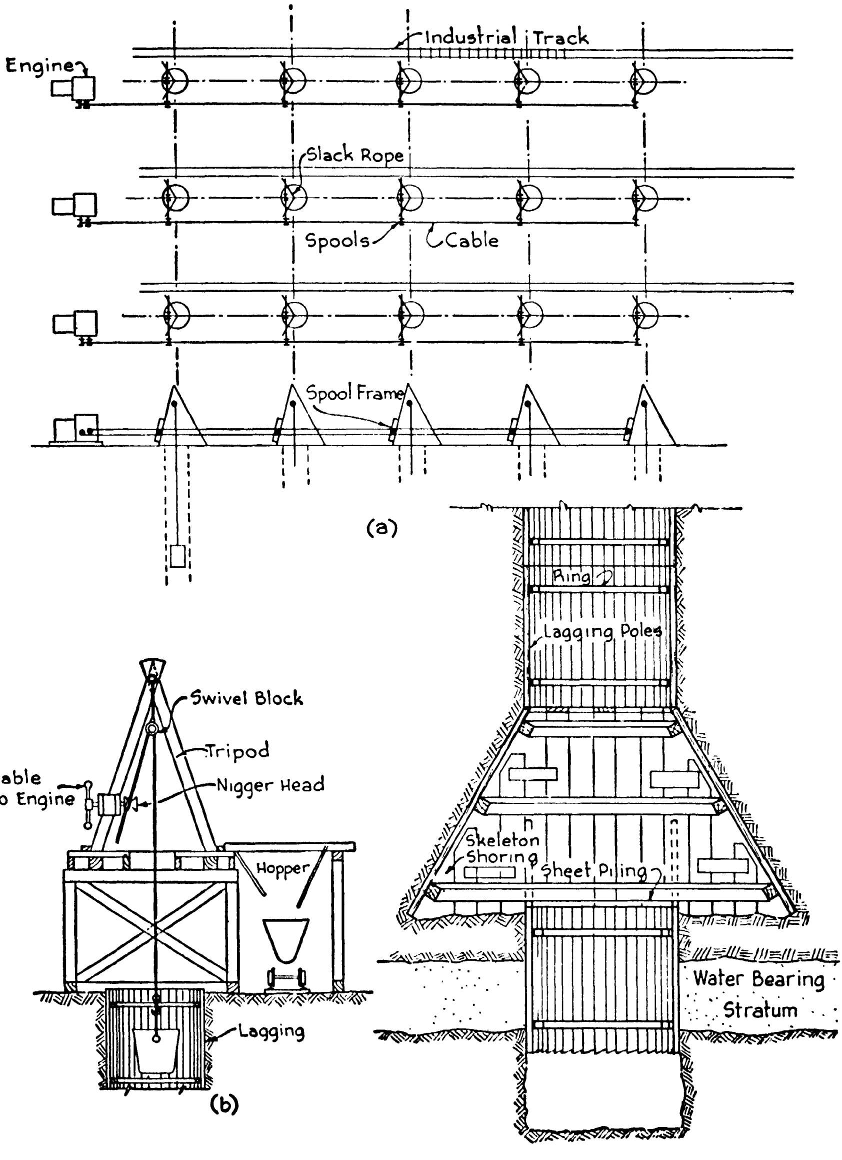


Fig. 4-9. Sinking Open Well Caissons. (a) job set-up; (b) tripod rig over caisson; (c) passing through sand layer.

plished the work may proceed in the usual way in the lower clay layer. It is always wise to have a supply of crushed stone or gravel handy to reduce quickly the tendency to "boil." Boiling is a quicksand effect and this is ameliorated by making the mass of the particles greater to offset the velocity head of the water. Thus, when the workmen approach a stratum which allows of velocity flow, the soil will begin to bubble and boil. If this is at the proper level for the bottom of the caisson the crushed stone may be bedded and sealed with one or two buckets of concrete. If the bottom of the caisson has not been reached, the crushed

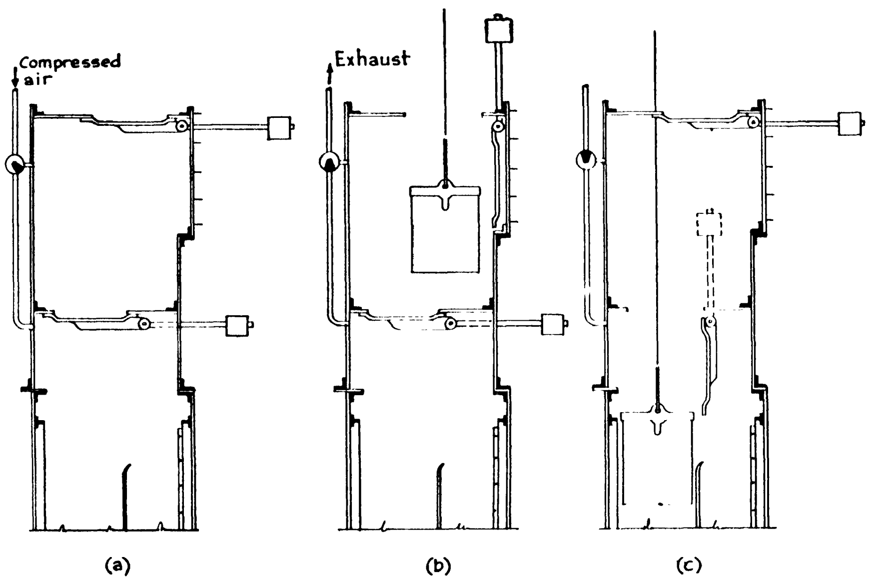


FIG. 4–10. Moran Pneumatic Lock. (a) pressure on caisson and lock; (b) pressure on caisson only; (c) pressure on caisson and lock, caisson gate open.

stone seal should be placed and the process of belling out and driving sheet piling to penetrate the water-bearing stratum should be used. Where water conditions are bad, pneumatic caissons are used.

f. In the pneumatic caisson, the excavation is kept covered at the top and compressed air is introduced to keep the water out. The pressure is kept about the same as the head encountered. Thus, for every 10 feet of water head a pressure of 4.5 pounds per square inch is developed. The maximum pressure under which men can work is 45 pounds per square inch, which would limit the depth to 100 feet. The top of the locking chamber is fitted up so as to conserve the internal pressure and the Moran lock, shown in Figure 4–10, is the common type of seal used. This provides a double trap door through which the excavated materials, the concrete, and the workmen may pass. The caisson is cast similarly to the open well type. The radical difference between outer air at normal pressure and the pressure of the air in the tightly sealed working chamber makes it obvious that the two doorways of the passage from the caisson chambers to the surface must never be opened simultaneously, and must be so constructed as to furnish absolutely airtight seats for the contact between doors and jambs. The entrance from the surface into the normal air pressure of the intermediate chamber must be followed by tightly closing the upper door and by subsequent raising of the pressure to the same amount per square inch as in the lower chamber, before entrance to the lower chamber may be effected. The exit process is, of course, the reverse, always based upon the same principle of passage from a void of one pressure to another of equal pressure. The principles applied to the single pier or shaft may be applied to walls, in which case double sheet piling is used to effect the caisson void.

4–9. Physiological Effects of Working Under Compressed Air

a. When a workman is under compressed air, nitrogen is dissolved in the fluids of the body in accordance with Dalton's law, to the extent of 1% for each atmosphere. It is during the process of decompression that danger arises. If the pressure is reduced too rapidly it will allow the liberation of bubbles or blobs of gas to develop in the muscles and joints, called the bends; in the spinal cord, causing partial paralysis; in the ear, causing auditory vertigo; in the heart, causing stoppage of circulation; and if in the liver, may cause lesions. Thus, deafness, embarrassed breathing, vomiting, paralysis (diver's palsy), fainting and even sudden death may result.

b. Therefore, slow decompression is the only answer to caisson disease. It is commonly agreed that the period of decompression should be at the rate of one minute per pound of pressure endured. Long shifts should be avoided because in cases of fatigue the circulatory and respiratory organs are rendered less able to absorb the released gases. Rapid decompression creates high partial pressures of oxygen which act as protoplasmic poisons. Liability to caisson disease increases with age, and no one over 40 years of age should be allowed to work under pressure.

4–10. Rules and Regulations Governing Compressed Air Work

a. The City of New York requires that the following rules and regulations shall apply to all work such as tunnels, caissons and the like, in the prosecution of which, compressed air is employed or used.

General Provisions

1. No work in which compressed air is to be used shall be started until seven days after the corporation or person undertaking such work has notified in writing the Department of Labor and Industries of such contemplated work.

2. Whenever the construction work is in progress there shall be present at all times at least one competent person representing the employer, who shall, in all respects, be responsible for full compliance of these regulations, and who shall have authority to require all employees to comply with such regulations.

3. In every tunnel or section thereof, or other work requiring the use of compressed air as covered by these regulations, there shall be a competent person designated by person in charge to make a regular inspection once every working day of all tunneling appliances, boilers, engines, compressors, magazines, shaft houses, explosives, locks, lighting circuits and gauges, and it shall be his duty to report in writing to the person designating him, on forms approved by the Department of Labor and Industries, or its representatives.

Hours of Labor

4. Pressure Shifts and Intervals. The working time in any twenty-four hours shall be divided into two shifts under compressed air with an interval in open air. The minimum rest interval in open air shall not begin until the employee has reached the open air. Persons who have not previously worked in compressed air shall work therein but one shift during the first twenty-four hours. No person shall be subjected to pressure exceeding fifty pounds per square inch except in emergency. The maximum number of hours to each shift and minimum open air interval between the shifts during any twenty-four hours for any pressure, as given in columns one and two of the following table, shall be that set opposite such pressure in columns three, four, five and six.

PRESSURE SHIFTS AND INTERVALS OF WORK FOR EACH

TWENTY-FOUR HOUR PERIOD

Gauge Pressure per Square Inch					
Col. 1 Minimum Number of Pounds	Col. 2 Maximum Number of Pounds	Col. 3 Maximum Total	Col. 4 Maximum First Shift in Compressed Air	Col. 5 Minimum Rest Interval in Open Air	Col. 6 Maximum Second Shift in Compressed Air
Normal	18	8	4	½	4
18	26	6	3	1	3
26	33	4	2	2	2
33	38	3	1½	3	1½
38	43	2	1	4	1
43	48	1½	¾	5	¾
48	50	1	½	6	½

The employer may determine the time of each shift when the pressure is less than eighteen pounds, provided that the total for the two shifts does not exceed eight hours.

Decompression

5. No person employed in compressed air shall be permitted to pass from the place in which the work is being done to normal air, except after decompression in the intermediate lock as follows:

A stage decompression shall be used in which a drop of one-half of the maximum gauge pressure shall be at the rate of five pounds per square inch per minute. The remaining decompression shall be at a uniform rate and the total time of decompression shall equal the time specified for the original maximum pressure.

(a) Where the air pressure is greater than normal and less than fifteen pounds to the square inch, decompression shall be at the minimum rate of three pounds per minute.

(b) Where the air pressure is fifteen pounds or over and less than twenty pounds to the square inch, decompression shall be at the minimum rate of two pounds per minute.

(c) Where the air pressure is twenty pounds or over and less than thirty pounds to the square inch, decompression shall be at the minimum rate of two pounds per minute.

(d) Where the air pressure is thirty pounds or over to the square inch, decompression shall be at the minimum rate of one pound per minute.

The time of decompression shall be posted in each man lock.

6. Decompression lock shall be in charge of a special employee whose duty it shall be to be in attendance at the lock during the periods of decompression and to regulate the valves controlling the supply of air and the rate of pressure.

7. A record of men employed under air pressure shall be kept by a special employee who shall remain outside the lock near the entrance. This record shall show the period of stay in the air chamber of each employee and the time taken for decompression.

Temperature, Lighting, Sanitation

8. The following provisions shall be observed in the conduct of air pressure work:

(a) The temperature of all working chambers which are subjected to air pressure shall, by means of after-coolers or other suitable devices, be maintained constantly at a temperature not to exceed 85° Fahrenheit.

(b) All lighting in compressed air chambers shall be by electricity only. In cases of emergency portable electric lamps shall be used, which shall be provided by the contractor. Lighting in tunnels and working chambers shall be supplied from a different circuit from that supplying lights in shafts.

(c) All passages shall be kept clear and properly lighted.

(d) No nuisance shall be tolerated in the air chamber and smoking shall be strictly prohibited in air chambers.

Air Supply, Exhaust Valve and Telephone Communication

9. The air supply pipe shall be carried to and within one hundred feet of face of tunnel. The air shall be analyzed at least once in every twenty-four hours, and record of such analysis shall be kept at medical officer's office. The amount of CO_2 shall never exceed one part in one thousand.

Exhaust valves shall be operated at intervals, especially after a blast. The men shall not be permitted to resume work after a blast until the smoke and gas have cleared sufficiently.

There shall be means of communicating by telephone at all times between the working chamber, the outside thereof and the power house on the surface.

Shafts, Locks, Bulkheads and Screens

10. *Whenever a shaft is used, such shaft shall be provided, where space permits, with a safe, proper and suitable staircase for its entire length, with landing platforms not more than twenty feet apart. Where this is impracticable suitable ladders shall be installed, subject to the approval of the Commissioner of Labor and Industries or his representative.*

Shafts shall be subjected to a hydrostatic pressure of one hundred pounds per square inch, at which pressure they shall be absolutely tight and stamped on the outside shell about twelve inches from each flange, showing the pressure to which they have been subjected.

All man shafts shall be properly lighted, as required by the Commissioner of Labor and Industries or his representative.

Locks, reducers and shafting used in connection with caissons shall be riveted construction throughout. The material used in the manufacture shall be not less than one-quarter inch steel plate.

All necessary instruments shall be attached to all caisson and air locks showing the actual air pressure to which men employed therein are subjected. They shall include pressure gauge, timepiece and thermometer, and shall be accessible to and in charge of a competent person.

All outside caisson air locks shall be provided with a platform not less than forty-two inches wide and provided with a guard rail forty-two inches high.

All caissons, whether circular, square or rectangular in form, more than ten feet in diameter or length, shall be provided with a man lock and shaft for the exclusive use of the men to be equipped with a timepiece and gauge, to be heated to 70° Fahrenheit during the months when heating is necessary, with valves so arranged that the lock can be operated from within and without.

Locks shall be so located that the distance between the bottom door and water level shall be no less than three feet.

In addition to the gauge in the locks, an accurate gauge shall be maintained on the outer and inner side of each bulkhead. These gauges shall be accessible at all times and shall be kept in accurate working order.

Wherever space permits, each bulkhead shall have at least two locks in perfect working order. The man lock shall be large enough so that employees who use it shall not be obliged to assume a cramped position. The emergency lock shall be large enough for an entire working shift. Every lock shall be lighted by electricity, shall contain a pressure gauge and timepiece and have a nonshatterable bull's eye in each door or in each end. Valves must be so arranged that the locks can be operated from within and without. Each man lock shall be in charge of a competent lock tender, whose hours of labor shall be governed by those set down in the schedule governing compressed air workers.

Intermediate bulkheads with locks, or intermediate safety screens, or both may be required by the Commissioner of Labor and Industries in tunnels. The distance from such intermediate bulkheads or safety screens to the heading shall not be greater than that prescribed by the Commissioner.

Medical Attendance and Regulations

11. *Any person or corporation, carrying on any tunnel, caisson or other work in the prosecution of which men are employed or permitted to work in compressed air, shall while such men are so employed, also employ and keep in employment one or more duly qualified physicians to act as medical officers, who shall be in attendance*

at all times while such work is in progress so as to guarantee constant medical supervision of men employed in compressed air work. Said medical officer shall also be charged with the duty of enforcing the following regulations:

(a) No person shall be permitted to work in compressed air until after he has been examined by such medical officer and reported by such officer to the person in charge thereof as found to be qualified, physically, to engage in such work.

(b) No person not having previously worked in compressed air shall be permitted during the first twenty-four hours of his employment to work for longer than one half day period (as provided in rules for compressed air work adopted by the Department of Labor and Industries), and after so working shall be re-examined and not permitted to work in a place where the gauge pressure is in excess of fifteen pounds unless his physical condition be reported by the medical officer, as heretofore provided, to be such as to qualify him for such work.

(c) In the event of absence from work, by an employee, for ten or more successive days for any cause, he shall not resume work until he shall have been re-examined by the medical officer, and his physical condition reported, as heretofore provided, to be such as to permit him to work in compressed air.

(d) No person known to be addicted to the excessive use of intoxicants shall be permitted to work in compressed air.

(e) After a person has been employed continuously in compressed air for a period of two months he shall be re-examined by the medical officer, and he shall not be allowed, permitted or compelled to work until such examination has been made, and he has been reported, as heretofore provided, as physically qualified to engage in compressed air work.

(f) Such medical officer shall at all times keep a complete and full record of examinations made by him, which record shall contain dates on which examinations are made and a clear and full description of the person examined, his age and physical condition at the time of examination (including height and weight) also the statement as to the time such person has been engaged in like employment. This medical officer shall also keep an accurate record of any caisson or or other disease incapacitating any person for work that shall occur in the operation of a tunnel, caisson or other compartment in which compressed air is used. These records shall be open to the inspection of the Department of Labor and Industries or its representatives, and a copy thereof shall be forwarded to said Department within the forty-eight hours following the occurrence of the accident, death, injury or caisson disease, stating as fully as possible the cause of said death or caisson or other disease and the place where the injured or sick person has been taken, and such further information relative thereto as may be required by said Department.

(g) Properly heated, lighted and ventilated dressing rooms shall be provided for all employees engaged in compressed air work. Such rooms shall contain metal lockers and benches and shall be open and accessible to men during the intermission between shifts. Bathing accommodations equipped with running hot and cold water service shall be provided: also suitable and adequate toilet accommodations, at the ratio of not less than one for every twenty-five men employed.

(h) Whenever compressed air work is carried on during the period from October 1 to April 1 a covered passageway shall be provided from the opening into the caisson or tunnel to the lockers or dressing rooms of the employees.

(i) A medical lock at least six feet in height shall be established and maintained in connection with all work in compressed air. Such lock shall be kept properly heated, lighted and ventilated, and shall contain medical and surgical equipment. Such lock shall be in charge of the medical officer. The patient's chamber in the

medical air lock shall be so arranged that the patients may be kept under constant observation through a non-shatterable glass window without the necessity of the attendant entering the chamber.

(j) A liberal supply of hot coffee and sugar shall be provided and served to the men during work in compressed air. The coffee must be heated by means other than direct steam and shall be supplied to the employees free of charge. It shall be the duty also and the joint responsibility of the contractor, persons or corporation employing the medical officers to enforce these rules governing the medical officer's duty.

(k) Identification Badge. An identication badge, such as approved by the Department of Labor and Industries, shall be furnished to all employees, advising police officials that the employee is a compressed air worker, stating the location of medical lock and stating that in cases of emergency an ambulance surgeon shall remove the patient to the medical lock and not to the hospital.

Fire Prevention

12. *All reasonable precaution shall be taken against fire hazards and such regulations as may be prescribed by the Commissioner for protection against fire shall be promptly complied with.*

Posted Copies of the Labor Law

13. *Copies of such sections of the labor laws as apply shall be furnished by the Department of Labor and Industries to the person in charge and posted by him in a conspicuous place at the entrance to each work place.*

4–11. Casting Concrete in Caissons

a. In casting the concrete, tubes or buckets may be used in the ordinary open caisson. In the pneumatic caisson buckets are used exclusively. As the concrete is cast, in open well caissons, the men, provided with safety ropes and signals, gradually work up on the bracing, rings or other transverse support. In the lagged shell, the steel rings are removed as concreting progresses and the lagging is often allowed to remain. The steel shells are withdrawn as that section of the caisson is being filled. As the pneumatic caisson employs steel shells, these too are removed through the lock, as for the open well type.

4–12. Steel Piles

a. Steel piles are used quite frequently where bedrock or hard pan can be reached at a depth of about 70 feet or less. The units may be steel tubes or structural shapes. When tubes are used they vary from 8″ to 16″ in diameter and the wall thickness of the tubes averages about ⅜″. The tubes come in lengths of about 20 feet and usually the pile will be confined to a length of 40 feet so as to involve only one joint. The joining is done by the insertion of inside sleeves, wedged and shouldered into place. Structural shapes are used for greater depths and are spliced to increase the reach of the pile. Because of the greater strength of these shapes it is possible to drive them through ground which would exclude other types of piles.

b. Both piles are driven by the usual air or steam hammers. The tubular piles, after being driven with open ends, are blown out by the use of

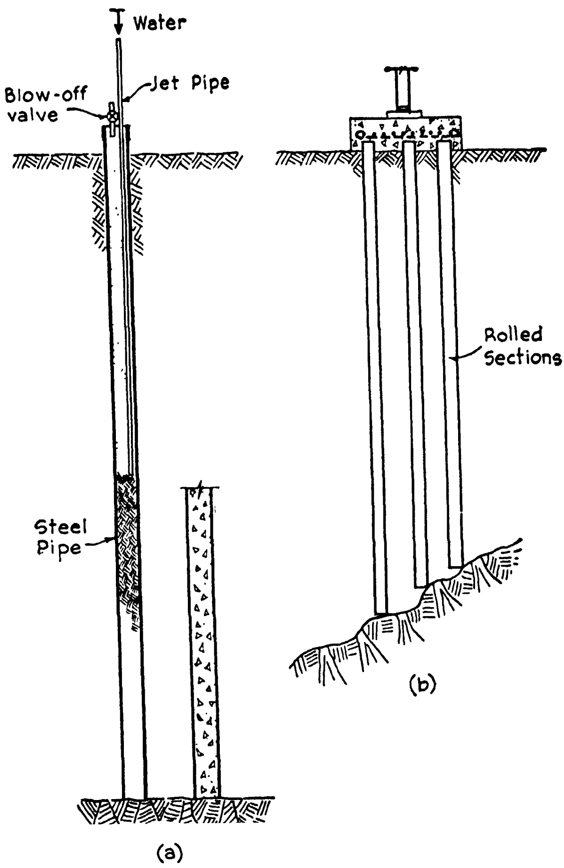


FIG. 4–11. Steel Piles. (a) pipe; (b) structural shapes.

compressed air or water jets. After cleaning they are frequently filled with concrete. The structural shapes are left just as driven. When these piles are squarely seated they provide the highest load valves of any pile foundation. Rusting is negligible, as the piles are always below the water table. One of the objections to rolled steel piles is the likelihood of the introduction of eccentric loads into the column because of uneven bearing as shown in Figure 4–11. This is readily overcome in the tubular piles by introducing a chambering charge at the base of the tube after it is blown out, and before concreting is started. It is impossible to accomplish this same correction when structural shapes are used.

c. The City of New York requires that tubular steel piles be faced perpendicular to the axis of the tube. It also allows only one splice in any one pile. The length of the pile is limited to forty times the inside diameter. The loads which may be safely applied to these piles are specified as not more than 500 pounds per square inch on the concrete and 7500 pounds per square inch on the steel.

CHAPTER 5

STRUCTURAL FRAMES

5-1. Types of Frames

a. There are two major types of structural frames for first class buildings. One is the full, skeleton frame in which columns are provided to support all elements of the structure. The other is the interior frame and uses the exterior walls for circumferential bearing or support. Reinforced concrete and structural steel may be used for either, or both materials may be used in combination with either type. Many engineers hold preferences for one type or another. Nevertheless, the best type will be definitely related to cost in any particular case.

b. For buildings more than ten stories in height structural steel is usually more economical. For buildings not so high, reinforced concrete gives very economical results. Where the exterior walls are thick for protective and architectural reasons, they usually are made to work. A more recent combination allows the exterior walls to carry only themselves and provides exterior columns which carry the floors and furring only. In these frames the exterior walls are anchored to the frame, but do not rest upon it.

c. When a building rests upon compressible soils, which may cause differential settlement, concrete frames are more desirable than structural steel frames. Concrete has a plastic flow which takes place at about the same rate as the strains imposed by settlement. Structural steel, on the contrary, refers high stresses to the concrete encasement due to the same amounts of settlement.

d. There are many variations of the use of structural steel and concrete in combination which may be desirable expedients in special cases. One of these is the use of structural steel for columns and light erection ties of structural steel. The entire floor system is of reinforced concrete. This system necessitates provision for the support of concrete beams upon brackets on the column. A common detail used for this support is shown in Figure 5-1.

5-2. Architectural Plans

a. A study of any set of architectural plans reveals that they furnish through plans, sections, elevations and scale details the conventional representation of:

(1) exterior walls defining the plan,
(2) exterior wall openings,
(3) positions subdividing the floor areas,
(4) stair and elevator shafts,
(5) column center lines and members,
(6) room numbers and names,
(7) ceiling heights and other vertical dimensions,
(8) materials used for walls, floors and finish (finish schedules), and
(9) location of heating, lighting and sanitary equipment.

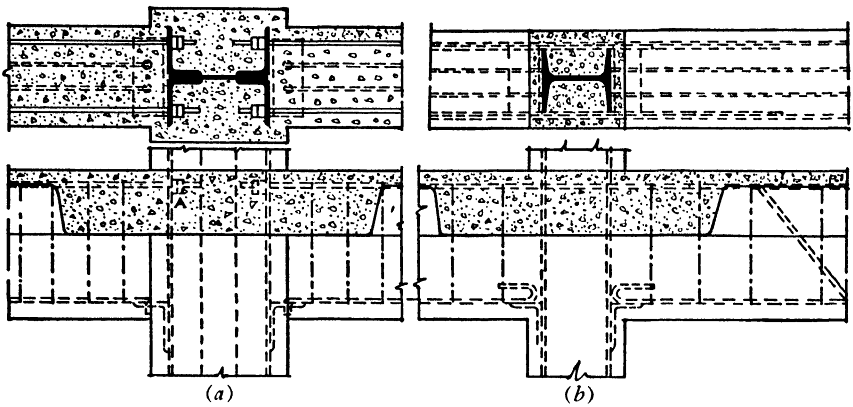


FIG. 5-1. Combination Reinforced Concrete and Structural Steel Frame. (a) discontinuous reinforcement; (b) continuous reinforcement.

b. The purely architectural plans are, of course, further augmented by structural, heating and ventilating, electrical and plumbing plans. When the architect's preliminary sketches are approved by his clients, the engineers are brought into the problem and prepare the framing, the heating, the ventilating, the electrical and plumbing plans.

5-3. Relation of the Frame to the Architectural Plans

a. In preparing the structural plans the structural engineer decides upon the type of frame and the materials to be used. When these matters are decided upon the engineer makes his preliminary studies. Using the architect's plan of a typical floor, he locates the columns, places the beams and girders in places where they will carry most of the directly indicated loads, such as fixed partitions, openings in the floor and the like. The columns and beams must be located so they will not adversely affect the architectural treatment of rooms and ceilings. They must be of such a size and so located that they will not interfere with properly planned mechanical services. If any serious discrepancies are developed in the architectural plans by the study of the structural plans these must be corrected either structurally or architecturally. Only years of experience in structural design can give an engineer that discriminating judgment which almost always results in the most economical solution.

b. Perhaps as good an illustration of the relation between architectural and structural plans is shown in Figures 5–2 and 5–3, where Figure 5–2 shows the architecural plan of the second floor of a residence in New York City and Figure 5–3 the structural plan of the same floor. One should compare these two plans and note:

(1) location of columns,
(2) relation of beams and girders to plan,
(3) openings in the floor structure,
(4) relation of frame to the continuity of the structural slab, and
(5) provisions for hiding the structural elements in architecturally unimportant places, or of making them a part of the scheme.

5-4. Structural Plans

a. When the architect's preliminary sketches are approved by his client, the structural engineer is consulted on the general framing plans and the foundation layout. The latter involves consideration of information furnished by borings at critical points on the site and by any information the engineer may obtain by consulting the city records of previous adjacent work. The former requires conferences to determine how the frame may affect the architectural treatment of the building both exteriorly and interiorly. The decisions made at such conferences impose certain limitations on both the architect and engineer and each should strive to fix certain basic elements early in the process of planning. Thereafter the architect will have to use his ingenuity to conceal the frame in the fireproofing and finish. These studies establish the type and materials to be so used. The engineer should be conversant with the local building code, particularly with respect to loads and design stresses.

b. The several plans which the engineer must prepare will, of course, vary with each building, but generally they will include the following:

(1) foundation plan,
(2) column center line plan,
(3) floor plans,
(4) roof plan,
(5) column schedule,
(6) beam schedule (for reinforced concrete frame),
(7) slab, or floor arch schedule (this may be a part of the several floor plans), and
(8) details, sections and diagrams (as required for lucidity).

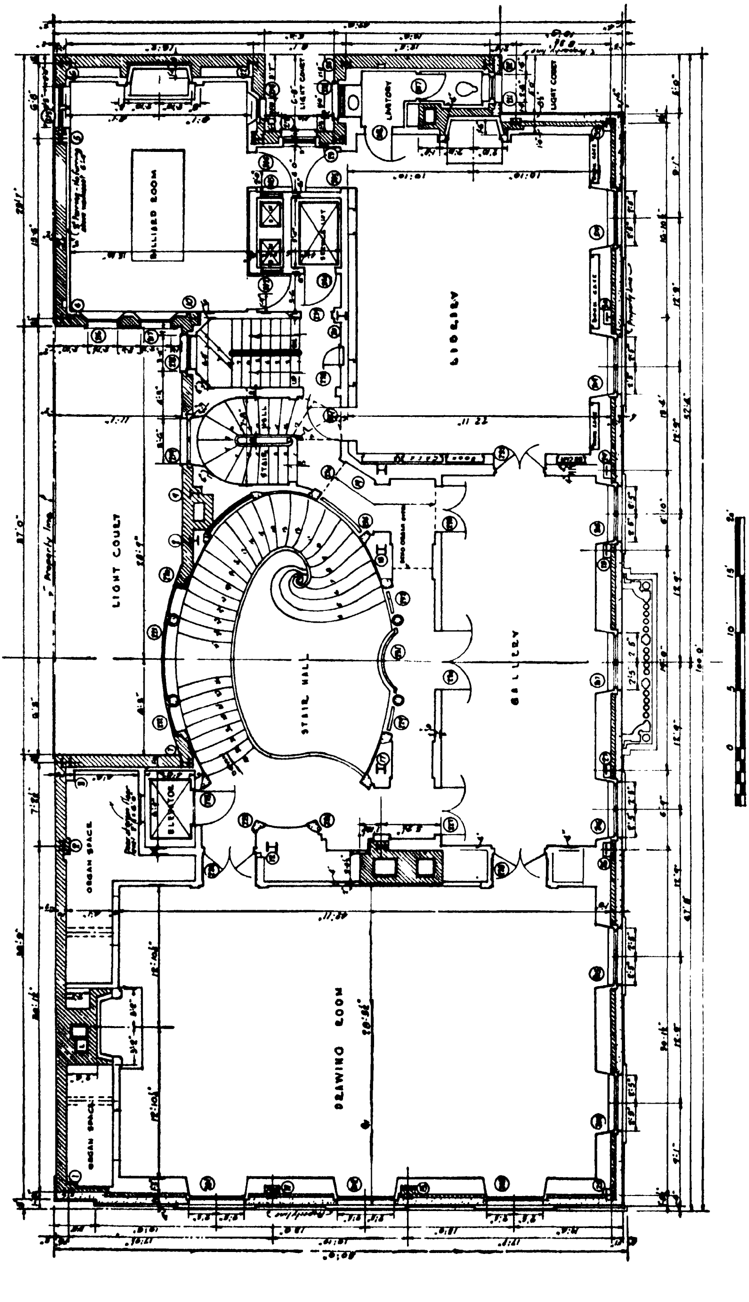


Fig. 5-2. Architectural Floor Plan.

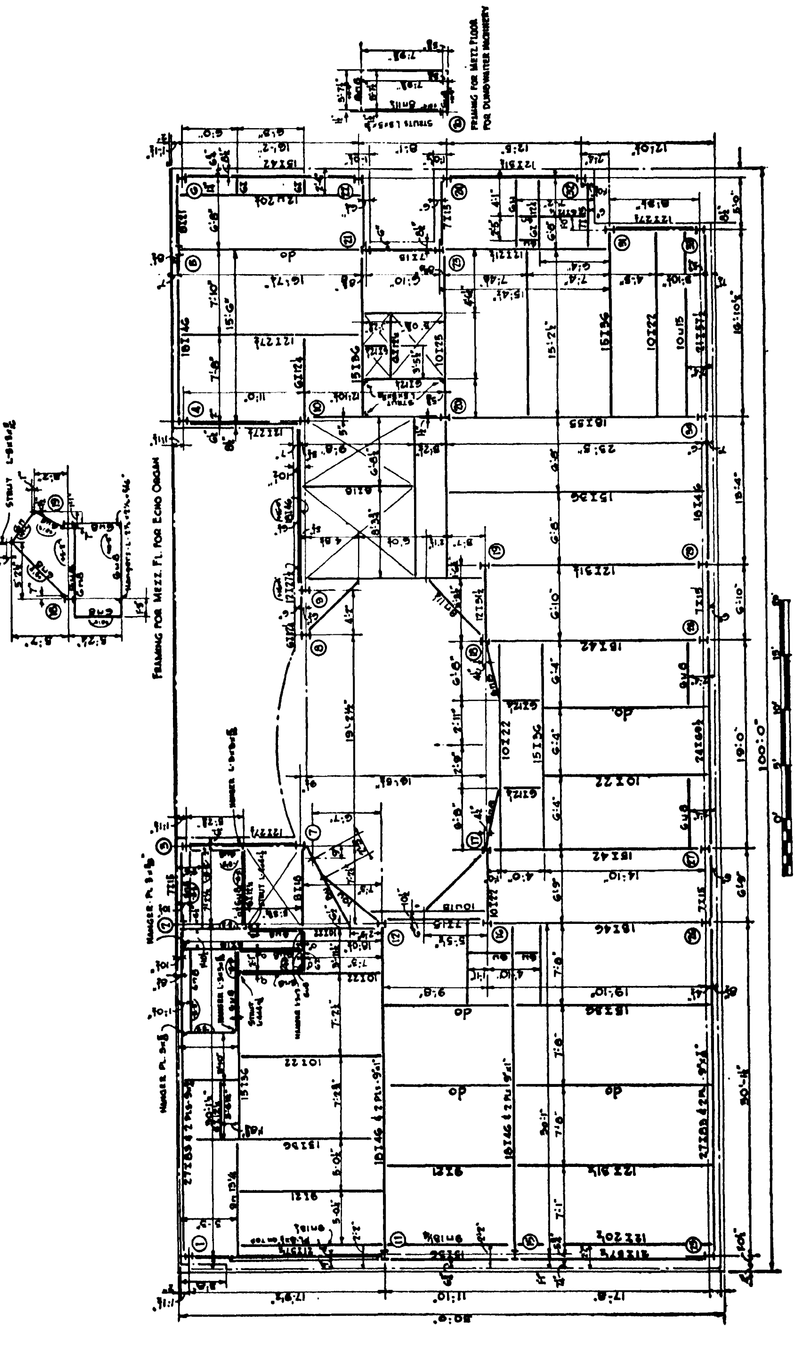


FIG. 5-3. Structural Floor Plan.

These plans are usually numbered S1, S2, etc., while the architectural plans will carry numbers 1, 2, etc. Later, when the erection plans are prepared by the fabricator they may carry the numbers E1, E2, etc.

c. The foundation plan will give the dimensions necessary for all basement walls, their reinforcement, if any; the location, dimensions and reinforcement of column foundation slabs or grillages; and carefully prepared elevations for all walls and foundations up to the underside of the columns are given on the column schedule.

d. The column center line plan is often omitted as a separate sheet and the information combined with the foundation plan. The importance of care in checking these dimensions or this plan cannot be overemphasized.

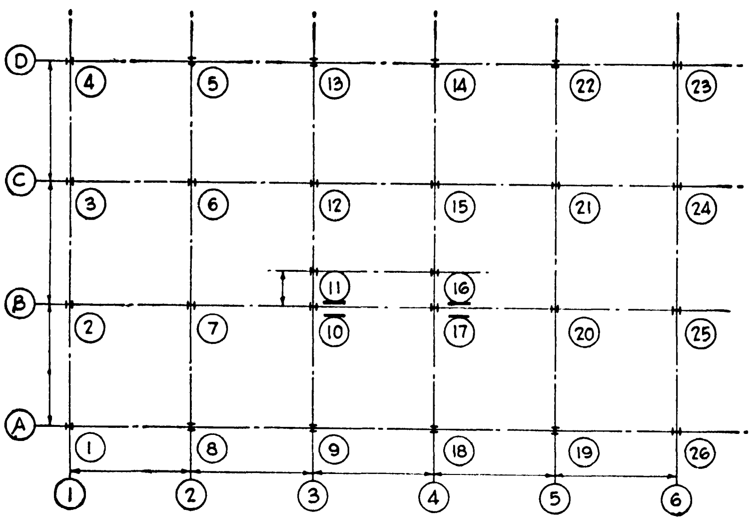


FIG. 5-4. Numbering Columns.

For multi-story buildings, errors in these plans may be very embarrassing. The columns are numbered, and two methods for such designation are common. One of these methods employs a system of coordinates as shown in Figure 5-4 while another method merely designates the columns consecutively as shown. At any rate a conveniently understood and obvious method should be used, as many references in correspondence about the job will refer to these numbers.

e. The floor plans prepared by the structural engineer should be sufficient to delineate the structure for each floor which has significant variations in its framing. Thus one may find a First Floor Framing Plan, a

Second Floor Framing Plan, a Typical Floor Framing Plan and a Roof Framing Plan. There will be times when the design of the building allows the engineer to combine several floors on one sheet. In this instance he will prepare it for the principal floor involved, and give the variations where they occur for the other floors involved, by noting that a beam, a dimension or some other structural detail is added or omitted for the varying floor. The engineer should preferably number every beam. This avoids the establishment of special numbers later when it may be found that some of the beams vary in some detail or another. Some engineers do not number the beams at all, but simply give their sizes. This is not too bad in the case of the structural steel frame, but is unfortunate in the case of the reinforced concrete frame. The completely numbered plan makes references on the design calculation sheets easy, and later the fabrication details and erection plans are more simply and correctly prepared.

f. The column schedule is an important reference sheet for the preparation of estimates and details. Figure 5–5 shows a typical schedule for the structural steel frame, and Figure 5–6 shows the schedule for a typical reinforced concrete frame. It will be noted in the case of the structural steel frame that the floor elevations, the sizes of the sections, the splice joints, plate girders and truss supports and column design loads are all a part of the schedule. The footings are often added at the bottom of the schedule. Although the schedule is in columnar form, the vertical dimensions should always be to a definite scale to afford a check on floor elevations. In the reinforced concrete column schedule, the dimensions affecting height and floor lines are similarly given, but in addition the cross section of the column is shown and all of the reinforcement, such as vertical steel, spirals or ties and splices, is shown. It will also be noted that these schedules make it simple to prepare estimates, and it must be kept in mind that this information should be complete and clear.

g. When the reinforced concrete frame is used, a beam schedule should always be prepared. Figure 5–7 shows such a schedule. An examination of this schedule will reveal that the careful engineer furnishes the general details of the shape by showing beam sections and elevations, and that all of the reinforcement is specified as to size, length, location and bending. This schedule is necessary to afford the contractor the information for proper estimates of cost. Merely to number the beam, give its nominal size, the area of tension and compression steel, and the number and sizes of stirrups, is poor practice. If the contractor is confronted with such a drawing, he should prepare his own beam schedule and obtain the engineer's approval, before committing himself to a hard and fast bid.

h. The floor arches (Chapter 6) are often detailed on one or another of the floor framing plans, but a separate sheet giving this information is

Floors \ Col. Nos	1	2	2A	3	4	5	6	7	8	9
Pent House Roof Gr. 193'-1"	X	X		X	X	X	X	X		
Mach. Room Gr. 184'-1"	X	X		X	X	X	X	X		
Roof (Top of Cols. 175'-6")	64.5	95.1		71.0	58.8	58.8	58.8	58.8	58.8	61.3
H.Pt. Gr. 173'-1" 15th 10'-1"	8BH32 (1-10in15.3) 93.3	8BH39.5 151.5		8BH32 110.3	8BH32 92.2	8BH32 92.2	8BH32 92.2	8BH32 92.2	8BH32 92.2	8BH32 95.3
14th 9'-11"	115.0	194.1		140.2	117.0	117.0	117.0	117.0	117.0	121.0
13th 9'-7"	8BH39.5 139.7	8BH62.5 239.5		8BH44 171.4	8BH39.5 143.8	8BH39.5 143.8	8BH39.5 143.8	8BH39.5 143.8	8BH39.5 143.8	8BH39.5 148.7
12th 9'-7"	161.4	281.8		200.8	168.6	168.6	168.6	168.6	168.6	174.6
11th 9'-7"	8BH48.5 183.7	10BH83.5 325.7		10BH60.5 231.6	10BH55 194.4	10BH55 194.4	10BH55 194.4	10BH55 194.4	10BH55 194.4	10BH55 201.5
10th 9'-7"	205.8	368.5		261.5	219.7	219.7	219.7	219.7	219.7	227.9
9th 9'-7"	10BH60.5 229.3	10BH106.5 415.6		10BH77.5 294.2	10BH66 249.4	10BH66 249.4	10BH66 249.4	10BH66 249.4	10BH66 249.4	10BH66 256.6
8th 9'-7"	252.8	462.3		326.5	275.0	275.0	275.0	275.0	275.0	285.5
7th 9'-7"	10BH72 276.3	10BH130 509.0		10BH95 360.6	10BH77.5 302.6	10BH77.5 302.6	10BH77.5 302.6	10BH77.5 302.6	10BH77.5 302.6	10BH83.5 314.4
6th 9'-7"	300.0	556.1		392.6	330.5	330.5	330.5	330.5	330.5	343.5
5th 9'-7"	10BH89 328.3	12BH154.5 606.0		10BH112 427.9	10BH95 360.3	10BH95 360.3	10BH95 360.3	10BH95 360.3	10BH95 360.3	10BH100.5 374.6
4th 9'-7"	366.7	663.1		461.1	397.6	397.6	397.6	397.6	397.6	413.1
3rd 9'-7"	10BH106.5 402.0	12BH169 2'-4" Girder	4'-1½" 581.9 Girder	12BH183 695.3	10BH112 431.8 1'-5⅝"	10BH112 431.8	10BH112 431.8 1'-5⅝"	10BH112 431.8 2'-6"	10BH112 431.8 1'-5⅝"	10BH118 450.6 2'-6"
2nd 15'-1"	449.2	X	640.8	775.2 2'-6"	Girder	1001.7	Girder	1001.7	Girder	753.0
1st 13'-9"	10BH118	X	12BH169	12BH190 805.8	X	12BH190 2-24x1" 1035.4	X	1035.4	X	12BH140 2-24x⅜ Pl. 781.1
Bsmt 6'-10"		X			X		X		X	
Gr. 12'-0"		X			X		X		X	
Gr. Top of Plate	17'-0"		17'-0"	17'-0"	X	17'-0"	X	17'-0"	X	11'-6"
Size of Bases	24x24 x 3⅝ 728		30x30 x 4 712	34x34 x 4⅝ 670	X	38"x38" x 5⅜ 720	X	38x38 x 5⅜ 720	X	32x32 x 4½ 720
Col. Nos	1	2	2A	3	4	5	6	7	8	9

Fig. 5–5. Steel Column Schedule.

very desirable. When this information is thus segregated, it allows of special detail sections without crowding and confusing the general plans. Certain floor arches can be referred to by notes only and further ampli-

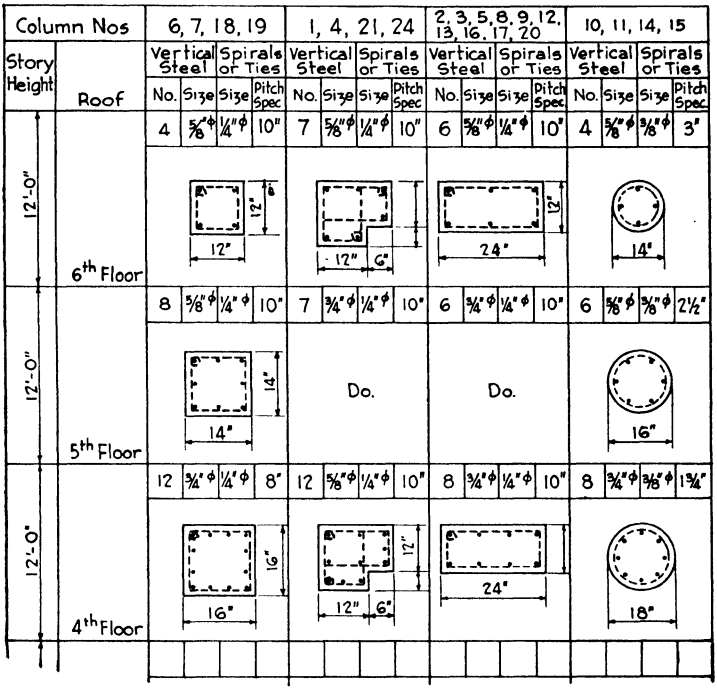


FIG. 5–6. Reinforced Concrete Column Schedule.

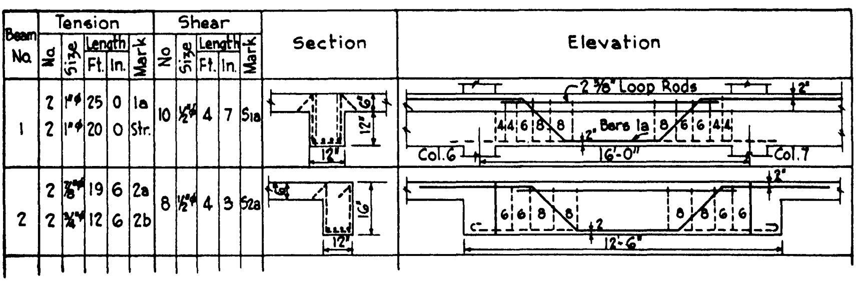


FIG. 5–7. Reinforced Concrete Beam Schedule.

fied by the specifications, while others require considerable detailing. (Figures 5–8 to 5–17.)

i. Perhaps the most important special details or diagrams which the structural steel framing plan should give are related to trusses and plate

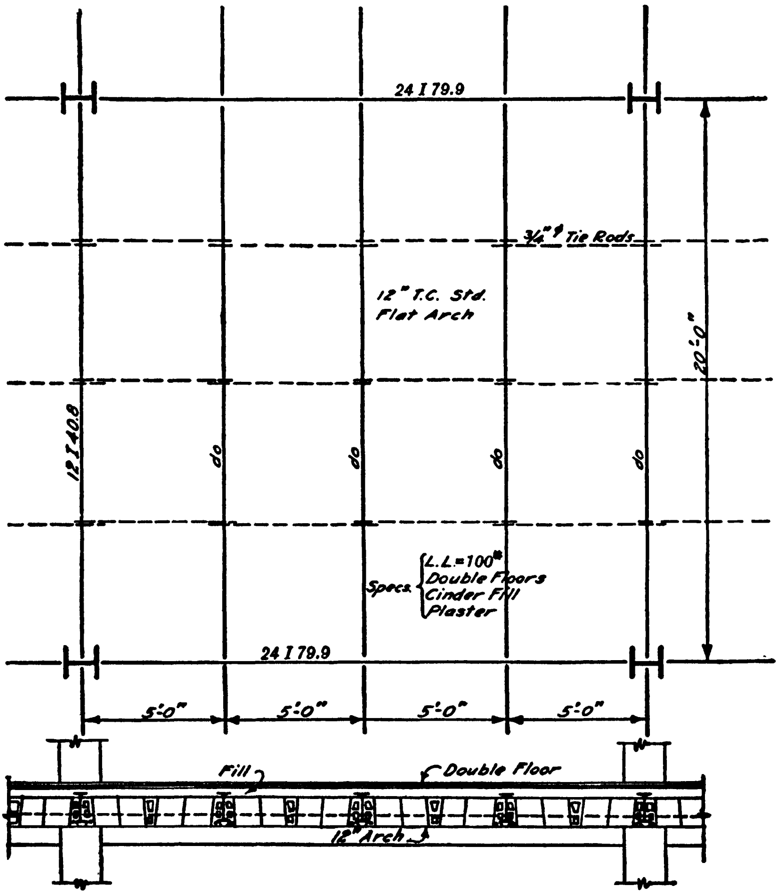


FIG. 5-8. Framing for Terra Cotta Floor Arches.

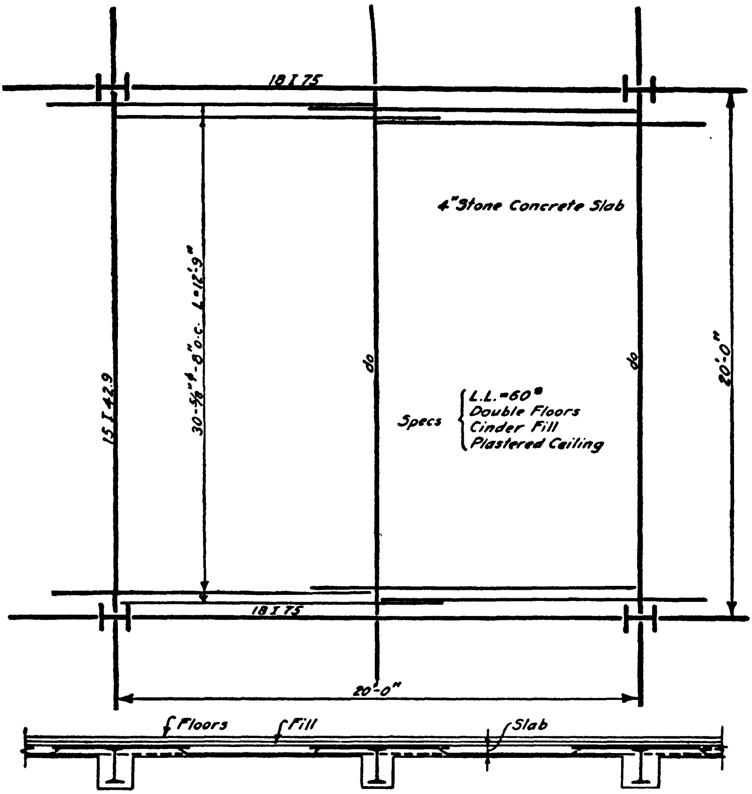


FIG. 5-9. Framing for One-Way Stone Concrete Slab in Steel Frame.

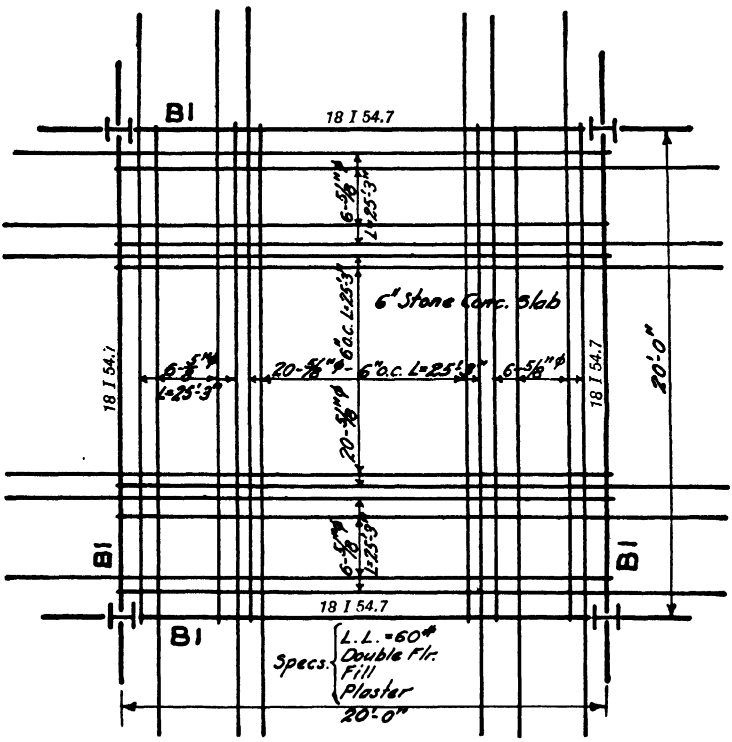


Fig. 5-10. Framing for Two-Way Stone Concrete Slab in Concrete Frame.

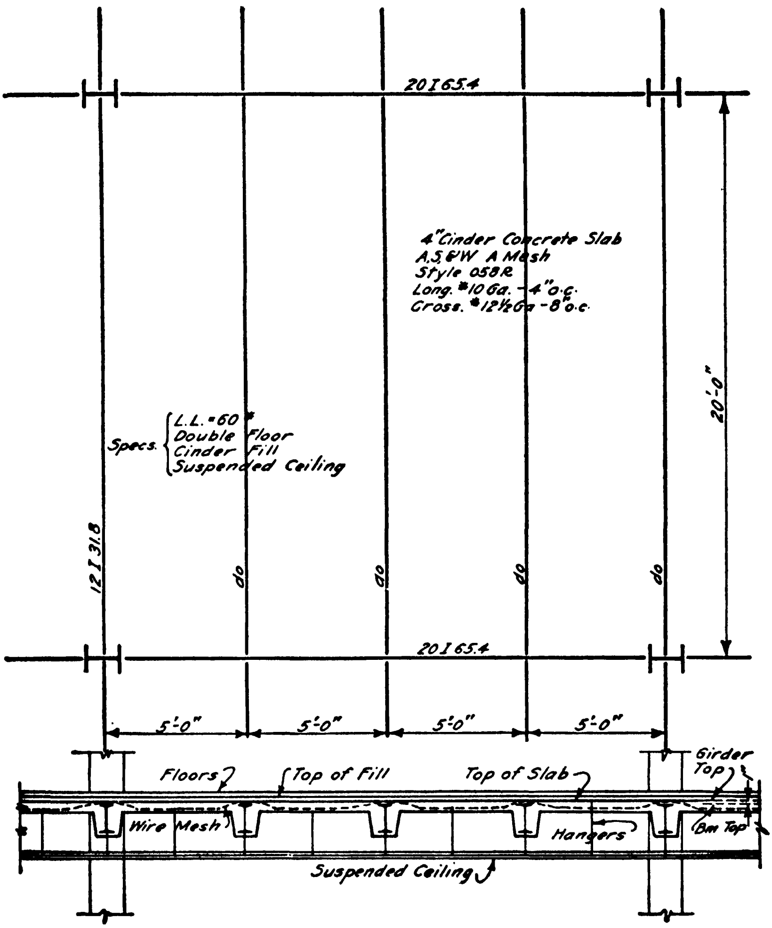


FIG. 5-11. Framing for Cinder Concrete Slab in Steel Frame.

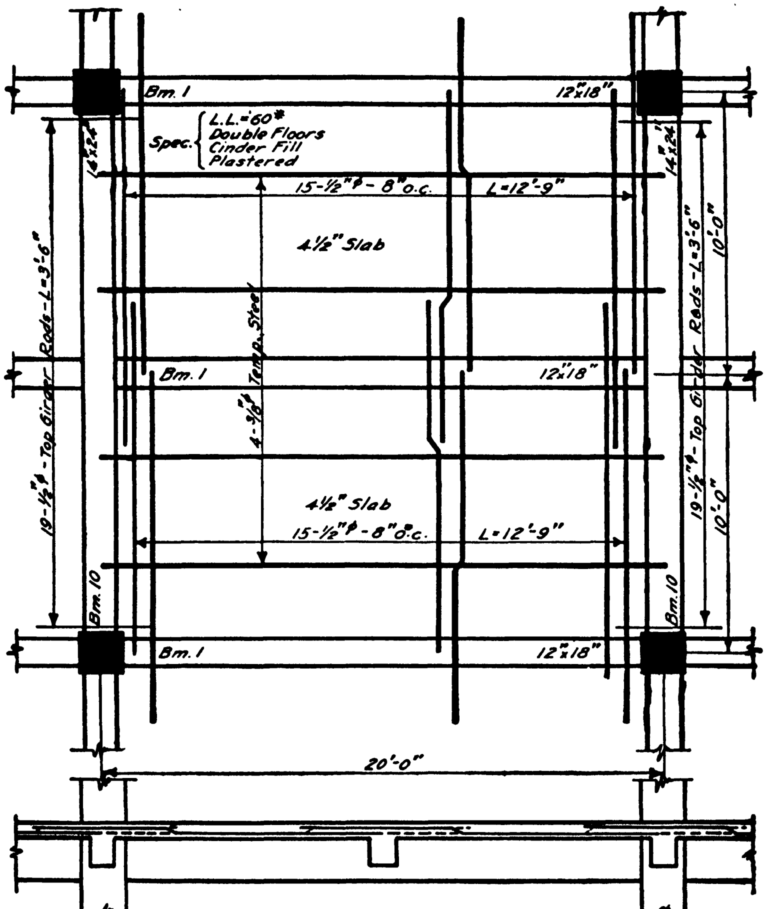


FIG. 5-12. Framing for One-Way Stone Concrete Slab in Concrete Frame.

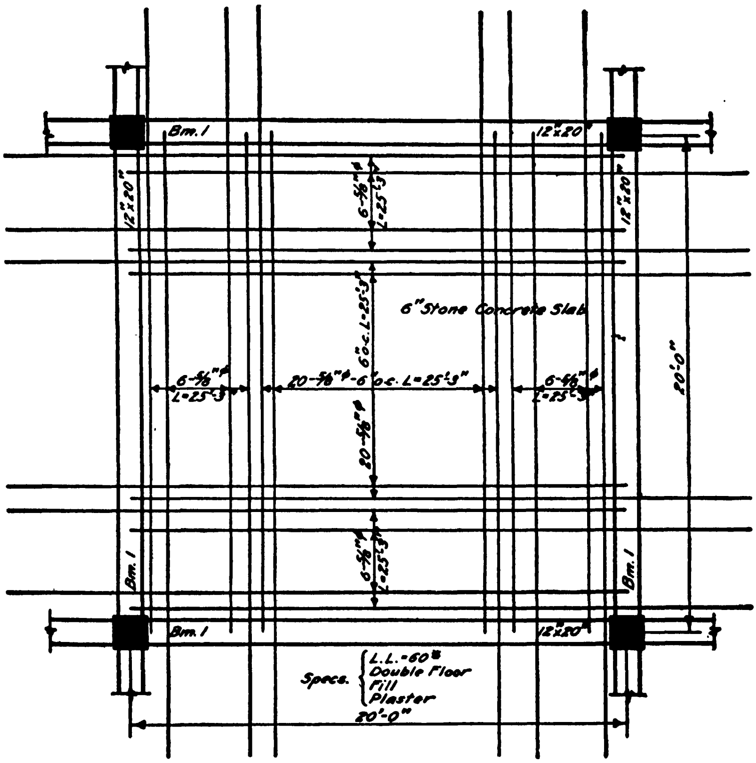


FIG. 5-13. Framing for Two-Way Stone Concrete Slab in Concrete Frame.

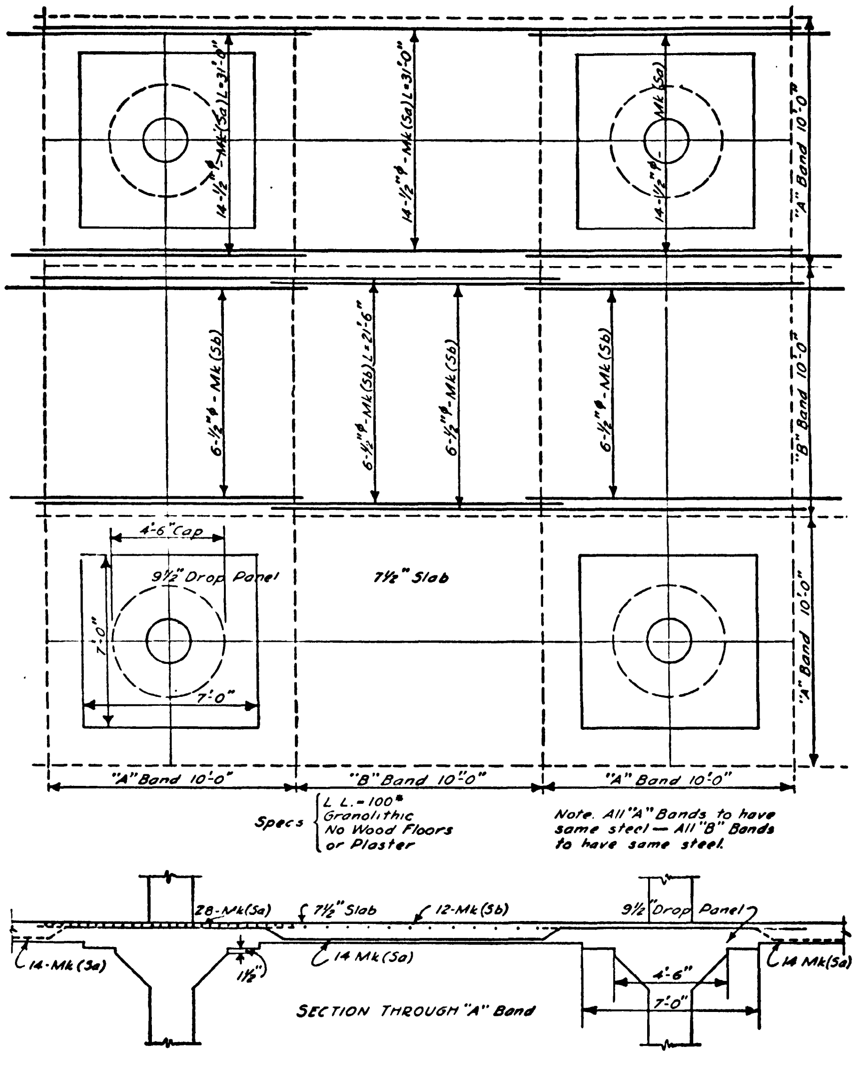


FIG. 5–14. Framing for Flat Slab Concrete Panel.

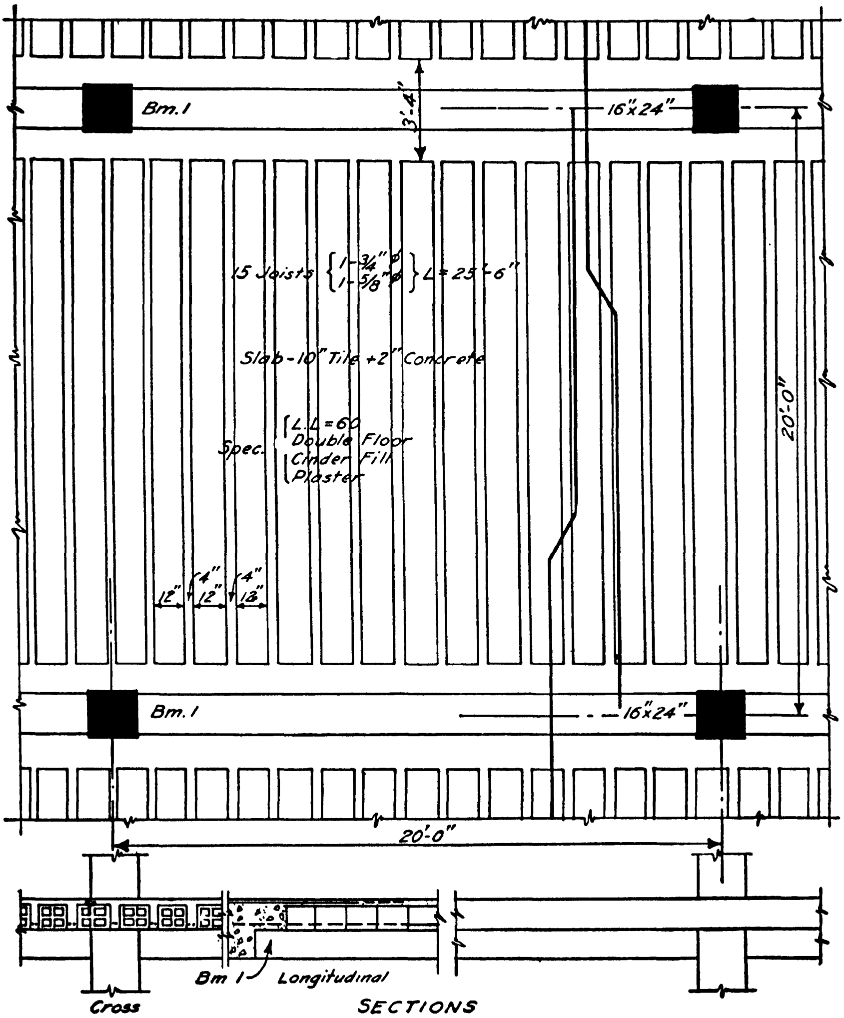


FIG. 5-15. Framing for One-Way Terra Cotta Ribbed Slab in Concrete Frame.

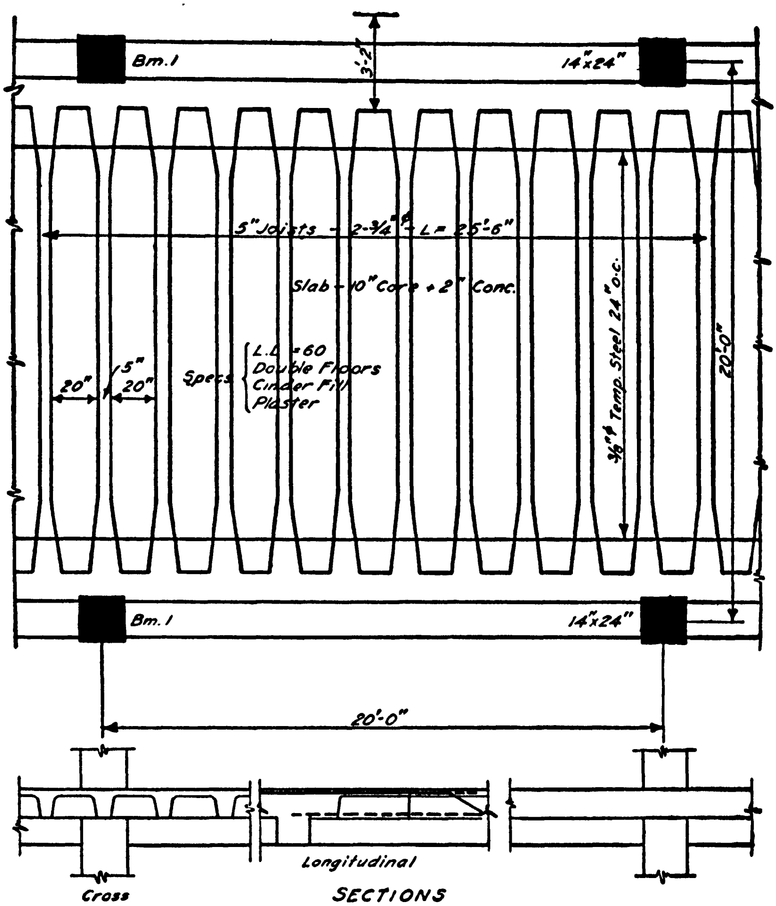


FIG. 5-16. Framing for One-Way Metal Pan Ribbed Slab in Concrete Frame.

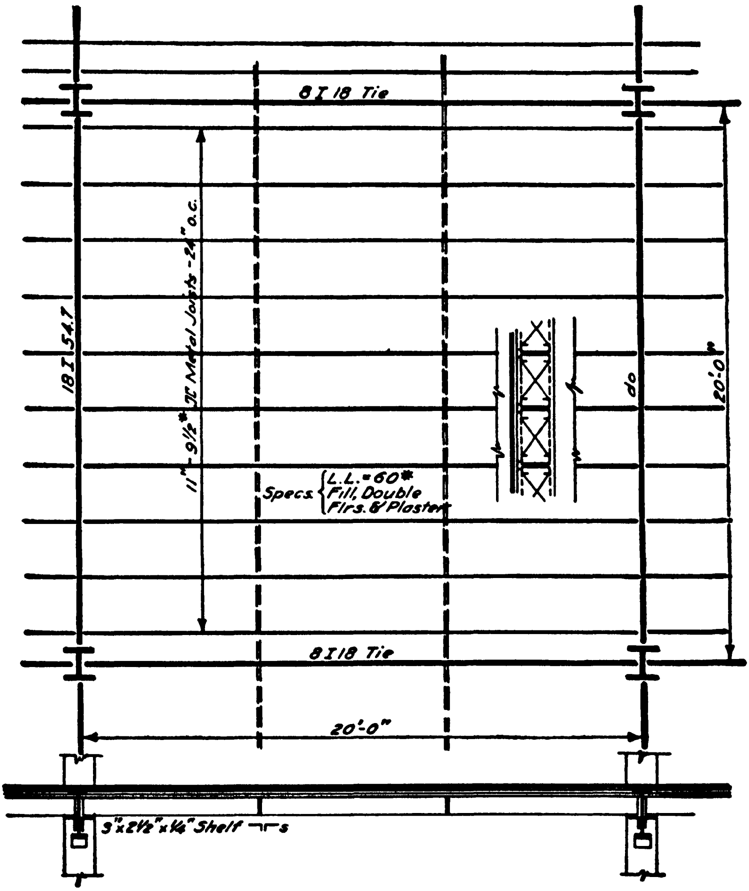


FIG. 5-17. Framing for Steel Joist in Steel Frame.

girders, if used. These are usually given a mark or number such as Tr 3A or Gr 3A. In these conventional numbers the Tr stands for truss, the Gr for girder, the 3 for the floor in which it occurs, and the A for the first type used on that floor. They are indicated on the framing plan as shown in Figure 5–18. It is customary and good practice to show a diagram

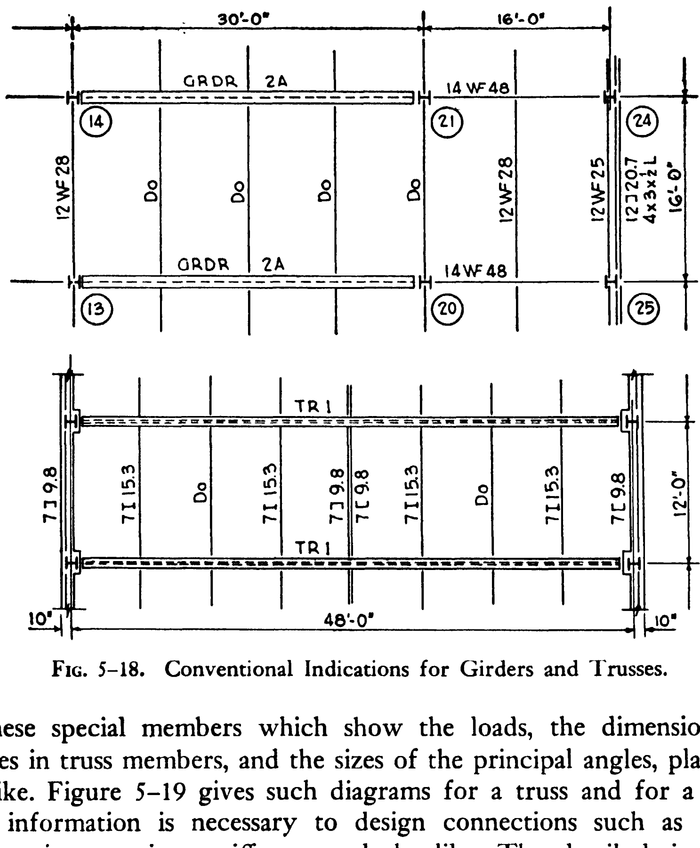


FIG. 5–18. Conventional Indications for Girders and Trusses.

of these special members which show the loads, the dimensions, the stresses in truss members, and the sizes of the principal angles, plates and the like. Figure 5–19 gives such diagrams for a truss and for a girder. This information is necessary to design connections such as gussets, splices, rivet spacings, stiffeners and the like. The detail design is, of course, done by the fabricator when he has been awarded the contract for the steel. The beam schedule as previously described for reinforced concrete takes care of these details when that type of frame is used.

j. Generally, it is advisable to include in the contract structural drawings as many details as possible to convey to the contractor the complete idea which the structural engineer had in mind when he prepared his design. This does not mean that he would design all details and connections. There are certain accepted standards known to engineer and fabricator alike which are always omitted. Where a method contrary to this accepted practice is intended, however, the engineer should show his method clearly.

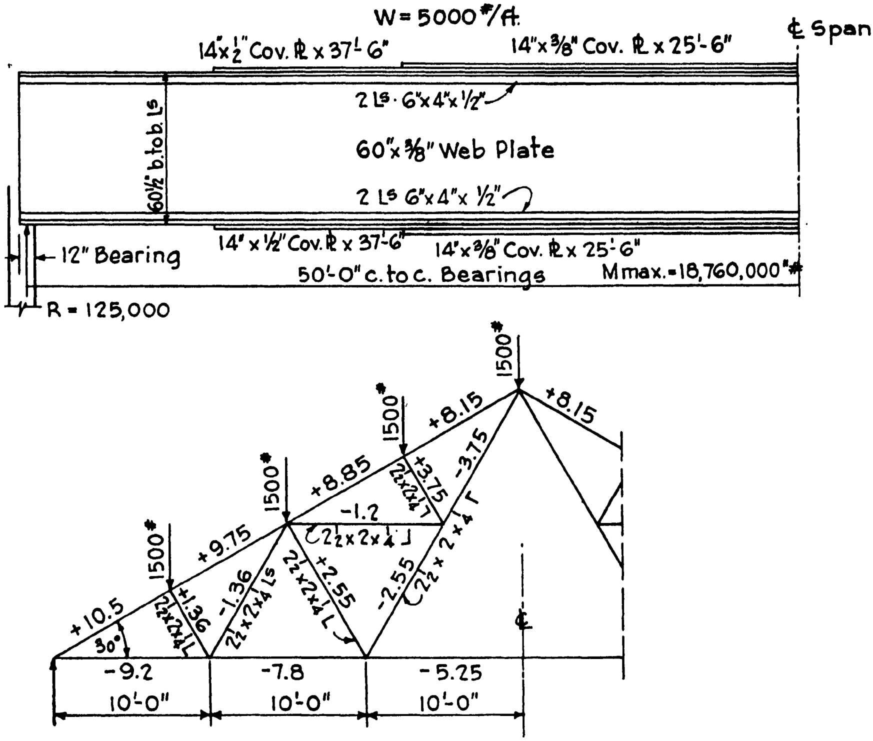


Fig. 5–19. Engineer's Diagrams for Plate Girders and Trusses.

5–5. General Structural Considerations

a. There are several generally accepted principles and details which not only affect the selection of structural sections in the design, but influence the details and erection of the frame. Some of these also apply to reinforced concrete frames. Among these is the practice to frame around openings in the floor such as elevator shafts, stair wells and pipe, duct and wire shafts. The fireproofed steel or the reinforced concrete beams should form the rough size of the opening. Beams should be located so that the ceilings of the rooms below show a degree of symmetry to avoid too many arrises for expensive plaster work. If the plans call for a suspended ceiling the beams can be located in the interest of greatest uniformity and economy and questions of architectural balance do not enter into the details. When a suspended ceiling is used the engineer may also select varying depths of beams in the interest of economy. When the beams are to be exposed they must either be selected of the same depth or the shallower beams must be furred down to match. (Figure 5–20.) Deep

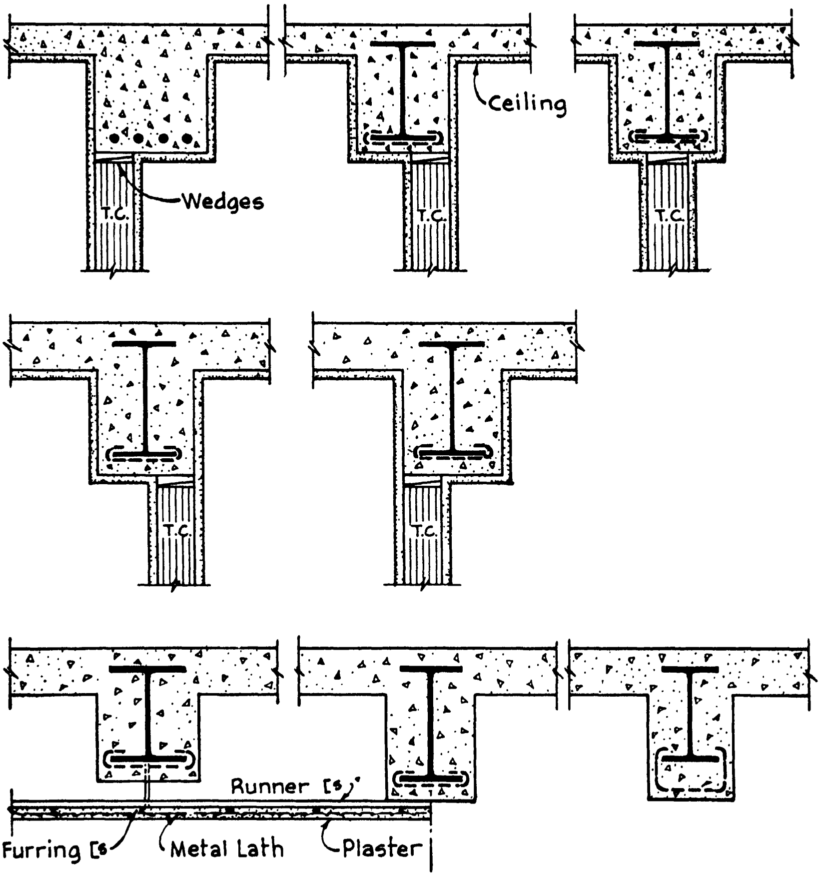


FIG. 5–20. Relation of Beams to Partitions and Ceilings.

beams are not usually framed into shallower beams. Beams framing into girders may be framed with the tops flush or the beams may be dropped down sufficiently to clear the girder flange and thus prevent coping or blocking. Unless complete fixation is required at the columns, beams and girders which frame into columns are supported upon column shelves with top clip angles. Web connection angles are not used. Beams which frame into other beams or girders are connected with web connection angles. (Figure 7–7.)

5–6. Service Plans

a. Included in the plans and documents which are submitted to contractors for estimates and proposal will be separate plans and specifications for the:

(1) heating, ventilating and air-conditioning,
(2) electrical work, and
(3) plumbing.

Each of these sets of plans is prepared by consulting engineers who are retained by the architects to advise on these matters.

b. These services are important adjuncts to the success of each project and must be provided adequate space for equipment needed for their operation. To do this the architect must provide areas, rooms, shafts and spaces for the vertical and horizontal runs of lines leading from centrally located points of power, water, and steam and provide for disposal lines for sewage. It can readily be seen that the construction bears an important relation to these matters. Floor arches, columns, framing members, partitions and shafts must be so designed, detailed and specified that the subcontractor will be able to use direct and economical paths for his lines.

c. Anyone who wishes to understand, in a thorough manner, the intricate relations between architectural, structural and service plans must study a complete set of plans for a building. When acquainted with the delineation he should make every effort to visit such a building, at frequent intervals during construction, to become thoroughly acquainted with the sequence and methods of correlation. In this book we will have to content ourselves with the presentation of details which include the interrelation of structure and service wherever possible.

CHAPTER 6

FLOOR SYSTEMS

6-1. Classification of Types

a. Many kinds of floor systems have been devised. Each of them has its advantages, but the general tendency has been to preserve the maximum of strength and fire protection with as much reduction in weight as possible. In addition some of these also lend themselves to the ready accommodation of the service lines. The general classification is given in the approximate chronological order of adoption by the industry:

(1) hollow tile arches,
(2) solid concrete slabs,
(3) flat slabs,
(4) ribbed concrete slabs,
(5) steel joists, and
(6) solid gypsum slabs.

b. In discussing each of these it will be desirable to consider the construction in the sequence of erection. In the structural steel frame the structural support is erected previous to all floor construction and fireproofing. In the reinforced concrete frame the columns and beams are erected with the slabs. All of these floor arches require some sort of forms or "falsework" and these schemes are considered for each type.

c. An interesting commentary on floor arches was written by Mr. H. R. Dowswell, of the office of Shreve, Lamb and Harmon, Architects, and is reprinted here from the Engineering News-Record of February 19, 1931.

The construction industry has successively employed floors constructed of brick arches, hollow-tile arches and reinforced-concrete and gypsum slabs. The brick floor arch spanning between structural beams was abandoned very early in favor of the hollow-tile arch, first segmental in form but later replaced by a flat arch. This construction produced a floor much lighter than the brick arch but open to the objections that unless the soffit of the arch was built flush with the beam soffit fireproofing, the intermediate beams projected below the arch soffit; also, in both systems the structural-steel beams had to be reinforced or tied to withstand the arch thrust. Furthermore, the thickness of this construction become excessive unless the floorbeams were closely spaced.

The problem was partly solved in New York City by the adoption of a beam-and-slab system consisting of steel beams with reinforced cinder-concrete arches or slabs, using anthracite cinders both for the arch and for fireproofing. This system produces not only a light but also a relatively thin floor, since a 4-in. slab can be safely used with a beam spacing of 8 ft. Moreover, if the relation of the top of the slab to the steel is well considered, practically all electric conduit and outlet boxes may be placed on the forms and embedded in the arches.

Bituminous cinders have been used to some extent in localities where anthracite cinders are not available, but the difficulty of controlling the sulphur content renders their use open to question. The substitution of a heavier coarse aggregate adds materially to the dead load.

Before the concrete arch came into general use a similar but much lighter construction, using gypsum mixed with wood shavings or similar light aggregate, had a considerable following; but although this system successfully withstood both fire and load tests it never seemed to meet with general favor.

A growing demand for a system which would eliminate intermediate beams that break up ceiling surfaces, and the search for lightness in construction, ease and speediness in installation, minimum thickness and adaptability to the ever-increasing electrical and mechanical requirements, have produced many types of floors. Projecting beams have been eliminated by employing closely spaced reinforced-concrete joists spanning between girders. Of the many variations of this form of construction, the systems employing two-way joists with slag block or hollow-tile fillers offer the thinnest construction and require the least formwork. A flat-slab floor system has also been designed, that compares very closely both in regard to thickness and weight with the two-way joist and filler systems, but its use has been limited to a few buildings and these in widely separated localities. All of these systems, however, when compared with reinforced cinder-concrete slabs, carry the penalties of added weight, slower construction and less flexibility in running conduit.

The floor systems so far discussed have, in addition to their weight, the disadvantage of requiring forms for their erection, the placing and subsequent removal of which limit the rate at which other trades may proceed. Notwithstanding this objection, however, concrete still offers the most satisfactory method of fireproofing structural-steel beams and girders, and in the slab-and-joist systems provides a ready means of housing electric conduit, a base for floor finish and a soffit which can be readily plastered.

Much effort is now being directed toward the development of lightness in concrete without reduction in strength. A number of materials suitable for concrete aggregate have been discovered which give promise of achieving the desired result, but their adoption for high buildings must await the outcome of tests in less important structures.

The tall building needs a floor system which is light, provides the utmost freedom in placing piping and conduit, permits of shop frabrication and lends itself to speed and ease in erection. Floor systems having some of these characteristics have been devised, such as those employing shallow intermediate steel beams or channels with a precast top slab or steel deck and a precast bottom or ceiling slab.

The precast top and bottom slabs have also been used in conjunction with the bar or trussed joist, and some authorities see in this construction a solution of many problems since the open truss webs permit the running of pipes or conduit in any direction. This type of joist, however, has not been generally accepted for use in connection with the construction of tall buildings.

These systems, while light and largely shop-fabricated, are much thicker than the systems now in use and make no provision within the construction (excepting the bar joist design) for pipes or conduit without a further increase in the thickness.

For example, the depth of intermediate beams or channels as used in this construction for the usual office-building column spacing would be at least 7 in., to which must be added a ceiling slab of 1½-in. minimum thickness and a top slab of 2½-in. thickness, making a total thickness without fill or finish, of 11 in., compared with 4 in. for the concrete arch or 6 in. for the two-way concrete joist-and-block filler system. Even when steel plates are used in place of a top slab there is still an increase in thickness of more than 4 in., compared with the 4-in. concrete slab. This excess would, in a ten-story building, add sufficient exterior wall for two additional stories, without producing any increase in floor area.

It would seem, therefore, that the building industry has not yet produced a fabricated floor system meeting the needs of the tall building. However, in view of the many efforts being made to devise such a system, it does not seem unreasonable to expect that developments of the near future may overcome the present limitations and that a logical and efficient floor will result.

6–2. Hollow Tile Arches

a. Hollow tile arches followed the old style brick rowlock arches, which were very commonly used after structural steel frames were first introduced not so long ago. The terra-cotta manufacturers developed a series of types during the period when tile arches were common and these were called:

(1) side construction,
(2) end construction,
(3) combination construction, and
(4) segmental.

These are illustrated in Figure 6–1. It will be noted that the tile are made in two general types, aside from the skewbacks and keys. In one the webs and walls of the tile parallel the structural supporting beams, as in side construction, and in the other they are perpendicular to the supporting beams. The depth of flat arches should not be less than 1½″ per foot of span and in no case less than 9″.

b. In the side construction arch, the steel beams are partly covered with a skewback which fits the lower flange and web. Then a sufficient number of side construction tile are set to bring the two sides of the arch to the key block which is wedged into the center of the span. In the end construction arch, the skewbacks are shaped from end construction tile to fit the web and flange of the beams. Then the end construction tile are set similarly to the side construction arch until they meet a similar side construction key at the center of the span. The combination construction merely uses the side construction skewback and has end

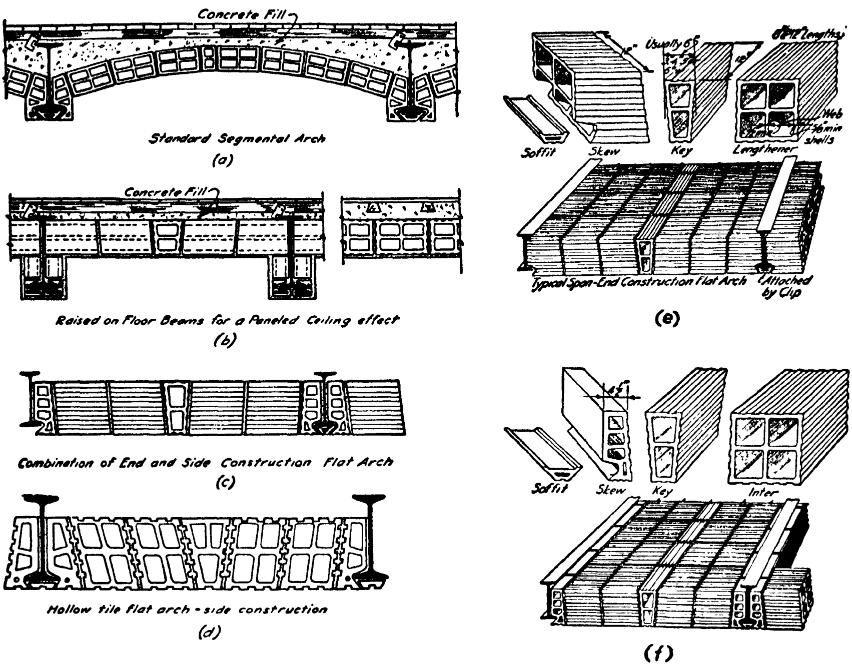


FIG. 6–1. Standard Terra Cotta Floor Arches.

construction "voissoirs" or arch tile, as used in the regular end construction arch.

c. It will be noted that none of these types are true arches as far as shape is concerned. Nevertheless, they act as arches by transferring thrust in an arch shaped area which is a part of the tile structure itself as shown in Figure 6–2. The true tile arch, which was commonly used for roof construction and at times for longer span floor construction, was known as the segmental arch. In this case the tile were set to a definite rise, usually not less than 1″ per foot of span, and it was always assumed that the tile were in compression on all faces. The flat arch provides a flat horizontal surface for plastering, while the segmental arch either produces a vaulted ceiling or must have a suspended ceiling, if it is to be flat.

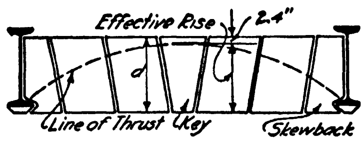


FIG. 6–2. Line of Thrust in Terra Cotta Floor Arches.

d. Tile arches are exceptionally strong inasmuch as it is just as economical to select deep tile to cover the structural steel as to use shallower tile and fill the top with concrete to bring the floor to a level with the top flanges of the steel. These alternatives are shown in Figure 6–3. To take up the thrust which these arches impose upon the beams, tie rods, usually ¾″Φ, are spaced in such a way as to pass through a joint in the tile work. This would mean that they should most generally be at some even foot spacing. These rods are passed through the steel beam webs at a distance about 3″ above the lower flange so as to be at the

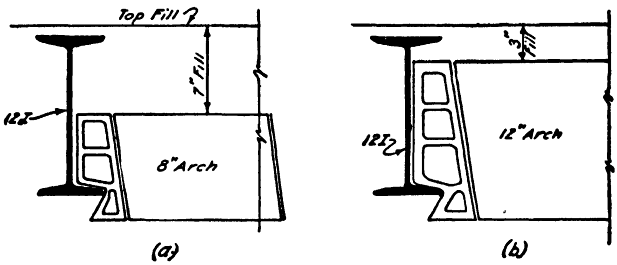


FIG. 6–3. Relation of Tile and Beam Depths. (a) for economy of tile; (b) for reduced floor fill.

point of maximum thrust. They should not be spaced more than eight times the depth of the supporting beams.

e. In order to erect tile arches, a system of forms is first erected. These forms consist of lagging which rests upon the top flanges of the steel beams, as shown in Figure 6–4, from which steel rods are suspended.

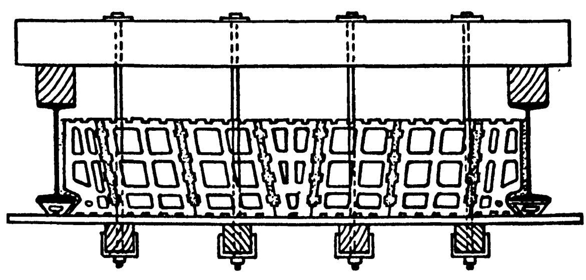


FIG. 6–4. Erecting Terra Cotta Arches.

At the lower ends of these rods is another set of lagging, supporting planking at the proper elevation to provide a base upon which the tile may rest. The tile are set from the beams inward to the key. The mortar used to set the tile should be composed of 1 part of cement, from ⅓ to ½ part of hydrated lime, and 4 parts of sand. After the mortar has set, which would be within some 8 or 10 hours, the forms are removed and the arches considered complete, ready for the fill and such details as the final finish of the floor requires. (See Article 6–9.)

6–3. Solid Concrete Slabs

a. These floor arches are here so named to distinguish them from the arches which replace a part of the concrete below the neutral axis of the slab by cores of one kind or another, as discussed in Article 6–5. They are further segregated from the slabs used in the so-called "flat slab" construction, which are also solid slabs. These floor arches may be so designed that the load is carried in one or two directions forming what are known as one-way or two-way slabs. These slabs carry their loads to parallel beams and girders, running in a direction perpendicular to the reinforcement in the slab. For the one-way slabs, girders may run in one direction only, the slab itself being used structurally to tie the columns in the other direction. For the two-way slabs, girders run into the columns from all directions, thus supporting the slabs on all four sides. These slabs can be used with the structural steel frame or the reinforced concrete frame.

b. The forms used to support the concrete during casting may vary some depending upon the type of structural frame used, but the general conformation and details of those panels which are in contact with the concrete will be almost identical. When the structural steel frame is used it is often used to support the forms, thus doing away with the rather extensive set of jacks, or posts, normally used with the all concrete frame. With the structural steel frame the steel members are merely fireproofed by the concrete while with the reinforced concrete frames the beams, cast at the same time as the slabs, must be supported during the hardening of the fresh concrete.

c. Figure 6–5 shows alternate methods for forming a concrete slab supported by a structural steel frame. In these cases the beam bottoms, beam sides and slab panels are suspended from the structural frame or supported upon jacks as shown. Figure 6–5 also shows the details for the forms for the casting of a solid concrete slab and the supporting girders in the reinforced concrete frame. In this case all beam bottoms, beam sides and slab panels are carried by girts supported on jacks resting upon the previously cast floor.

d. In both of these schemes it should be noted that the rule for concrete forms, namely, "that all panels should be so assembled that they may be stripped without being damaged, so they may be re-used as often as possible, and so that the panels forming vertical surfaces may be removed without disturbing the beam bottoms or slab panels," is observed. Figure 6–6 shows a larger detail at a girder. It will be noted that the beam bottom is supported upon jacks with "Tee" heads, the horizontal member of the Tee being long enough to carry a girt which, in turn, carries the end

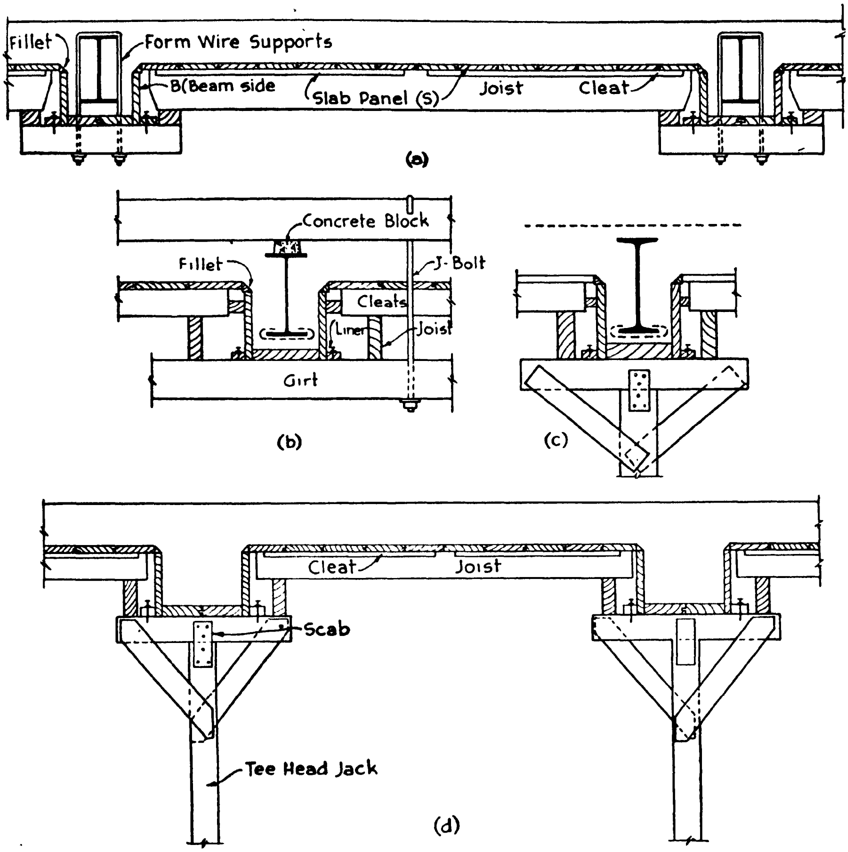


FIG. 6-5. Forming Concrete Slabs. (a) & (b) suspended form, steel frame; (c) jack supported forms, steel frame; (d) jack supported forms, concrete frame.

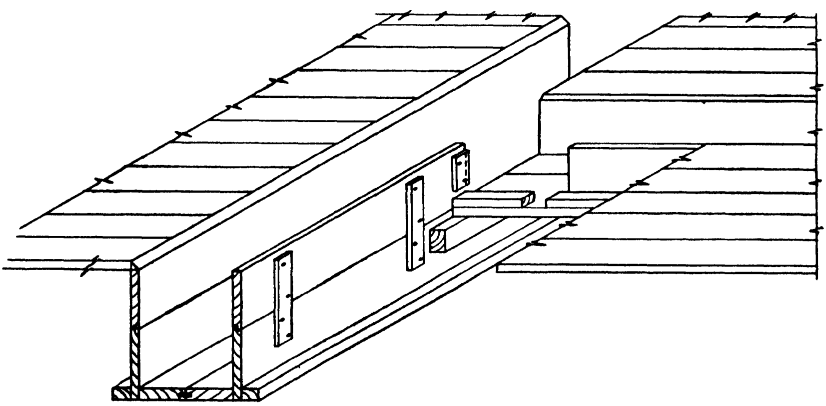


FIG. 6-6. Forming Beam at Girder Support.

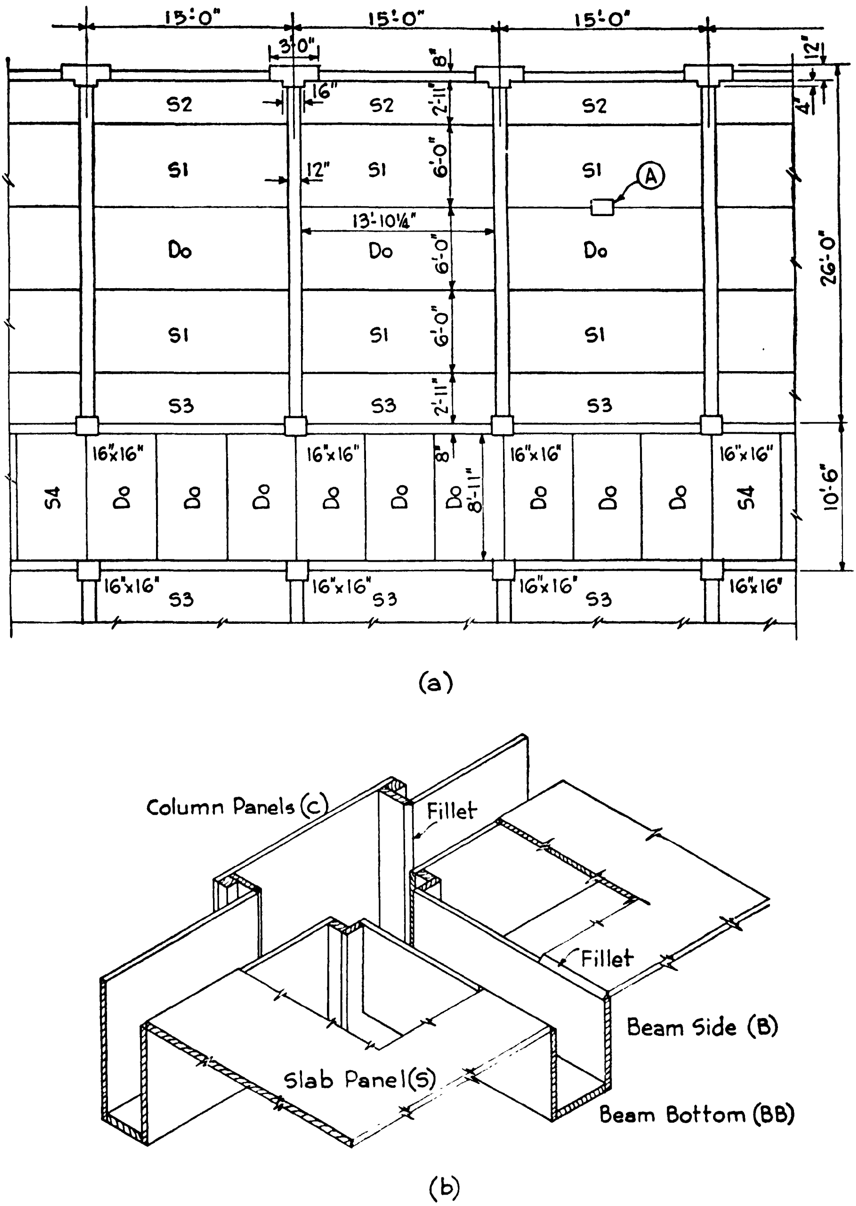


FIG. 6-7. Assembly Plan for Slab Forms. (a) typical numbering; (b) detail at exterior column.

of the joists supporting the slab panels. These joists are supported on girts at proper intervals which, in turn, are supported on jacks spaced at proper intervals for the strength of the girts. It will be seen that it is possible to strip the beam sides by removing the liners, (a), and tipping the beam side out over the Tee-head, having previously taken out the joist support (b).

e. The slab panels should so be detailed that they may be somewhat of a standard, using small special panels for closures where necessary.

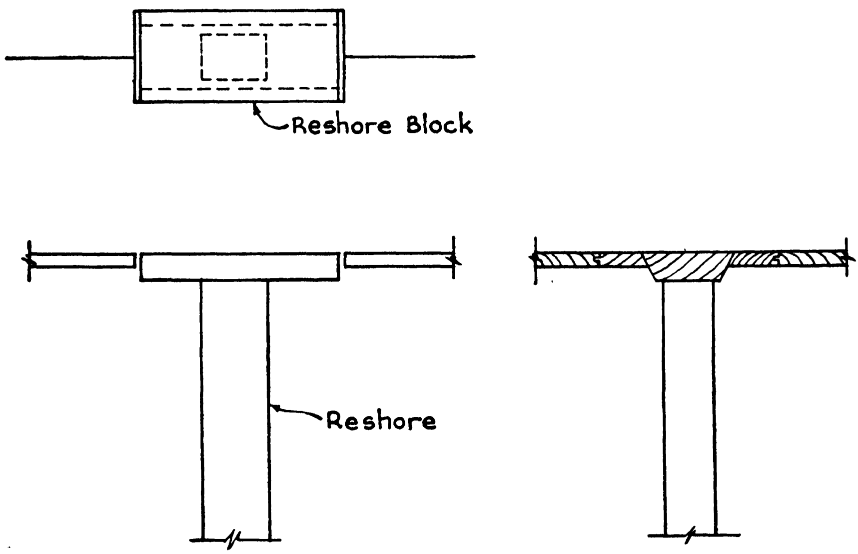


Fig. 6–8. Reshore Block in Slab Forms.

This is diagrammatically indicated in Figure 6–7. Frequently a separate jack carrying a single panel is placed at proper intervals so that the slab panels may be removed, leaving a series of shores to carry the hardened concrete for a longer period of time. This detail is shown in Figure 6–8. When this precaution is not taken, the slab panels are removed and the slab is re-shored immediately at the center of the bay. Sometimes the slab panels are made of pressed steel sheets. The general support of this alternative is similar to the one described for wood.

f. After the forms are leveled by wedging and tied by ledgers set head high from the floor below, sleeves for pipes passing through the slabs and beams are set and the reinforcement is placed. This may be either wire mesh or deformed bars. The latter are more commonly used. The bars come to the job bent to detail and marked in accordance with an erection plan. They are spaced by means of special appurtenances called spacers, such as shown in Figure 6–9. Also shown is the typical chair used for

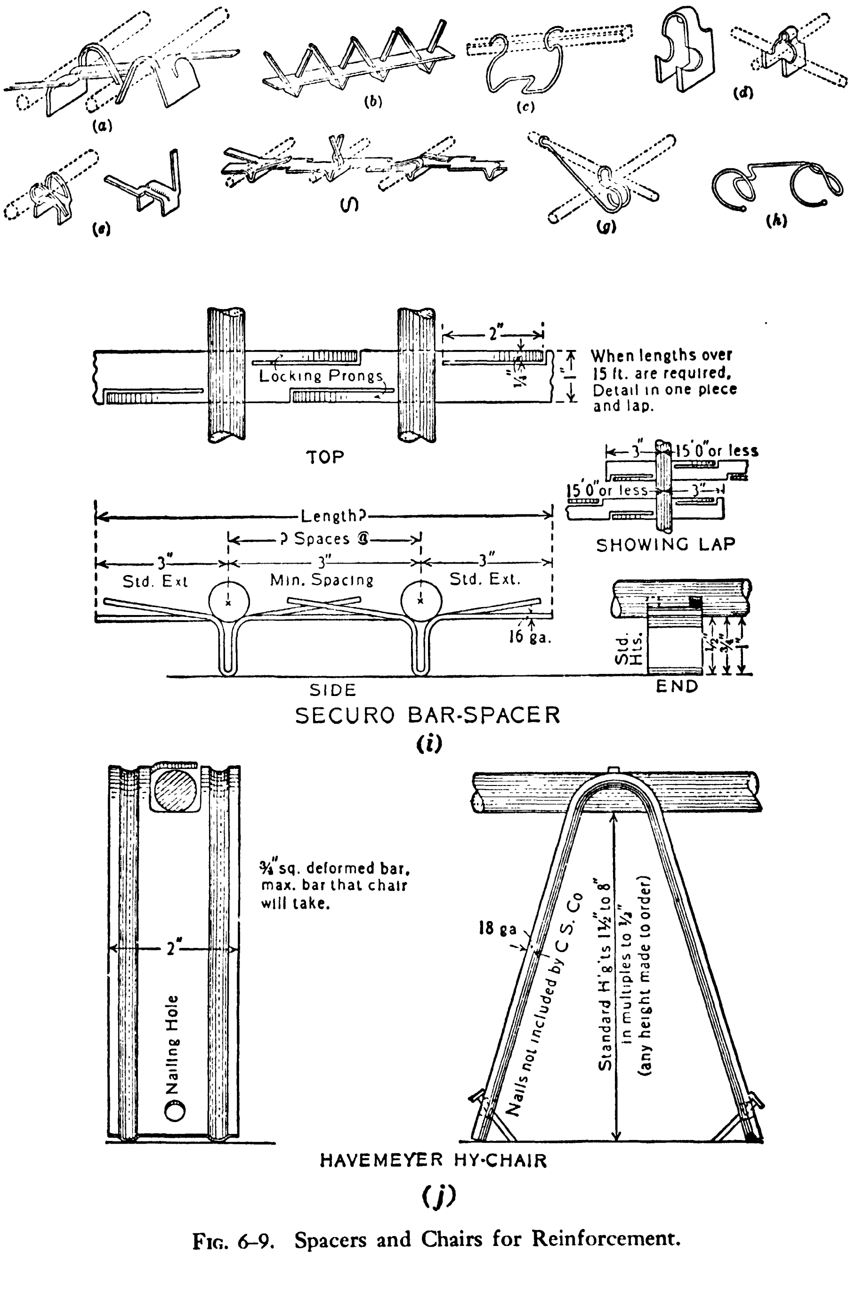


Fig. 6–9. Spacers and Chairs for Reinforcement.

supporting the negative steel. Loop rods, usually not shown on the engineer's drawings, are employed to afford support for stirrups beyond the point of the negative steel. These are shown in the beam schedule given in Figure 5–7. The principles of detailing the steel are discussed in Chapter 7.

g. After the reinforcement is in place the electrician installs all conduits and boxes which are to be cast into the concrete slabs. Sleeves for the accommodation of water, gas and steam pipes which pass through the slabs or beams are located and set, as shown in Figure 6–10.

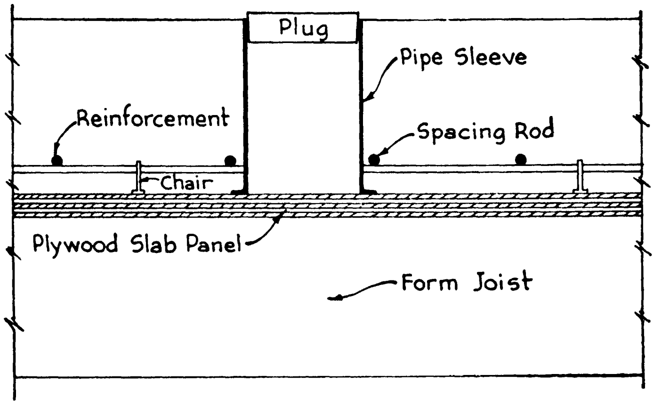


Fig. 6–10. Sleeves in Concrete Slab.

h. The removal of forms is closely related to the design strength of the concrete in the first place, the weather during casting, the size of members and their spans. If the design strength of the concrete is 3000 pounds per square inch or over, there is a sufficient amount of cement to produce early hardening under normal conditions; concrete hardens more slowly under subnormal temperatures and more swiftly under elevated temperatures; the heavier the member and the longer its span the more time should be allowed for the concrete to harden. The generally accepted precautions as to time for form removal are shown in Table 7–2. The reader should supplement these more or less empirical data with judgment based upon his knowledge of the nature of concrete.

6–4. Flat Slab Construction

a. About thirty-five years ago a contracting engineer conceived the idea that he could do away with deep beams and girders by using wide sections of the slab at the column center lines as girders, thus making the slab between these bands thinner and thus more economical. He found that the columns would have to be flared to reduce the possibility of failure in shear. Later it was found that the slab could be kept the same thickness over the entire area and that it was possible to provide for shear and high negative moments by thickening the slab at the columns producing what is known as a "drop panel."

b. Inasmuch as two-way slabs are more economical when the panels are square or nearly so, square panels are usually employed. Flat slab floors are particularly economical for heavy live loads and the absence of beams and girders increases the net headroom and makes it possible to run the sash clear up to the underside of the slab. The mushroom

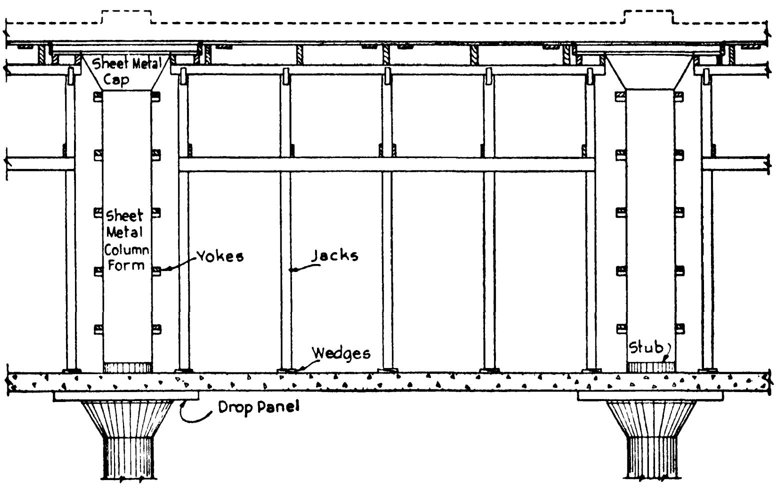


FIG. 6–11. Forms for Flat Slab Floor.

capitals make this type of construction undesirable where partitions are needed in finished areas. Even this difficulty can be overcome by special details at the upper end of partitions.

c. Figure 6–11 illustrates a typical section of flat slab floor construction and indicates the forming for the slab. The column forms are usually steel shells and these and the cap forms can be rented to take care of these parts of the work.

d. The most common flat slab design is the two-way system, with or without drop panels. Many flat slab floors have been built with four-way reinforcement. The two-way system is shown in Figure 5–14. It will be noted that the slab is divided into three types of bands, commonly called the "A," "B" and "C" bands. "A" bands are those, usually one-half the panel dimension wide which pass over the column caps. "B" bands are those passing in both directions at mid-span. "C" bands are those, usually one-quarter the panel width wide, adjacent to a wall or a girder framing an opening.

e. In casting these frames and floors it is customary to cast the column shafts first and up to a point at the base of the "flare" or mushroom capital. The slabs, drop panels and capitals are then cast later. If the capitals were cast with the column shafts the shrinkage of the concrete would cause a crack at the line where the cap joins the shaft and thus impair the integrality of the frame. The reinforcement of the columns, which are usually circular, is provided by spirals and vertical steel which are set and spaced as shown in Figure 6–12.

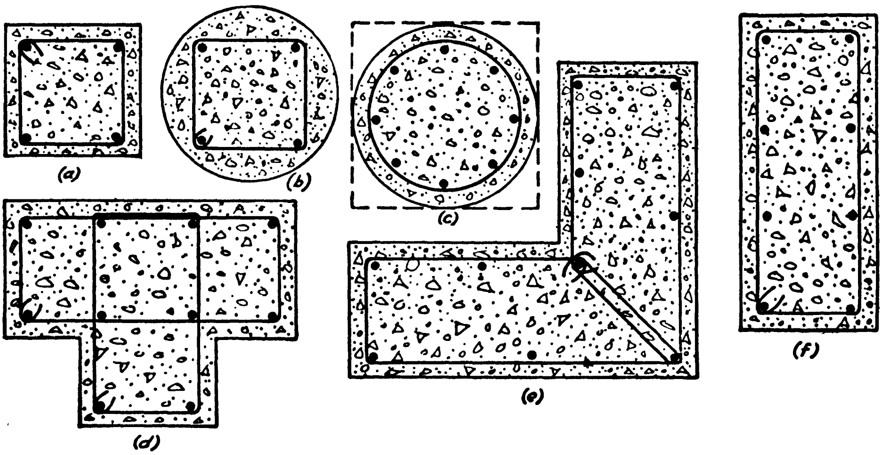


FIG. 6–12. Reinforced Concrete Columns. (a)&(b) vertical steel and ties; (c) vertical steel and hoops; (d),(e)&(f) exterior columns with vertical steel and ties.

6–5. Ribbed Concrete Slabs

a. Ribbed concrete slabs are merely innovations of the solid slab. In the solid slab the reinforcement is distributed over the entire area of the slab, and all of the concrete below the neutral axis, except at the supports, is useless structurally, but serves as a cover for the reinforcement and affords a flat ceiling. It thus would be possible to collect several of the bars at regular intervals and cover them with concrete, and then omit the concrete below the neutral axis in the space between these bars. Figure 6–13 illustrates this detail.

b. Thus it is possible to reduce the weight of the floor slab by eliminating some of the concrete or by substituting some other lighter material to fill this space. The advantage of having a continuous flat surface for the

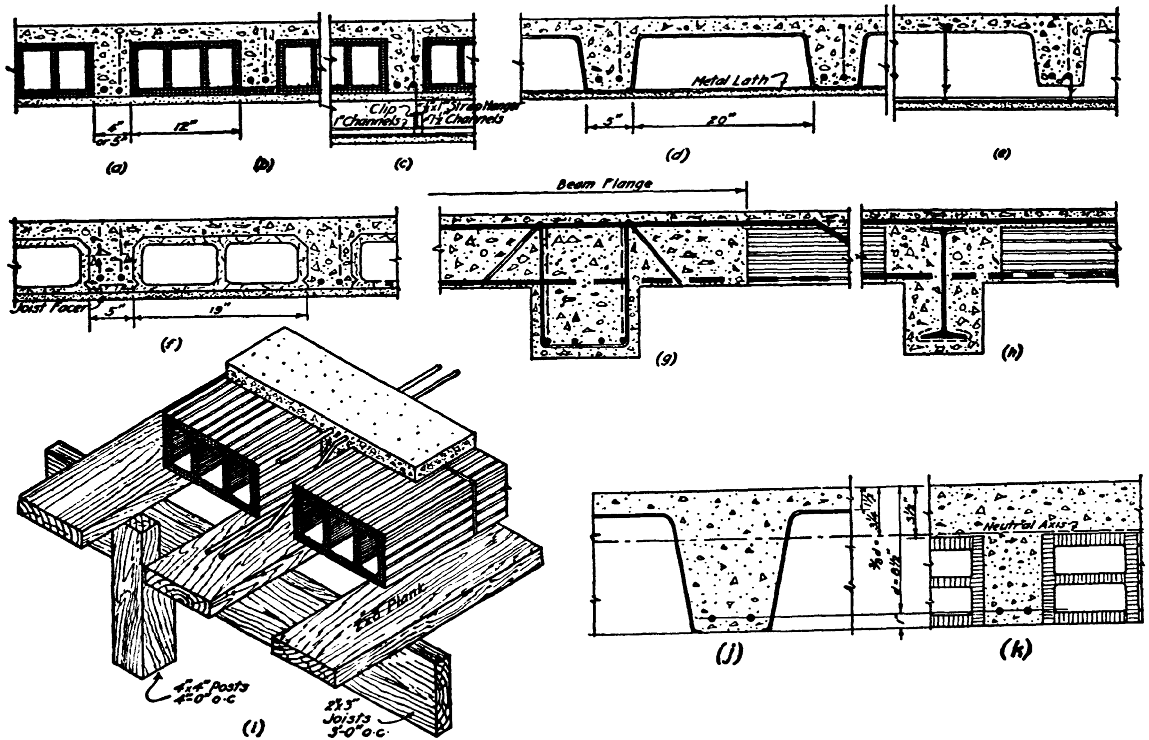


FIG. 6–13. Ribbed Slab Types. (a)&(b) T.C. fillers without and with soffit block; (c) T.C. fillers with suspended ceiling; (d) pan slab, direct plaster ceiling; (e) pan slab with released suspended slab; (f) gypsum fillers, direct plastered; (g)&(h) T.C. filler slab at concrete and steel girder; (i) skeleton forms for T.C. filler slab; (j)&(k) depth relation for pan and T.C. ribbed slabs.

ceiling finish must not be overlooked, although a suspended ceiling can be used where the filler is not used. The more common ribbed slabs are those which use fillers of clay tile, concrete tile, or of gypsum tile. The steel pan filler affords two alternatives. One employs removable pans and the ceiling is provided by suspending metal lath from the concrete. The second is the fixed pan which either has a lath surface for the ceiling, or the lath may be laid in the forms with the pans so that it will be ready for plastering when the forms are stripped.

c. The permanent metal floor core is used in places where the lath is laid first, and where it is not necessary to remove the cores. The cores vary in width, shape, and gauge to meet all conditions of design. Permanent cores 12, 16 and 20″ wide are made of 26 gauge steel; 25″ wide cores are made of 25 gauge steel. Cores wider than 25″ are not recommended for permanent type of construction. They are corrugated to give them more strength, and the sides are sloped to give lateral stability. The corrugations also provide an end lap that prevents the leakage of concrete through the forms. The forms are made in three shapes: straight, single tapered, and double tapered. The purpose of the tapered forms is to give more concrete at a point where it is required to take shear. It often happens that a certain size of joist will be found to be satisfactory, except that the shear values at the ends of the joists are excessive. In this case, a tapered form is placed at the ends to form a wider joist of sufficient cross sectional area to take care of the shear. The double tapered form not only gives a wider joist, but also a thicker slab over the forms. The standard length of cores are 2′-6″ and 3′-0″, and the standard depths are 6, 8, 10, 12 and 14″. Special depths and widths, as well as special tapered cores, may be obtained if desired. End caps are obtainable for all sizes of forms.

d. The removable metal core is made in sizes and shapes the same as the permanent core. The 25″ and 30″ base forms are of 18 gauge metal, and 22 gauge metal is used for 20″ and narrower widths. Removable forms are heavier so that they can be used again. This type of construction is also good where it is desired to attach the lath after the concrete work is completed. Also, the fact that many uses may be obtained from one set of forms makes them particularly efficient in multi-story construction.

e. Some of the advantages of this type of construction are: (1) It is economical. The cores may be nested so that they take up little space and the shipping cost is low. Also enough cores for many square feet of floor may be easily carried by one man in a wheelbarrow. The large-sized units permit the placing of a larger area of floor with less effort than is the case in either tile or gypsum core floors. The removable forms may be rented or purchased, whichever is found cheaper, and permit of an indefinite number of uses. (2) The floor system is adaptable to any purpose. The floor system has all the strength and durability of a solid concrete slab, without the disadvantage of excessive weight. This floor will stand the heaviest loads, but may be also economically designed for light floor loads. (3) This floor system has the same excellent fire-resistant qualities that a solid concrete slab has. (4) The voids in the floor leave ample space for the running of electrical conduits in one direction.

f. Gypsum floor cores are precast blocks of structural gypsum which are specially designed for use in concrete joist construction. These blocks are made in two sizes. The first type is 12″ wide by 30″ long and is made in thicknesses of 3, 4, 5 and 6″. These voids are spaced 16″ on centers, thus leaving a 4″ concrete beam. The second type is 19″ wide and 18″ long and is furnished in thicknesses of 6, 8, 10 and 12″, and are spaced 24″ on centers, leaving a 5″ beam. Joists facers are slabs of gypsum that are placed at the bottom of the beam, so that the slab surface will be all gypsum on the underside to facilitate plastering. These are furnished in standard widths of 5″ and are 1″ thick and 12″ long. Special widths may be obtained if desired.

g. A special advantage of gypsum block construction is obtained by using these facers in that the plastering may be attached to one type of material instead of two. When concrete and gypsum are both in the exposed ceiling the plastering must be carefully done or light and dark bands will in time appear in the ceiling, because the resistance to the passage of air is different in one material than in another.

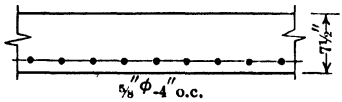
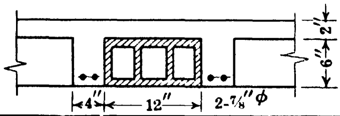
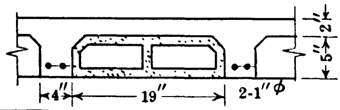
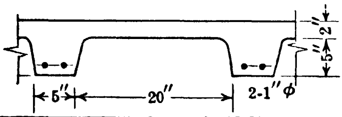
h. The gypsum block is light and strong and is easily installed with less form work than for some of the other types. Gypsum also possesses good properties for fireproofing and insulation of floors. Also, because of the lightness of the material, a saving can be made in reinforcing steel.

i. Ribbed slabs may be one-way or two-way, just as solid slabs. The fillers in these instances will be special tile, or tile with end closures, or steel domes, removable or fixed.

j. The desirable characteristics of the ribbed slab are illustrated by the tabulation in Table 6–1 of several types of one-way ribbed slabs giving the dead weights of the structural slabs per square foot of floor as compared with each other and with the solid slabs. All of these slabs are capable of supporting a 75 pound live load on the same span. This tabulation indicates further savings in the beam, girder and column framing because of lighter dead weight. In a large building this may be a substantial amount.

k. In forming ribbed slabs various schemes are used. In some instances the entire area is formed just as for solid slabs. This can be avoided and be done more economically by forming the soffits of the joists only. The

TABLE 6-1.

Type	Section	Wt. per Sq. Ft.	Lbs. Steel per Sq. Ft.	C.F. Concrete per Sq. Ft.	Comparative Cost
Solid Slab		95	3.13	.67	1.00
Clay Tile		70	4.09	.28	.83
Gypsum Cores		55	5.34	.30	1.00
Pans		50	5.34	.26	.95

jacks or posts are usually 3 x 4 or some form of patented, extensible shore. The joists, or stringers, are 2 x 8 to 2 x 10 plank. The soffit planks are 1½" to 2" stock about 4" wider than the joist soffit to afford support

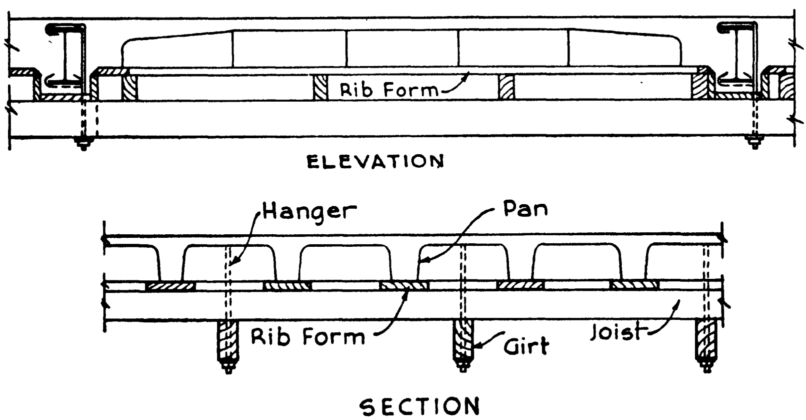


FIG. 6-14. Forms for Pan Ribbed Slab in Steel Frame.

for the pile or pans. It must be remembered that strength, rigidity and watertightness are important characteristics of good forms. Figures 6-14 and 6-15 show the typical forming of such a slab.

l. When the permanent metal core is used the metal lath is laid on the centering and the pans set upon the soffit planks. In some cases the lath is attached directly to the pans and both are set at the same time. When a hung ceiling is to be used the lath is omitted, and hanger wires are provided to which the ceiling mesh and frame is attached. The hung

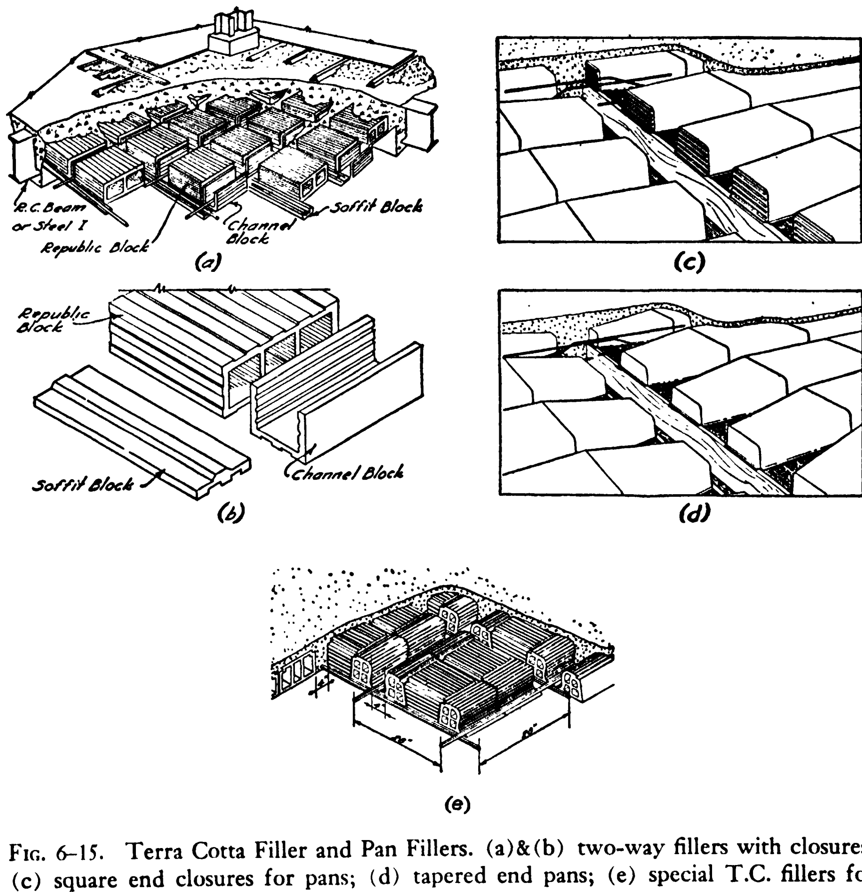


Fig. 6–15. Terra Cotta Filler and Pan Fillers. (a)&(b) two-way fillers with closures; (c) square end closures for pans; (d) tapered end pans; (e) special T.C. fillers for two-way ribbed slabs.

ceiling may be used with fixed or removable cores. All cores should be set according to a setting plan. The cores should be lapped about 1½ corrugations, or an equivalent distance if plain pans are used.

m. After the cores are set and before the reinforcement is placed the forms are oiled so as to facilitate their removal. The oil should be a good grade of mineral oil. Crankcase oil may be used. The reinforcement is then placed, as for the solid slab. The concrete is then cast and allowed to harden.

n. When a two-way ribbed slab is used the cores are provided with closures to avoid the entrance of the concrete into the voids of the clay tile, gypsum cores or concrete tile. The metal cores are in the shape of domes. Certain of these variations are shown in Figure 6–15.

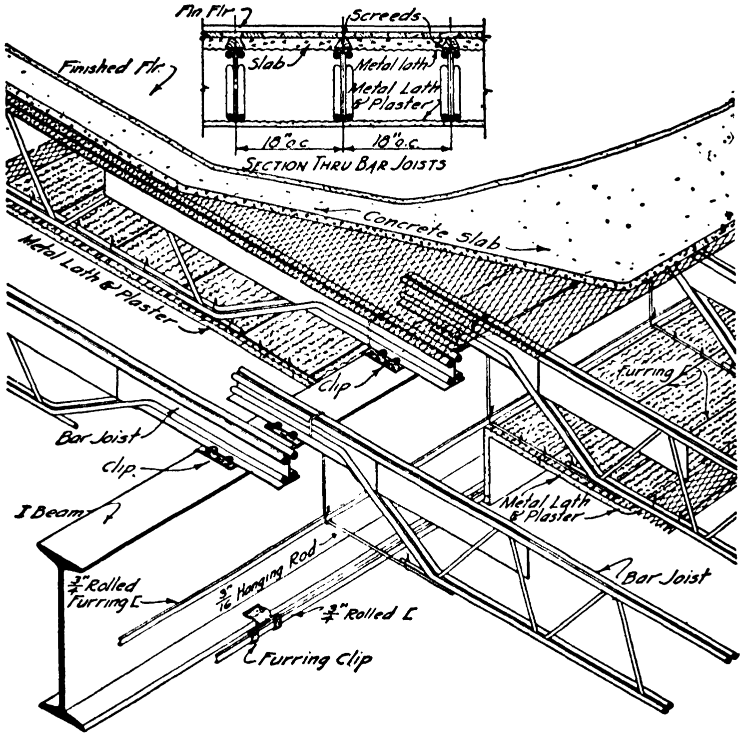


FIG. 6–16. Trussed Joist Construction.

6–6 Steel Joist Floors

a. Light structural steel members are excellent to produce lightweight floors. They eliminate the use of costly centering and they are easily adaptable to simple erection. The common types of such members are the junior beam, pressed steel joists and trussed steel joists. The pressed steel and trussed joists are illustrated in Figures 5–17 and 6–16. Junior beams are rolled sections produced in the same manner in which the usual rolled sections are. The pressed steel joists are, as the name implies, fashioned from steel sheets into channels, angles and other shapes, and these are then welded or riveted to form compound unit members with variable strength factors. Trussed steel joists are an extension of the experience which we have had with the junior beam and the pressed steel joist. It is a more rational design, employing the principle of light truss design. It may be made of a combination of stiff upper and lower chord members of rolled sections or doubled rods, while the web members are made of round bars. Another type uses the expanded web process. There are several types of these trussed joists, all of which are carefully designed and all of them afford many advantages in construction.

b. It will be noted that in all cases where concrete slabs are used, a ribbed mesh is laid over the top chords of the supporting joists using various methods for the attachment of wood floors, granolithic, linoleum

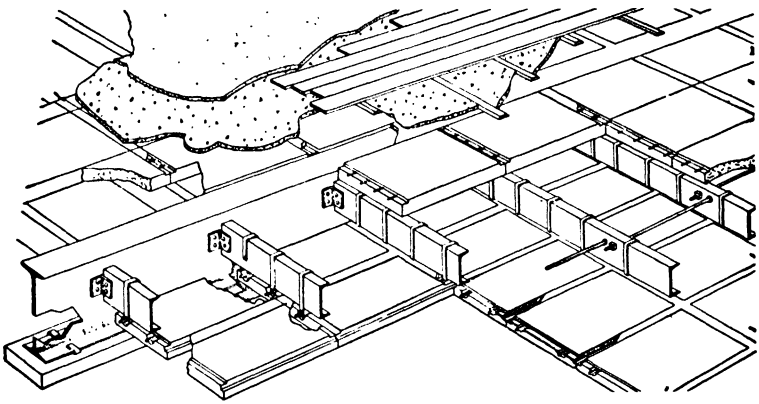


FIG. 6–17. Precast Gypsum Slabs for Steel Frames.

or other floor coverings. The ceilings are provided by fastening metal lath to the lower flanges; the ceilings are then plastered. The joists are stabilized laterally by wire or strap bridging, as shown.

c. A variation from the standard concrete slab scheme which has been used to some extent employs precast gypsum slabs for the floor slabs and for the ceiling slabs. (Figure 6–17.) This method affords lighter construction and has the advantage of lower cost.

d. All of these joist systems depend upon a structural frame of the usual type for general support. The disadvantages of light steel construction of this type are the danger of corrosion and their inevitable failure if exposed to intense heat. Another disadvantage of the trussed joists is that they cannot be cut or altered much. The expanded and trussed joists have the advantage of affording ease of running pipes and conduits in either direction. Where the question of corrosion and exposures to fire are controlled by proper details and considered occupancy, this type of floor construction should have many advantages to offer in reducing construction costs.

6–7. Solid Cast Gypsum Slabs

a. These slabs are built in much the same way as the solid concrete slab. They have many advantages over the concrete slab. The earlier forms of this type of slab were made of gypsum plaster mixed with planer or other forms of wood particles. This produced a light and inexpensive floor which had excellent fire resistance and helped expedite construction because of its rapid hardening characteristics. The strength of this arch was low enough to require closer spacing of supporting structural steel beams. The objections raised against this early floor was its characteristic of holding its moisture for long periods and the resultant tendency toward corrosion of the steel.

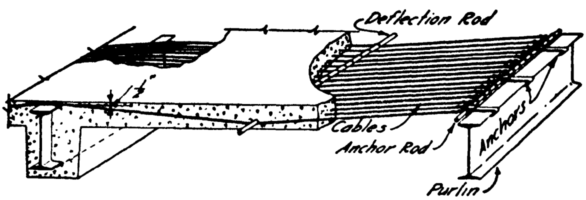


Fig. 6–18. Cast Gypsum Slab Construction.

b. Recently, however, one of the large gypsum companies has developed a gypsum with extremely high compressive strength and density, and with extremely low residual water content. This material will undoubtedly make a bid for prominence in floor design where light live loads are specified.

c. The reinforcement used in these gypsum slabs is a mesh or steel cable. Each of these is draped over the structural steel beams, as shown in Figure 6–18. An examination of these methods of steel reinforcement will show that they are faulty in several particulars. The first of these is the lack of providing variable negative reinforcement across the top of the beams to take care of moving loads or varying positions of live loads. The second is the tendency for the reinforcement to move vertically under concentrated loads. This is particularly true of the cable type. If a concentrated load were placed at the quarter point the proper place for the cable low point would be under the load. This movement of concentrated loads to various positions would cause very complicated stress exchanges which would bring about fatigue of the gypsum and eventual structural cracking. For light loads, however, and with caution in design, this type of floor would bring to many structures some highly desirable economies which should be exploited.

6–8. Concrete for Slabs, Beams, Columns and Fireproofing

a. The mixing and placing of concrete in first class buildings is similar in most respects to that for other types of buildings. The use of cinder concrete is, however, definitely linked with the structural steel frame.

b. As early as 1896, a segmental arch, known as the Roebling system, was introduced into the City of New York, and in which the concrete was made with anthracite cinders as coarse aggregate. Before this time these cinders were a waste product and were removed at great expense to the city. It was Ross F. Tucker who first introduced the cinder concrete arch with a flat ceiling into New York. In these early uses the cinder

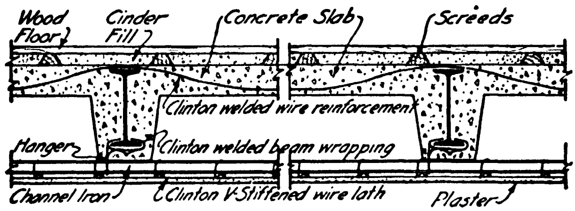


Fig. 6–19. Cinder Concrete Slab Construction.

concrete was mixed in the proportion of 1 part of cement, 2 parts of sand and 5 parts of cinder. The spans were confined to a maximum of 7 feet and were often cast only 3½″ thick. The reinforcement was a 16 gauge, 4″ mesh. The forms were placed 1½″ below the tops of the steel beams and were supported on the lower flanges. (Figures 5–11 and 6–19.)

c. Since that time many buildings, such as schools, hotels and others for commercial occupancy, have used cinder concrete arches with structural steel frames. The introduction of better means of conditioning the cinders and improvements in mesh and fabric have greatly implemented the successful use of cinder concrete slabs. Many engineers advocate the replacing of one bag in four of portland cement with a bag of hydrated lime or hydraulic lime. Anthracite cinders contain a soluble silicate which may unite with the lime and make a much tougher and elastic concrete than with portland cement alone.

d. The greatest objection leveled against cinder concrete is the corrosive action of the cinders on the reinforcement and the structural frame. The factors which determine the quality of cinders are:

Conditions of combustion-type of furnace or boiler, and the care exercised in firing and maintenance.

Type of fuel used, and degree of combustion.

Cinders are made up of:

Ash, in combustible residue from complete combustion, usually with a large mineral content.

Cinder, not entirely consumed, but with most of the gaseous content burned out.

Clinker, a hard, fluxed, vitreous material, fused because of lack of oxygen for complete combustion.

Coke, occurring at the interior of the clinker, consisting almost entirely of carbon, with gases driven off.

Coal, unburned fuel, often occurring inside the clinker.

Cinders should be kept drenched for about a week before they are used. This will help wash out most of all of the soluble materials and to prevent the cinders from absorbing excessive moisture from the concrete during drying. This wetting can be accomplished by exposure to rains before using, but otherwise it should be accomplished artificially.

e. The reinforcing in cinder concrete slabs is usually mesh or fabric. An expanded diamond mesh is made of reticulated sheets of soft steel. There are rows of parallel slots cut in the sheets at alternate intervals, after which the sheets are pulled out or "expanded" in a direction perpendicular to the slots. This expanded mesh comes in varying gauges and weights, ranging from the light expanded lath to sheets of much greater thickness.

f. Expanded metal mesh may be used widely for light construction, but the most common type of cinder concrete reinforcing is the fabric; either welded together or laced with interwoven wires. The electrically welded fabric is good for about 60,000 to 70,000 pounds per square inch in tension and the triangular fabric develops 70,000 to 85,000 pounds per square inch. In both kinds of fabric the wires running crosswise serve merely as ties and are therefore of smaller cross section than the main longitudinal ties. Since these main wires are usually fairly stiff, rolls of the fabric will uncoil very readily when the clip wires are cut; in view of this fact, therefore, it is excellent personal policy to keep on the side of the roll opposite that in which direction it is unrolling.

g. Fireproofing. Owing to its expansion and distortion due to reduced modulus of elasticity with temperature rise, structural steel must always be protected against fire. All principal load bearing members, such as beams, girders and columns, should certainly be encased in fire-resisting materials. It is generally conceded that concrete is the most efficient and useful fireproofing material in use at the present time. In referring to the fire-resisting properties of a material the word "fireproof," as commonly used, is, to a large degree, a misnomer, as no building can be made absolutely fireproof. Fire resistance is a matter of degree only and the degree required will vary with occupancy, loads and matters of design. Many experiments have been made to determine the fire-resisting qualities of concrete and other fireproofing materials. The complete present status of recommendations are set forth in the literature of the National Board of Fire Underwriters and the National Fire Protection Association.

h. In order to obtain satisfactory fireproofing around the soffits of beams or girders, it is important that the concrete be cast sufficiently fluid to flow readily into place without excessive tamping, to avoid voids and pockets. Large clinkers should be eliminated from cinder concrete and the maximum size of aggregate in stone concrete should be limited to ½″ when casting concrete in confined spaces. The concrete should be cast from one side only until the head developed on this side will insure intimate contact with the soffit of the steel beams. Beams should be cast uniformly along their entire length, keeping the concrete at a reasonably constant level.

6–9. Provisions for Finish Floors (Figure 6–20)

a. The mechanical and electrical distribution lines which extend horizontally are carried in the structural concrete slab, on top of the structural slab or under the slab when furred or suspended ceilings are used. The method used has a distinct bearing upon the detail used for the attachment of the finish floor. Floor finishes may be of many types. Thus wood floors, linoleum, rubber or asphalt tile, natural or cast stone flagging, quarry tile or terazzo may be used. When the services are cast into the structural slab these finishes can be applied directly to the slab. When the services are run above the structural slab a fill, either of cinder concrete or some other form of lightweight fill such as "aerocrete" or "mascrete," is used to provide the clearance for the conduits and pipes. When suspended or furred ceilings are used the floor finish can be attached directly to the slab.

6–10. Comparative Costs

a. In addition to the relative costs given for ribbed slabs in Table 6–1 it is interesting to consider the all-over relation of cost for all types of so-called fire-resistant floor construction. A survey made in 1929 for the New York area indicated the following costs for a particular building using a live load of 100 pounds per square foot. These prices were developed by Messrs. B. M. Whitten and R. A. Bisson in their analysis entitled "Certain Fireproof Floor Systems."

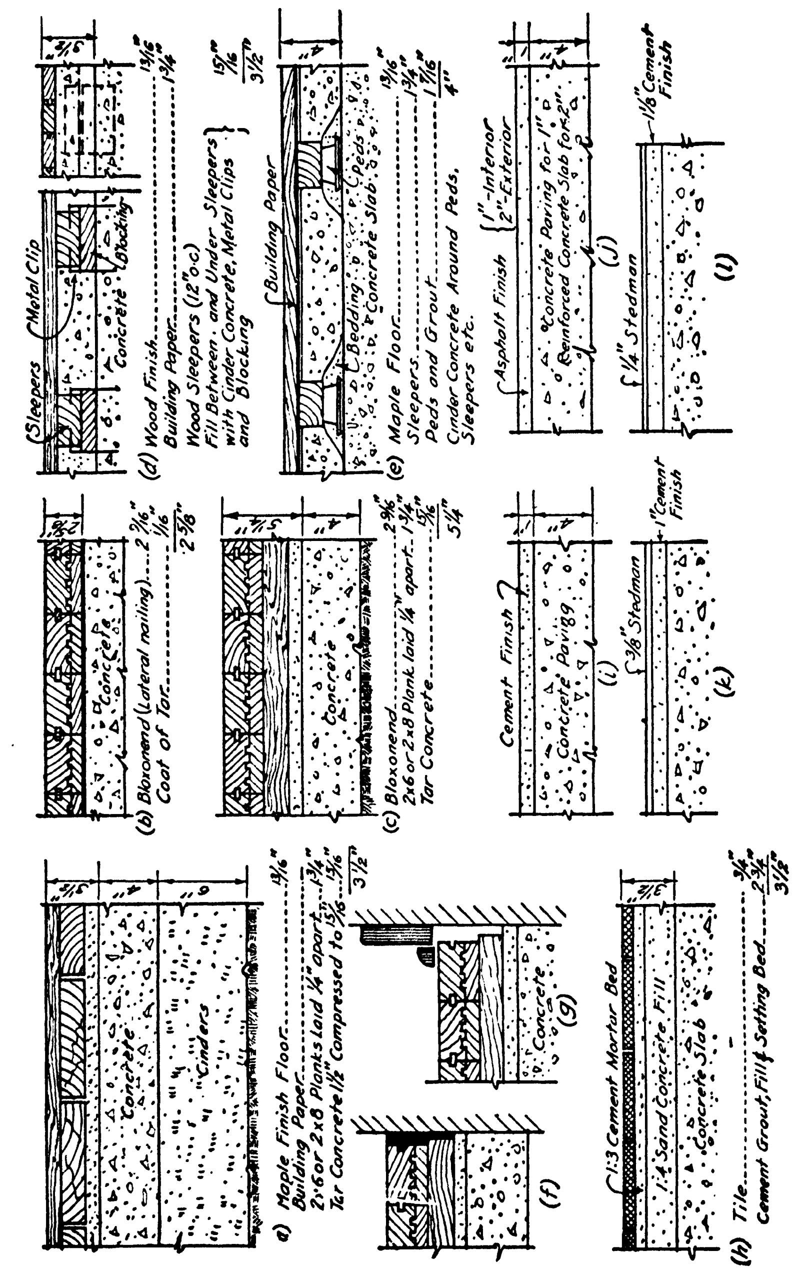


FIG. 6-20. Attaching Finish Floor Surfaces on Concrete Slabs.

Type of Floor	*Cost per Square Foot*	*Comparative Values*
Hollow tile arches	$0.518	131%
Cinder concrete slab	.51	129%
Junior beams	.41	104%
Reinforced one-way slab (used as base)	.396	100%
Gypsum tile, ribbed slab	.395	100%
Pressed steel joists	.382	96%
Cast-in-place gypsum slab	.381	96%
Permanent metal pans	.378	95%
Precast gypsum slab	.37	93%
Removable metal pans	.34	86%
Trussed joists	.34	86%
Tile (clay) ribbed slab	.33	83%

As previously discussed, each of these types have certain specific advantages which may outweigh their immediate cost because these advantages may reflect savings in other matters which would more than offset their increased cost. It must always be remembered that the ultimate objective of good design is to produce a building which costs less in the long run, which means first cost plus maintenance and effective economy of operation. Thus savings in the cost of the product of occupancy may well be credited to the cost of the building. First cost economy may be a delusion.

CHAPTER 7

ERECTION OF THE STRUCTURAL FRAME

STRUCTURAL STEEL

7-1. Detailing and Scheduling

a. The conventional indications of architectural and structural elements are shown on the contract drawings, an example of which is shown in Figures 5-2 and 5-3. From such plans the structural fabricator would make an erection plan such as illustrated in Figure 7-1. The essential differences between the erection plan and the structural plan are that every structural member is given a number and all detail dimensions and sections are shown so that every requirement of the architectural plans will be met.

b. The various members of the structural steel frame are joined by the use of rivets, bolts or welds. The great majority of structural steel frames are still riveted, bolts being used only for unimportant frames, not subject to great transverse forces or to vibration. However, turned bolts fitted into reamed holes may be considered as efficient as rivets. In some frames the bolts are prevented from working loose by spot welding the nuts to the bolts after they are pulled up tight. Girder, beam and column connections should always be riveted, unless welded, and in the main, frames of multi-story buildings should be secured by riveting or welding. Welding is becoming more and more reliable and is being used in many structures. The variations in the details used for riveting and welding are discussed in Article 7-8.

*c. **Structural Plans.*** In preparing the drawings for structural steel work two scales, one for the length of the member, or the skeleton of the structure, and one for the details. Members are commonly shown by one projection and the drawings may not be to scale, all differences being governed by figures and dimensions. These drawings are made sufficiently complete so that templates can be made for each individual piece. These are then used to center punch the individual parts ready for punching. When the connections and details are standard the connection is given a designation which enables the template shop to select the proper template for such a connection. These standards are all recorded in the "shop standards" in order to eliminate unnecessary repetition. These standards

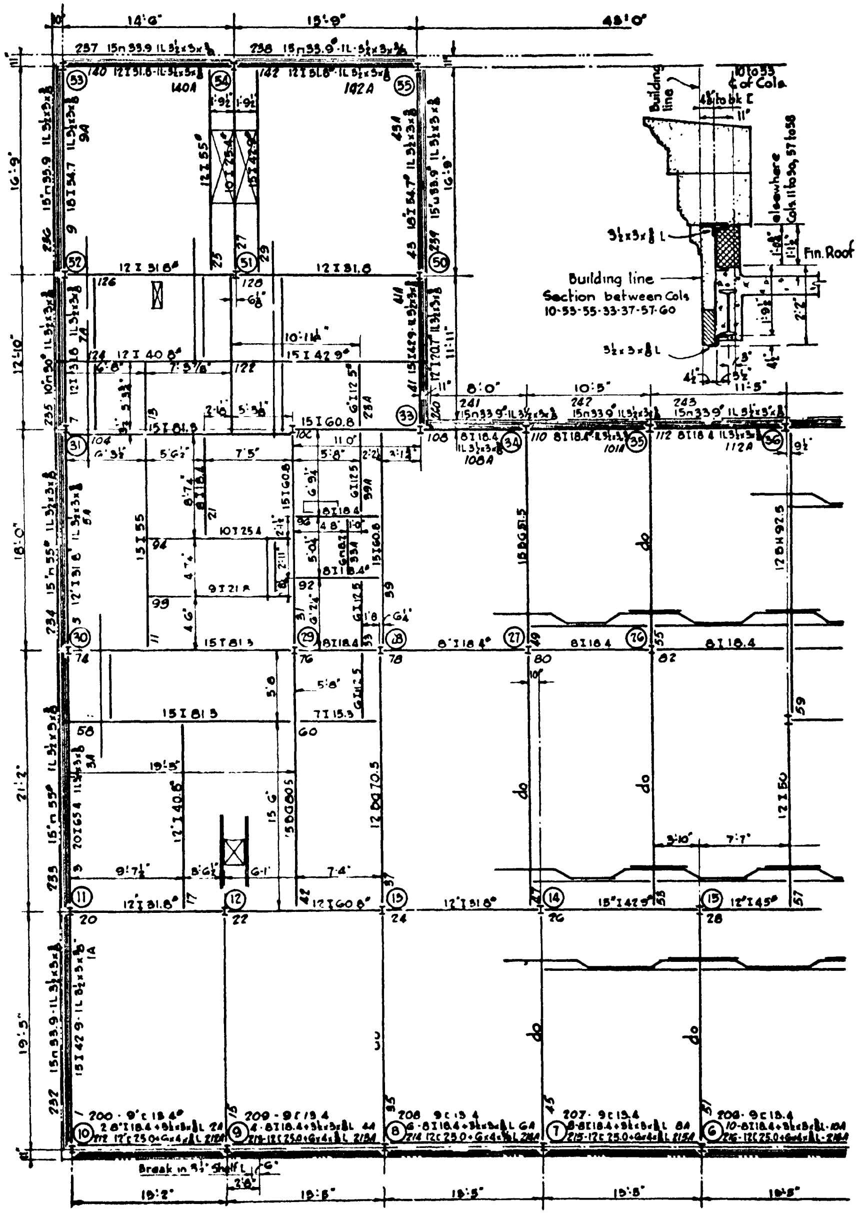


Fig. 7–1. Steel Erection Plan.

have been extended to include practically every connection of beam to beam and the usual beam to column connections.

d. There are some general rules for the preparation of shop drawings which are more or less standard in the industry. Each sheet should be arranged uniformly for each contract and the title should be placed in the lower right hand corner. The title usually carries the name of the job, its location, the name of the architect and engineer, the job number and the sheet number. The drawings should also carry the following information when practical:

(1) general notes,
(2) specifications,
(3) special requirements,
(4) painting, etc.

The usual scale for the lengths of members or the skeleton of the structure should be ¼″ or ½″ to the foot depending upon the available space on the standard sheet and the complexity of the member to be detailed. Members should be detailed in the position they will occupy in the structure, thus horizontal members should be shown lengthwise and vertical members crosswise on the sheet. It is customary to arrange the structural plan so that all dimension and member sizes read either from the bottom of the sheet or from the right hand edge of the sheet. Details of members should be drawn so that they read the same way on the detail sheets.

e. Elevations, sections and views should be shown in their proper positions. The top view should be placed directly above and the bottom view directly below the elevation. The bottom view should always consist of a horizontal section as seen from above. In sectional views, webs and gusset plates should always be blackened; angles, fillers and the like may be blackened or cross hatched, but only when necessary to clarify the detail. Holes for field connections should be blackened and should be shown in all elevations and sectional views. Rivet heads should be shown only where necessary; for example, at the ends of members, around field connections, when countersunk, flattened, and so on. These details together with the conventional signs for riveting are shown in Figure 7–2.

f. Shop bills should be written on special forms provided by the company for the purpose. Figure 7–3 shows a typical form used by one company. When the bills appear on the drawing as well, they should either be placed close to the member which is billed or at the right hand side of the sheet. A single sheet of shop billing should contain only the billing for one sheet of the drawings. The shop bills should serve as a guide for the laying out and assembling of the members besides being a list of materials required. For this reason members which are radically different as to material should not be grouped on the same shop bill; neither should pieces which have different marks be grouped in the same item, even if the material is the same. The main material of a member should be billed first, then the smaller pieces beginning with the left end of a girder, or at the bottom of a column. Each different bracket on a column should be billed by itself. When elements such as angles or fillers for plate girder stiffeners are billed, the angles and fillers belonging to each stiffener should be billed consecutively, first angles, then fillers. In this way the materials for each unit of a member should be billed together.

g. When machine-finished surfaces are required, the drawing and shop bill should specify the finished width and length of the piece, proper allowance for shearing and planing being made in the mill bill. When the

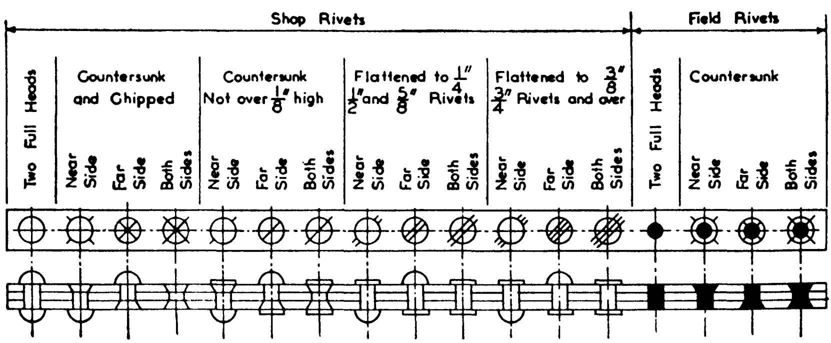


FIG. 7-2. Conventional Indications for Rivet Details.

metal is to be planed for thickness, the drawing and the shop bill should specify both the ordered and the finished thickness, for example—1 Plate—12″ x ¾″ x 1′-6″ (Planed from 13/16″).

h. A bill of field rivets should be made for each structure. It should give the number, the diameter, the grip, the length and the location of the rivets in the structure. The number of field rivets to be furnished to the erector should be the actual number of each diameter and length required, plus certain allowances. Field bolts should be billed in a like manner.

i. Details Facilitating Erection. Proper design will give due attention to the sizes of members and the arrangement of connections. It is therefore quite essential that the designer have considerable experience in steel detailing and erection. In this connection, Hool and Kinne* have given a few excellent suggestions.

* Hool and Kinne—"Structural Members and Connections." Copyright, McGraw-Hill Book Co.

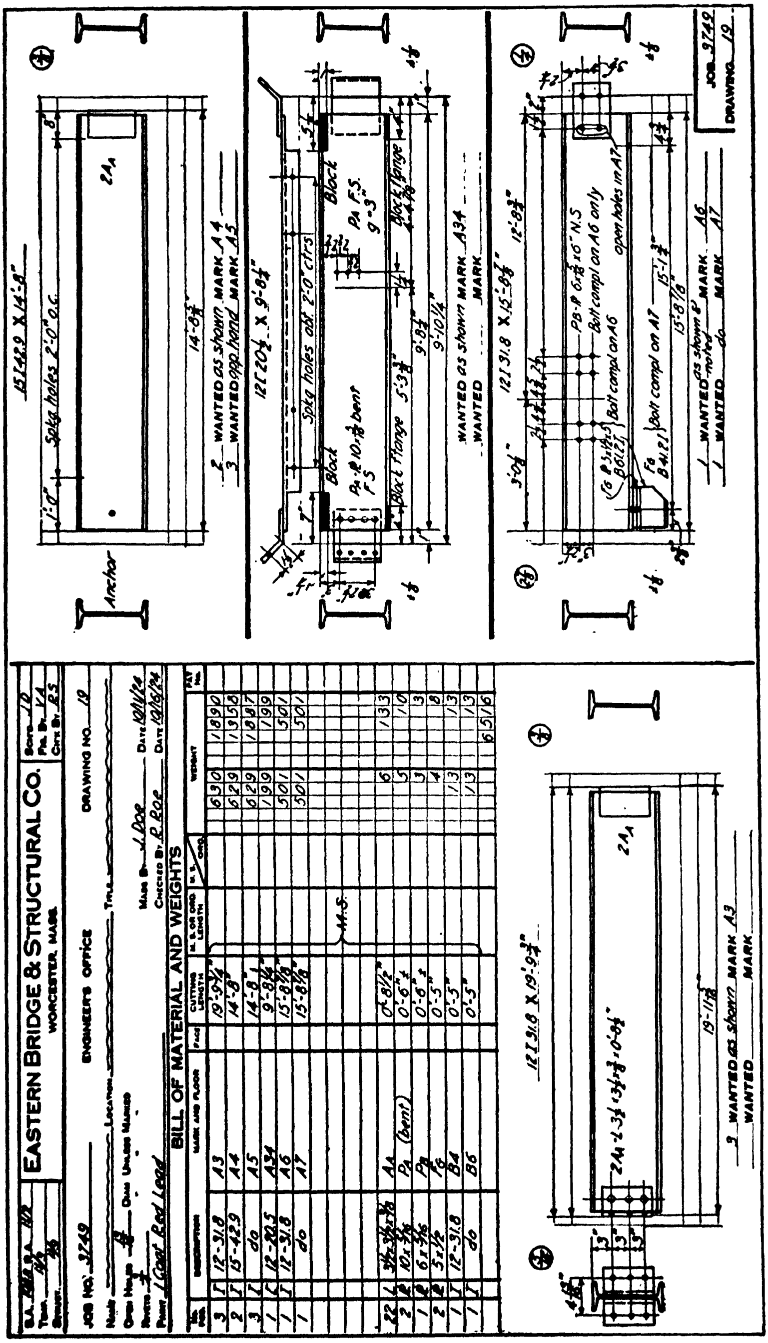


FIG. 7-3. Shop Bill and Details for Steel Beams. (*Courtesy Eastern Bridge and Structural Co.*)

1. Avoid entering connections. An entering connection is one which makes it necessary to slide a member into a connection with no way allowed to move the member either vertically or horizontally. These connections are usually most difficult and expensive to make and should be avoided.

2. See that proper clearances are given. It is important to allow ample clearance when members are packed in chords, posts, etc., as lack of sufficient clearance will cause an increase in the cost of erection by requiring more time.

3. The number of field rivets should be minimized. Shop rivets are more economical to drive than field rivets and are practically all driven by machine as compared to the hand driving of field rivets. Shop rivets should be used preferably instead of field rivets provided (a) minimum carload shipments are provided, (b) the shipping pieces are not too bulky, (c) the members conform in size to the train clearances, (d) the weight of any one piece is not too great for the derrick to be used in erection.

4. Sufficient space should be allowed around all field rivets to enable them to be driven. There should be enough room for driving and bucking up.

5. Details should be arranged so that the members can be swung into place without shifting the members to which they conform their final position.

6. When a beam frames directly into the webs of two columns, to permit the beam to be dropped into place, the rivets above one of the connections should be left out for field driving or should be countersunk.

7-2. Column Details

a. Splices. In designing steel columns, the engineer, in order to avoid too many splices, will carry each section through two stories. As the actual load on the columns is not the same in both stories it may be argued that steel is wasted. The ultimate cost, however, controls this point, as the cost of the extra column splice easily offsets the additional steel cost. The rigidity of the structure is also served to some extent by reducing the number of splices. The relation of local stock supplies and mill orders also enters into this problem. The steel for the basement framing is often taken out of local stock in order to facilitate immediate erection, and when only one basement story is planned. These columns would be only one story high.

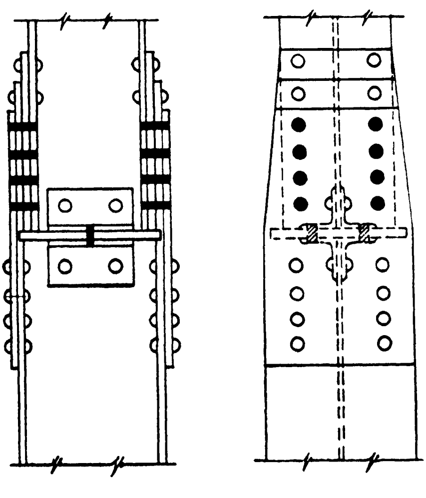


FIG. 7-4. Riveted Column Splice.

While this work is going on the fabricator is afforded time to get the first and second story steel to the job, using mill steel for the work. When splices are used they are ordinarily made about 2 feet above the floor steel and are detailed as shown in Figure 7–4.

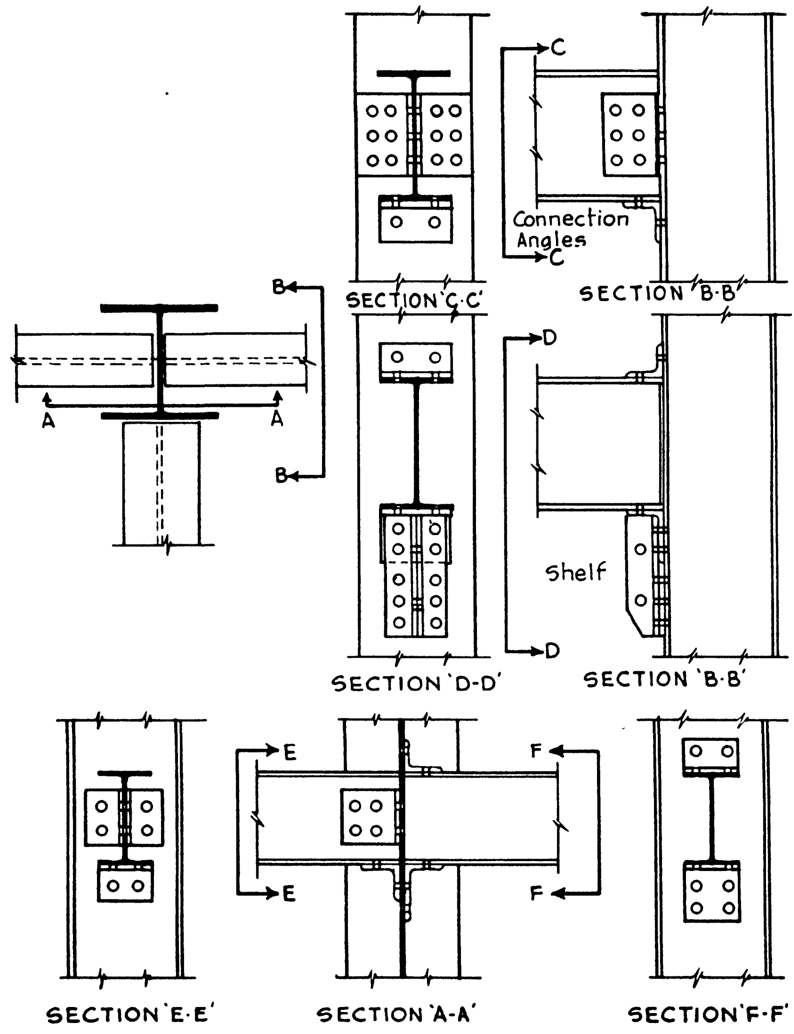


FIG. 7–5. Framing of Beams into Columns.

b. Beam Supports. The principal details made for column steel, now that heavier, wide-flange sections are in common use, are those for splices, the framing of beams and girders and for column bases. The most frequent of these are, of course, the beam and girder connections. The beams or girders may be framed into the column as shown in Figure 7–5, or they may be supported upon seats and provided with clip angles, having no web angles, as shown. When the framed connection is used the angles are riveted to the beam in the shop while the connections of the outstanding legs of the angles are riveted to the column web or flange in the field. The principal objection to this type of connection is the difficulty of making the connection in the field, so an erection seat is often riveted to the column to allow at least temporary support of the beam during securement. Without this seat the derrick is tied up longer in the erection process. Other objections raised against this type of connection are the difficulty of securing the beam into place because of the projecting flanges of the connection angles, and the amount of drawing required when the field rivets are driven, particularly when a pair of beams frame opposite each other, as they very frequently do. For these reasons it is usually desirable to use the seated type of beam connection. This type of connection eliminates the additional shop work on the beams, but for the larger reactions it is necessary to provide stiffener angles which afford support to the outstanding leg of the seat angle and the possibility of driving more rivets for shear support. The principal objection to such a connection is the interference of the outstanding legs of the stiffener angles with the fireproofing of the column. If this point is taken into account by the designer many of these objectionable cases may be eliminated.

*c. **Bases.*** At the bottom end of the lowest column section a base must be provided. The development of this detail has also been affected by the present use of heavy, wide-flange sections. In the past a built-up base made of structural sections was commonly used, as the column itself was a similarly built-up member. This detail is shown in Figure 4–3. In order to spread the load over a sufficient area of the concrete or the natural rock these bases were often provided with wing plates, as shown. To avoid these rather flexible plates the cast iron or cast steel base was used. Another method used for spreading the load involved the use of steel grillages as shown in Figure 4–1. The more recent and simplest means of spreading the load is the rolled steel slab shown in Figure 7–6.

d. Built-up bases, if used at all, should be confined to columns carrying relatively light loads. Cast steel bases may be used where the load must be spread over a considerable area, possibly where 6 to 9 square feet are required. It is wise to use either rolled steel slabs or grillages for column support. The American Bridge Company sets some very important requirements in connection with column bases. These are:

> Rolled steel slabs, instead of beam grillages should be used where the required length of beams is 3′-0″ or less. In general, preference is to be given to the use of slabs bearing directly on the concrete.

Single-tier grillages should be used in preference to double-tier grillages.

Column bases with wing plates and stiffeners should not be used.

Slabs 4" thick or less may be straightened true and smooth in the hydraulic press. Slabs over 4" thick should be planed where the surface has a steel bearing. Surfaces bearing on concrete need not be planed, but in order that slabs may be set true and level, proper allowance should be made for grouting between slabs and concrete.

e. When built-up cast steel and at times when rolled slabs are used, anchor bolts must be set into the concrete so that the column may be stabilized and secured. Then bolts should be set with the aid of templates made of boards or 2 x 4's of sufficient length to engage the bolts. To provide some adjustment of the bolts, they are often set inside of pipe

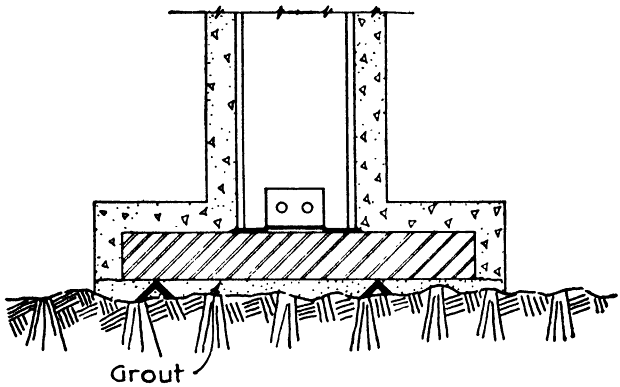


FIG. 7–6. Rolled Steel Slab Based on Rock.

sleeves which may be left in place or removed later. In any instance the sleeve should be about 1" larger in internal diameter than the bolt diameter. These sleeves should be packed with oakum to avoid the entrance of grout. When the concrete is cast, the oakum and templates are removed. After the base is set the space around the bolts and under the base are filled with grout. Perhaps no drawing and no construction is more important than the anchor bolt or column center plan and this work deserves careful checking and execution.

f. Built-up bases are a part of the shop fabrication of the basement columns and these are delivered and set as a unit. Grillages, made up of I beams, usually are delivered as one unit and handled as such by the derrick. If shoring interferes with this procedure, or if the grillage is too large, it can be built up on the foundation.

7–3. Beam and Girder Details

a. Beams and girders may be framed into column webs or flanges, into other beams or girders and they may rest upon other beams. When they are framed into columns their flanges may clear the flanges of the column and thus require no blocking. When framed into the flanges, unless other beams interfere, they never need to be blocked. In Article 7–2*a* the details of the column for these connections are discussed. The beam details are the matching counterparts for the same connection. When beams frame into other beams one of two schemes is used. When many lighter beams frame into heavier girders, the lighter beams are often framed so that

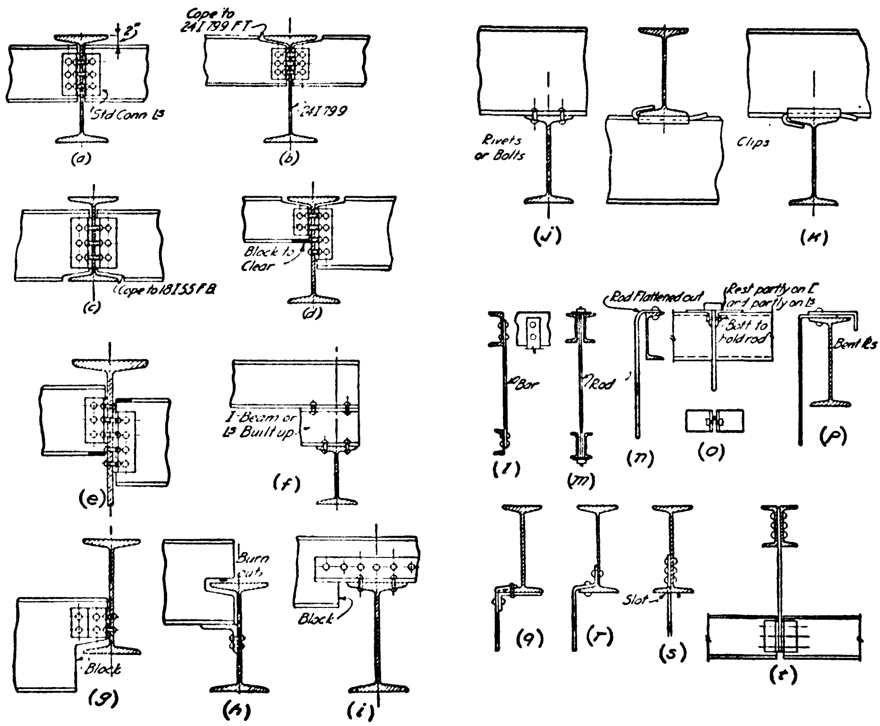


Fig. 7–7. Steel Beam Connections. (a) under girder flange; (b)&(d) tops flush; (c) bottoms flush; (e) offset opposite beams; (f) built-up bearing; (g) blocked, dropped beam; (h) reinforced, blocked, elevated beam; (j) riveted top bearing; (k) clipped top bearing; (l) to (t) hanger connections.

their upper flanges enter below the heavy upper flanges of the girders. The wide-flange girders now made with parallel faces permit this detail which was bad when the standard beams with sloping inner faces on the flanges were used. When this detail is used, coping of the lighter beam flanges is unnecessary and thus saves cost. It necessitates careful details in fireproofing and reinforcement locations. These details are shown in Figure 7–7. These details are the counterparts of the details of the girders into which the beam frames. When beams are rested upon other beams, the details are similar to those shown.

7–4. Truss Details

a. As for plate girders, trusses are indicated on the structural engineer's plan giving only the lines of action of truss members, their relation to their supports, the imposed loads, the reactions, the stresses in members and their composition as angles, channels, plates and so on. These are amplified by the fabricator as shown in Figure 7–8. These details give the size of every detail at joints, the gusset plates, the attachment for purlins or beams, and the location and number of all shop and field rivets.

7–5. Plate Girder Details

a. Plate girders are shown in a conventional manner on the structural engineer's plan as described in Article 5–4*i*. These, it will be remembered, give only the principal shapes, namely, the web plate, angles, and flange plates, the imposed loads, the location of supports and the reactions. These must be amplified by the fabricator in preparing his detail drawings for the approval of the consulting engineer. These details will show all rivet spacings, exact sizes of all plates, location and details of stiffeners, and location and details for the attachment of all members framing into the girder. This is illustrated in Figure 7–9.

7–6. Fabrication

a. Fabricating steel simply means preparing it for erection. The term "fabrication" includes all shop work necessary to lay out, cut, punch, and rivet or weld the steel shapes as they come from the rolling mills, to form complete members. The steel is handled cold in this operation rather than hot, as in rolling. Work at the site should be reduced as much as possible because of better facilities in the shop. However, members should not be made so large that it is hard to handle and ship them. All steel plants are planned so that the material passes from one machine to the next in logical sequence with a minimum of difficulty. The material is handled by overhead traveling cranes, jib cranes, gantry cranes, small hoists, derricks, small trucks on narrow gauge and rollers.

b. Templates are made in the template shop. They are wooden strips or skeleton frames of strips which show the location of all holes and cuts. They are usually ½″ or ⅝″ planed pine boards, but plywood is coming into more general use. Several grades of paper are used and the wood is resorted to only when the paper is not satisfactory, or when stiffness is a requirement for accurate work. Angles may have one or two strips for a template. When holes are to be punched in both legs of an angle, one strip may be used for both, or the template may be of two strips at right angles so that it covers the angles. One strip must be full length but the

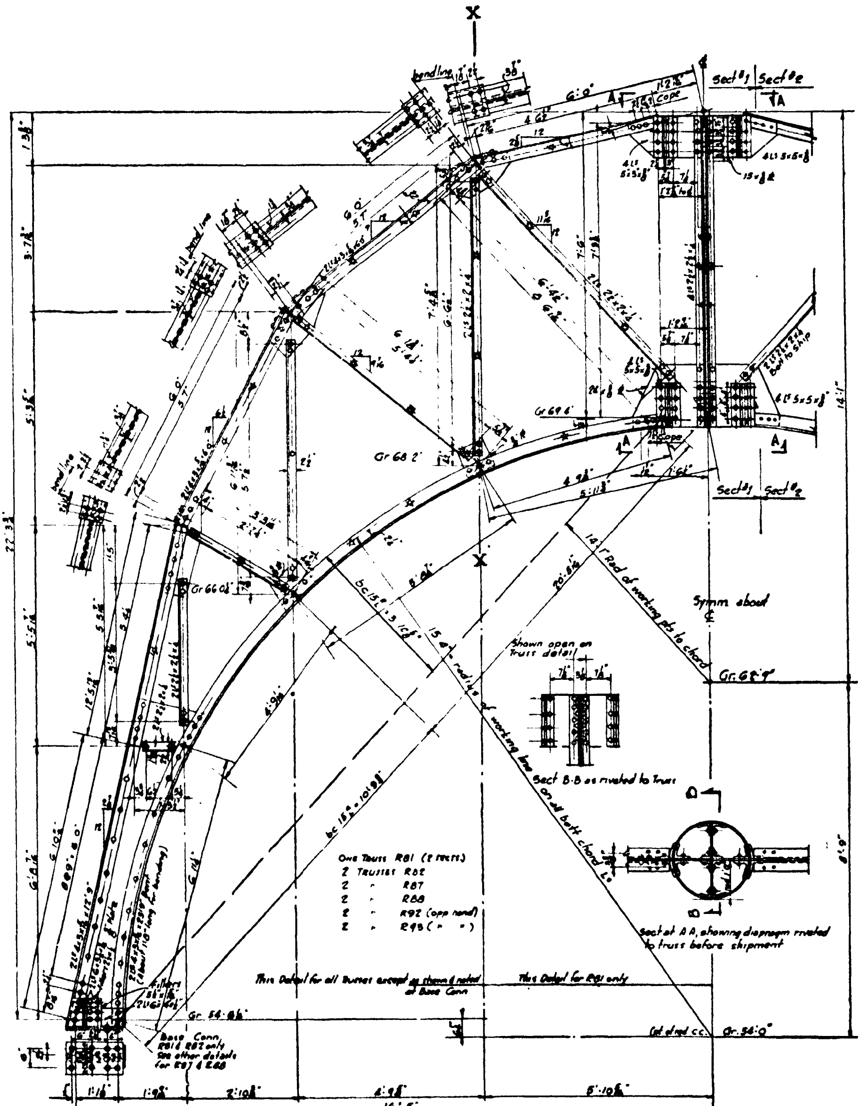
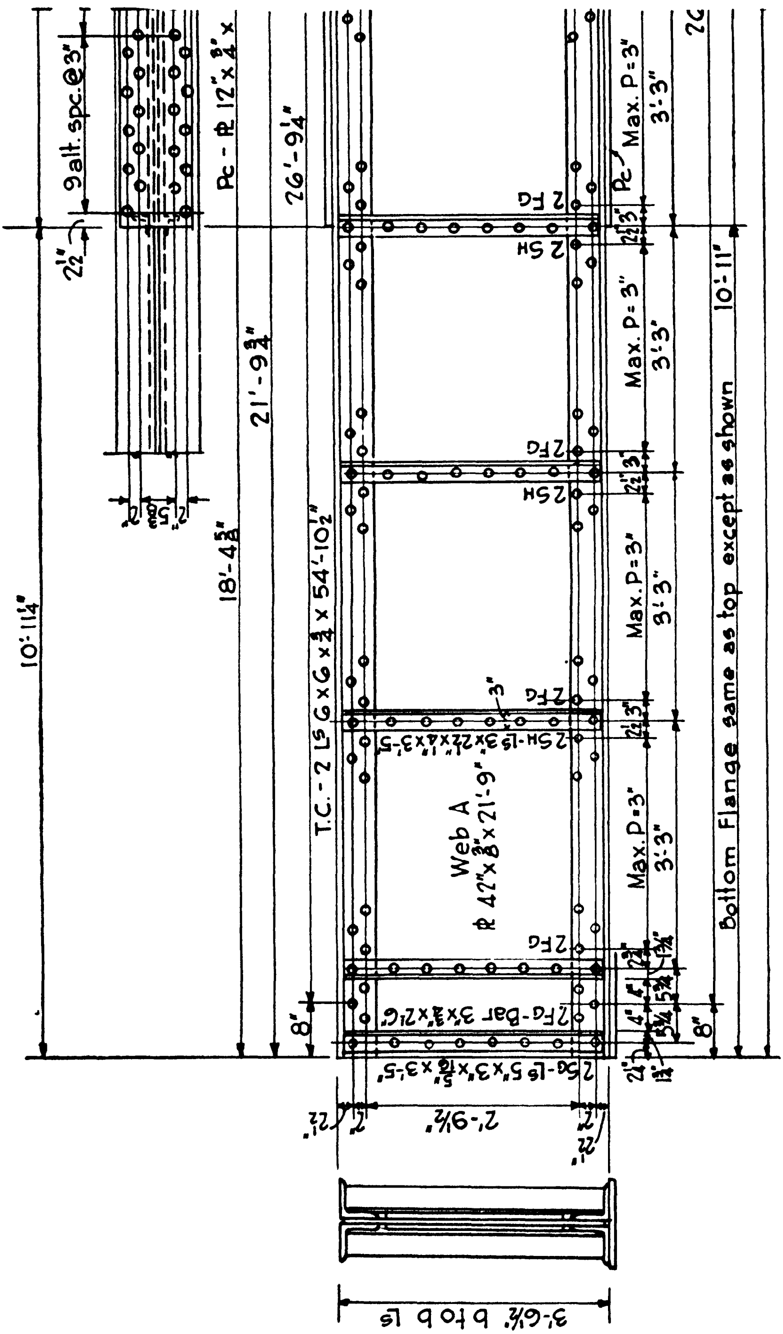


FIG. 7–8. Typical Truss Detail.

other may only be short pieces as needed. All distances are measured from the backs of the angle. When angles are made in pairs the template is


9 alt. spc. @ 3"
Pc - ℞ 12" x 5/8" x
26'-9¼"
21'-9¾"
18'-4⅝"
10'-11¼"
T.C. - 2 Ls 6 x 6 x ¾ x 54'-10½"
Web A
℞ 42" x ⅜" x 21'-9"
2 Fg
2 Sн
Max. P = 3"
3'-3"
10'-11"
Bottom Flange same as top except as shown
2 Fg-Bar 3" x ⅜" x 2'-6"
2 Sa-Ls 5" x 3" x 5/16" x 3'-5"
2'-9½"
3'-6½" b to b Ls

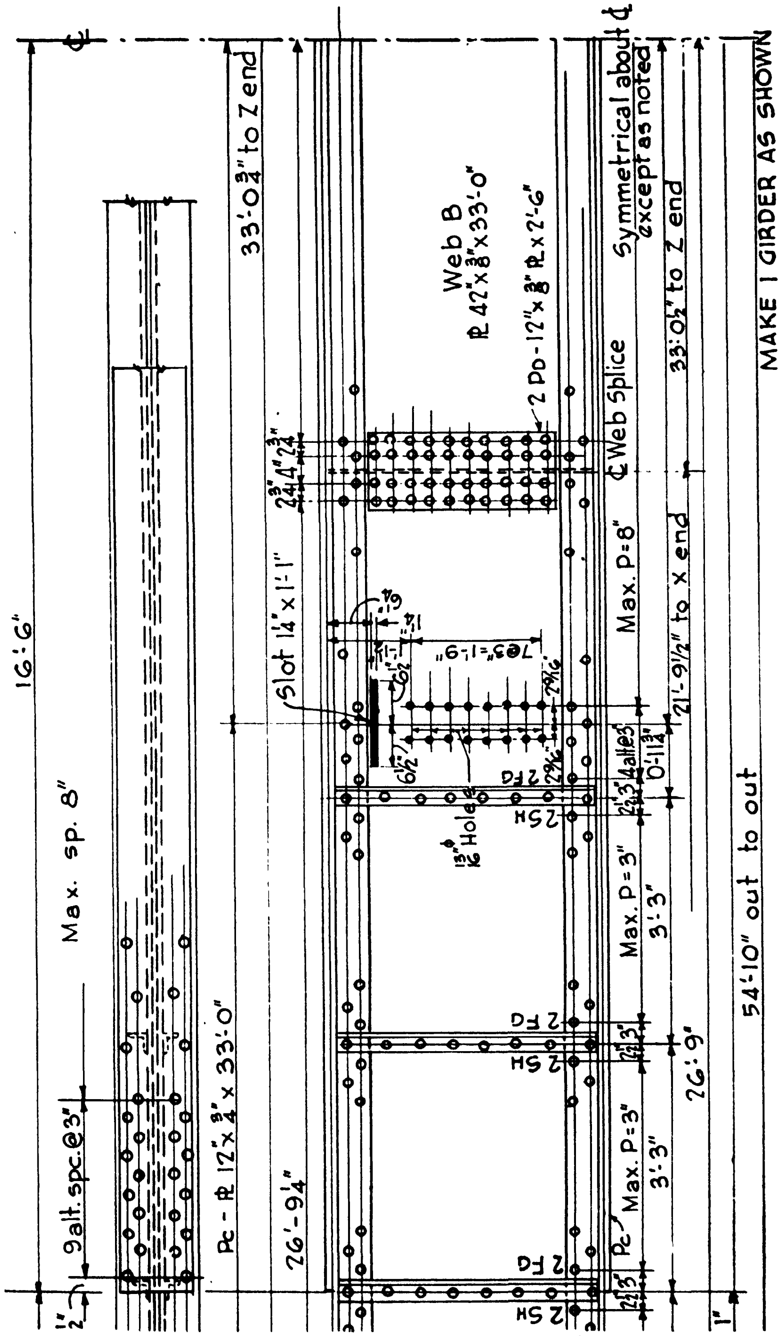


Fig. 7-9. Typical Plate Girder Detail.

T-shaped. These are full sized for smaller templates, but are frames for larger ones. For gusset plates, cardboard templates are sometimes used. If a number of beam and channel flanges are to be punched, a flange-strip template is made; otherwise, the holes are laid out directly. The same is done on the web except that another method of having groups laid out in separate templates is often used, especially for standard connections. Sometimes not all the holes in a template are punched at one time and the same piece is good for two or three combinations of holes. The contract number, drawing number, size of holes, identification marks, and the number of pieces required are placed on each template by painting. Typical numbering on a template is as follows: "3215, 4 angs. 3½ x 3½ x-⅜ x 3′-6″, Kb, item 41, sheet 5." "3215" is the contract number, "4" is the number of angles from the template, "K" is a symbol for a stiffener fitted at one end, "b" designates that there are different "K" angles, "item 41" identifies the material order from the mills, and "sheet 5" is the number of the drawing on which the piece is detailed. The positions of all holes are carefully laid out on the template and ½″ holes are bored through the wood at the centers indicated. These templates are used to locate centers on the steel by means of a "center punch." The template makers refer continuously to detailed dimensions of a working drawing.

c. As steel comes from the rolling mill it is placed in the stock yard. Extra material above the original order is kept there and thus additional material for alterations can be provided quickly. Most of the material for each contract is ordered especially for that contract and is placed in the receiving yard until needed. Plates and angles ordered in multiple lengths are cut to dimension in the receiving yard or in the receiving end of the structural shop. The "shop bills" are used to get the required length and numbers of plates.

d. Plates and angles are cut cold in one stroke by shearing. The plate shear has one fixed horizontal blade and that one moves vertically. One end of the upper blade is lower than the other so that the cut is gradual. Angle shears cut both legs at once. One leg is against a horizontal cutting edge, the other against a vertical one, and a single knife with two cutting edges moves diagonally past the two, shearing the angle. When diagonal cuts on plates or angles are required the material is run in obliquely, or the shears are rotated horizontally. Beams and channels usually are cut to the desired length in the mill. However, there are special beam shears which cut first one flange and then the other, but an inch of material is wasted and two or three inches of the steel at the cut is probably affected by the shearing action. A better way to cut the beams, especially heavy ones, is by means of a circular "cold saw," which is fitted with adjustable teeth of tempered tool steel on its circumference or oxyacetylene torches are used when the beam cannot be cut more economically by other methods available in the shop.

e. Having cut the material to the proper length the laying out process is next. This includes marking the steel either by means of templates or directly. The wooden templates are clamped in proper position on the steel and all notches and special cuts are marked with a piece of soapstone. The centers of holes are indicated by small dents in the steel which are made by a center punch through the ½″ holes of the templates by striking with a hammer. The punch is slightly smaller than the hole and is easily centered. A sharp point protruding from the end makes the dent. A series of punch holes are made along the soapstone lines to make them more permanent. White paint shows up all marks that otherwise might be overlooked.

f. Notches in plates and angles may be cut with blocking out punches or by punching a series of circular holes, using a pneumatic chisel to smooth the rough edges. Beams and channels are coped and notched in special machines or by using the oxyacetylene torch. A beam connecting to another of the same depth is coped at the end to clear the flange of the other beam. The flange is cut first and then the web. When stiffeners are used they must be rounded to fit the fillets, and this is done by grinding, planing or chamfering with rotating cutters.

g. Holes in the steel may be punched, drilled, or bored. Rivet holes are usually punched. The punch housing is stationary and the steel to be punched is moved until the dent in the steel is below the retractable point on the punch. The punch is released and forms the hole. Though most holes are single punched the larger plants have multiple punches, especially for standard connections. In the highest class of work, specifications call for drilled holes. The advantages are (1) the holes are true circles, (2) they are accurately centered, (3) they cause less damage to surrounding metal. Holes for important field connections are drilled through both parts using the same metal template. Holes are always drilled in metals too thick to be punched. Metal thicker than the diameter of the punch should be drilled. Fixed drill presses are used for small pieces, and gang drills are used where there are numerous holes in heavy members. To obtain the accuracy of drilled holes without the expense, sub-punching is resorted to. The holes are punched ¼″ smaller than the desired diameter and, after the parts are assembled, pneumatic reamers make the holes the proper size.

h. When the component parts of a member are ready, they are assembled by fitters and held in position by shop bolts. These are longer than necessary and have packing washers to save time in tightening. At least two bolts are placed in a member. The assembled members go next to the riveters. The rivets are driven by fixed hydraulic or compressed air riveters, by movable compressed air riveters (riveting bulls), by pneumatic hammers, or by sledges. The rivets are heated in the field and in some shops by the ordinary forge. The heaters commonly used in shops burn oil and the result is a steady flame. Electric heaters are used to a limited extent and will probably be used more and more as their advantages are recognized. The bucking up tools consist of different types of dolly bars. (Figures 7–23 and 24.)

i. A rivet is made with one head only and the other is formed in driving. The diameter of the hole is 1/16″ larger than the rivet shank so that the rivet may be inserted easily. A properly driven rivet has a well formed and centered head with a shank that fills the hole. Machine driven rivets make a better connection because of the enormous pressure employed in driving. Sledges and air hammers are used in driving otherwise inaccessible rivets. Countersunk and flattened rivets are driven similarly. Cutting out rivets is necessary at some time or other in any shop and also in the field. The most common way is to chip off one head with a pneumatic chipper and to back the rivet out with a pin maul. Burning off the heads with an acetylene torch and then backing out the rivets is more economical but more care must be taken so as not to mutilate the material.

j. Ends of members which are to be in direct bearing must be milled. A milling machine or rotary planer is used. The cutters are set in the plane face of the head toward the member to be cut. The member is clamped in front of the planer which can revolve in a horizontal arc so as to cut at the proper angle. Holes for pins of pin-connected structures are bored by large boring machines after the hole has been roughed out by punching a series of small holes. The cutter of the machine then enlarges it to the proper size.

k. When the work in the shop is done, the member is inspected as to important measurements, field connections and rivets. The inspector makes sure the member is completed and properly made. The defects that must be watched for by a shop inspector are listed as follows: pipes, laminations, bucklers, kinks, underfills, overfills, mill camber, shop camber, mispunched holes, cracked material, and short material. One or more coats of oil or paint are applied to each member before shipping. Parts which will be hidden when assembled are painted before assembly. The member should not be painted if a bond with concrete is wanted. Each member should carry its erection mark which should read the same as the erection plans from which it was detailed. (See Article 7–1*a.*)

l. The forge shop is a department of the fabricating shop and the work done in it is so diversified that to go through each process would be an endless task, and so a list of some of the many things done in it is as follows: forging, crimping, bending, rolling plates, rolling angles, beams and channels, rivet and bolt-making, upsetting, threading, pipe bending and heat treating.

m. There is no fixed price per ton of fabricated steel in a given market. A heavy job with mostly straight pieces and much duplication will be lower in price per ton than a light irregular job.

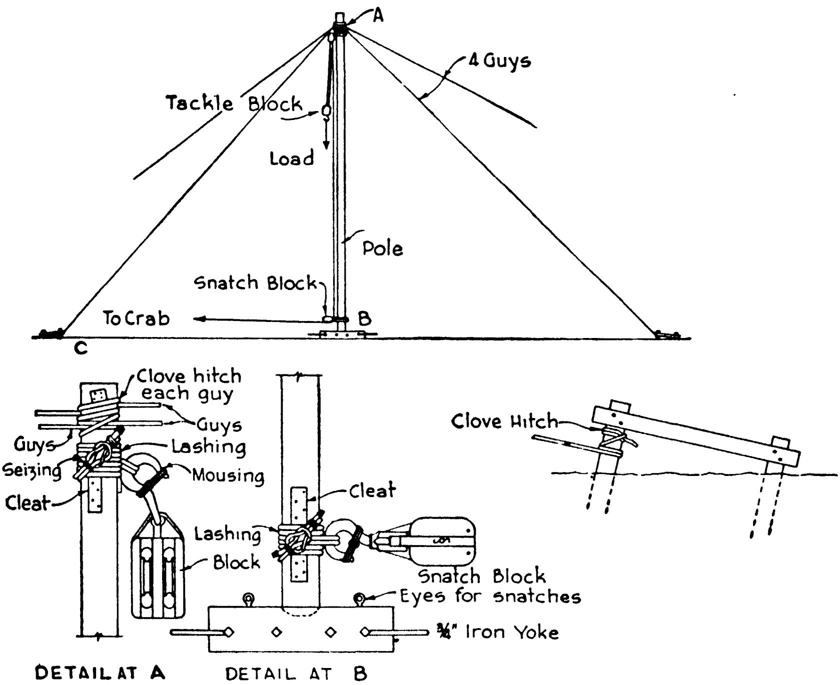


FIG. 7–10. Gin Pole Details.

7–7. Erection Equipment

a. Steel erection involves the use of many kinds of tools and equipment. Among these are those classed as derricks, slings, chains, tag lines, hammers, dollies, tongs, wrenches, drift pins, rivet snaps and forges.

b. Derricks (Figures 7–10 to 7–15). The gin poles and jib boom may be classed with the stiff-leg and guy derrick. The gin pole, illustrated diagrammatically in Figure 7–10, is used for auxiliary lifting where the weight to be raised does not exceed 8 tons. The pole length usually does not exceed 60 feet and the sticks used vary from a 6 x 6 to a 12 x 12. The slenderness ratio should not exceed 60. Poles 40 feet long can be raised by hand, but longer poles must be raised with the aid of tackle. The guys are lashed to the top of the pole and secured at the ends to staked anchorages as shown. The load tackle is lashed to the pole directly under the guy attachments as shown. The free end of the tackle line is led through a snatch block at the base of the pole and then led to some form of

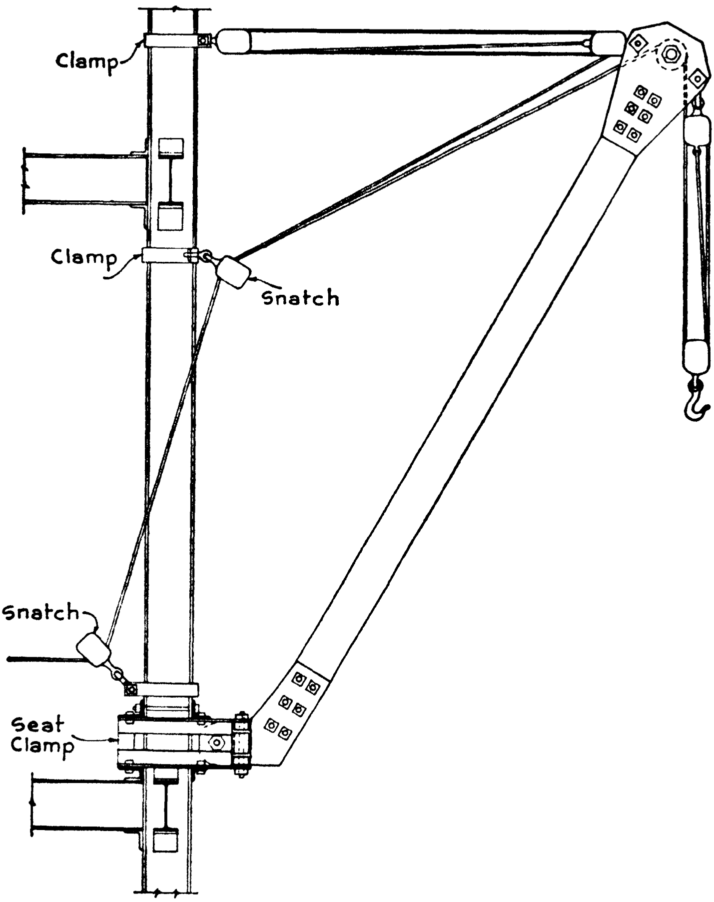


Fig. 7-11. Chicago Boom Detail.

hoisting device such as a crab or other form of winch. The pole may be bedded into a depression in the ground, when working on grade, or on a footblock provided with anchorage yokes. The weight may be moved a small distance horizontally by slacking off on a pair of guys and bringing the other two guys up to move the load.

c. The jib boom, called the "Chicago" boom in some quarters, is a stick attached to an existing vertical member, usually an exterior column of a building frame, and is guyed back to the frame. This assembly is shown diagrammatically in Figure 7–11. The boom may be rigged similarly to the gin pole, but because of its frequent use is made up with fittings to save the labor of rigging in each instance. When so equipped, as shown, the boom is equipped with a boom seat. The jib boom is equipped with a load tackle, just as with the gin pole, and a boom tackle

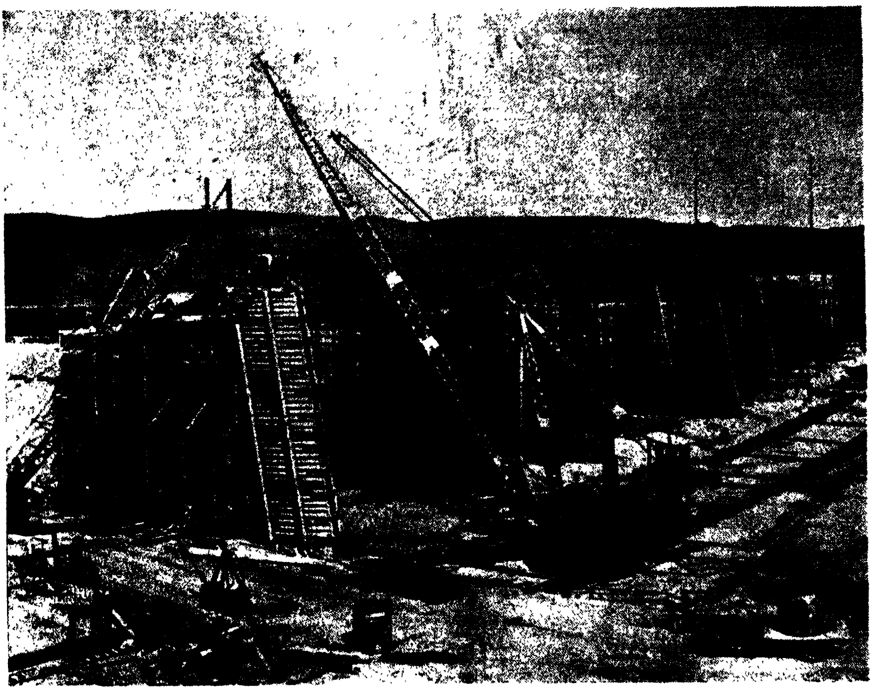


FIG. 7–12. Stiff-Leg Derrick and Tractor Boom Casting Concrete. (*Courtesy American Hoist and Derrick Co.*)

for raising and lowering the boom. The load tackle and boom tackle lines are led through snatches at the seat to power winches operating on the floor at the level of the boom seat. The reason for high level power is that the jib boom is commonly used for auxiliary work in the erection of the exterior wall construction.

d. The stiff-leg and the guyed derricks are usually rigged in the same way. The essential difference is the method for stabilizing the mast. In the stiff-leg derrick, the mast is held vertical by the use of two shear legs braced back to the sill members of the foot-block. In the guy derrick, guy cables attached to the spider plate at the top of the mast are run back to anchorages. These details are shown in Figures 7–12 and 7–13. Power

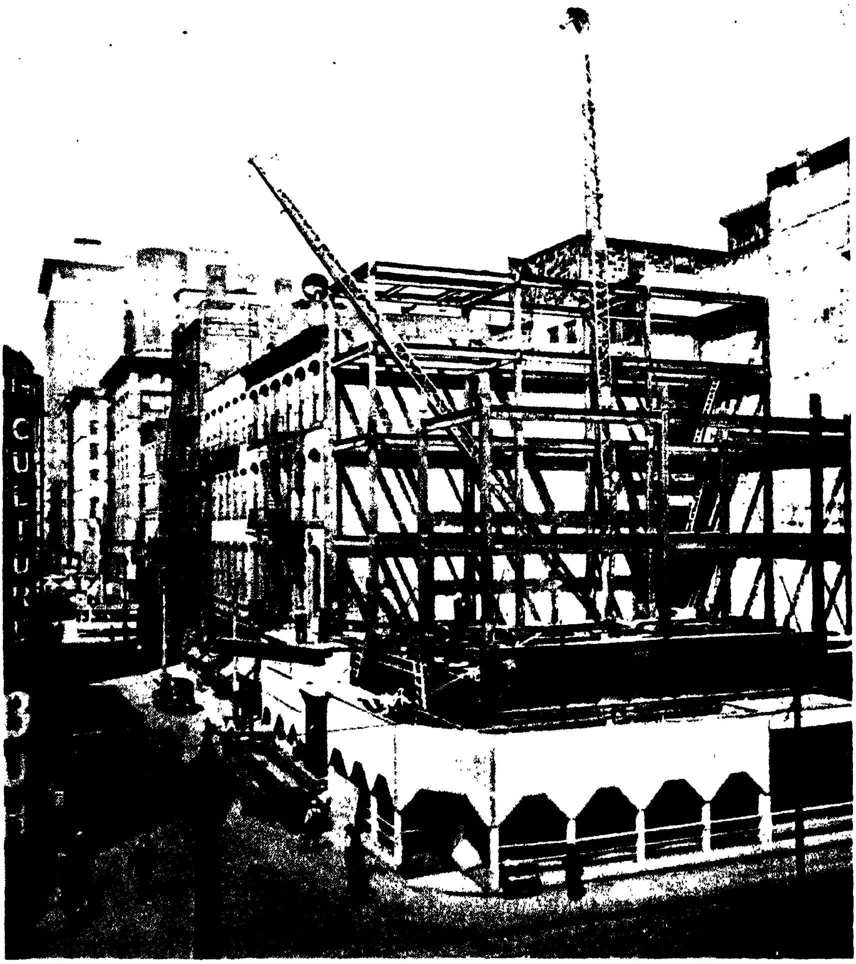


Fig. 7–13. Guyed Derrick. (*Courtesy American Hoist and Derrick Co.*)

for either may be furnished by a hand-operated device or some form of power unit. The stiff-leg derrick is adaptable only to erection in a fixed area. Thus, it is frequently used on the roof structure of a building frame to assist in the erection of the exterior wall stonework. Its angle of operation in a horizontal plane is usually 270 degrees. The guyed derrick has the advantage of economic movability, horizontally and vertically, and a sweep of 360 degrees in the horizontal plane. Both derricks can be swung in a horizontal plane by the use of the bull-wheel, which is attached to the mast and which is operated by power cables. In the absence of the bull-wheel, a bull-stick may be used. This is simply a horizontal lever used to revolve the mast and is hand operated.

e. The rigging for both types of derrick consists of a load tackle attached to the boom end and a boom tackle to the boom end and to the mast top. The free ends of both tackles are reeved through snatch or deflecting sheaves in the mast and at the base of the mast to be fed to the power unit. Figure 7–14 shows the details of the fittings for the mast and boom.

f. Both derricks are threaded in a similar manner. In the load tackle the rope or cable passes from the becket of the upper block around the lower block being reeved around the sheaves until the rope or cable is passed through the lower block and up to a deflecting sheave in the boom, from which it passes over to a deflecting sheave on the mast and from there down to a sheave in the mast step and then to the power unit. This tackle is used to raise and lower the load without any horizontal motion. The boom tackle is reeved by passing the rope or cable from a becket on the boom end block around the block at the mast top, and after passing around the sheaves to effect the mechanical advantage required, it passes from the last sheave at the boom end to a deflecting sheave on the mast and from there to a sheave in the mast step and then to the power unit (Figure 7–15).

g. A steel erector's derrick must have the following characteristics:

(1) ease of assembly of the boom to the mast,
(2) boom must be designed so that it may be brought up vertically close to the mast,
(3) sections must be of convenient shipping length and size,
(4) anchorages of guy wires must be easily made and changed.

The contractor's derrick is generally made of timber and is turned by a bull-wheel. Usually the engine is on the same level with the derrick, whereas this is seldom the case with the steel erector's derrick. While many of the derricks to be seen on building operations are of steel, many timber derricks are being used with great success. Many contractors favor the wood derrick.

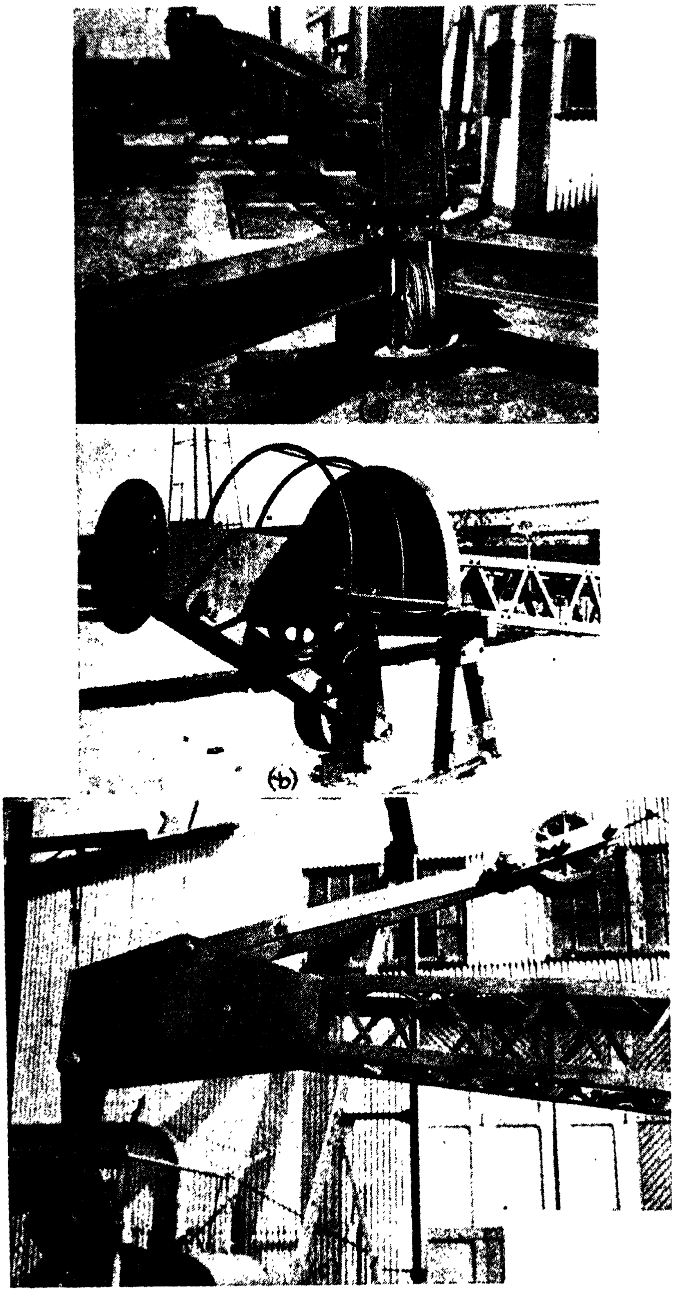


Fig. 7-14. Derrick Fittings. (a) mast base; (b) mast top; (c) boom end. (*Courtesy American Hoist and Derrick Co.*)

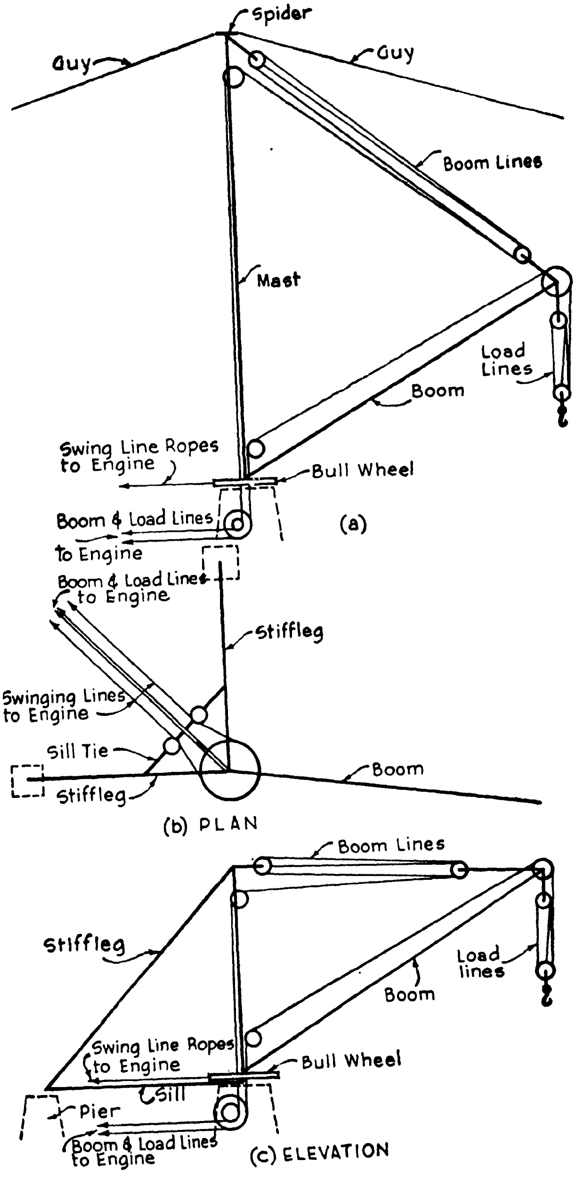


FIG. 7-15. Reeving Derricks. (a) guyed derrick; (b) stiff-leg derrick, plan; (c) elevation. (*Courtesy Insley Manufacturing Co.*)

h. Derrick Details. The parts of a guy derrick are:

(1) mast,
(2) boom,
(3) foot block,
(4) mast top,
(5) guy wires or cables,
(6) hoisting line,
(7) boom line, and
(8) hoisting engine.

i. In steel derricks the construction consists of four angles with lattice connections. The mast has one flat side near the boom, thus the boom can be raised to a position parallel to the mast. The mast and boom of sectional steel derricks are made with the standard connections so that one or more sections can be used, thus varying the height of the mast and the length of the boom. The length of any section is limited to the length of a single flat car, which is 40 feet.

j. The boom of steel derricks is also made up of four angles with a lattice connection. The boom tackle is fastened at one point, the load blocks at a second point, and the boom point sheave at a position below the other two connections. This construction places bending in the end of the boom and also causes whipping and quivering of the boom while in operation. Another type of derrick has all these connections in one pin, thus preventing both bending and quivering under load.

k. The mast has a foot block attached to its lower end upon which it rotates. The function of the foot block is that of distributing the stress to the sills upon which it is placed, and also to form a flexible connection for the mast. There are several methods of providing for the easy rotation of the mast and boom. In all derricks some form of bearing is used, either cast iron faces or some form of steel forging. The mast employed in structural work is generally of great height and considerable weight and it has been found difficult to rotate the mast for purposes of changing its position. When this is to be performed manually, the great amount of friction which is created at the base of the mast or foot block makes this operation difficult for one man to perform by means of a bull-stick. It has been found by actual experience that by the use of a ball bearing foot block this difficulty may be overcome, and the shifting or rotating of the mast may be accomplished with comparative ease and with less man-power than with other types of foot block. A feature of the construction of the foot block is to eliminate friction and to provide a support or base for the mast, whereby the pressure on the ball race is evenly distributed, regardless of the position of the mast—whether the mast is perpendicular to the foot block or at some angle to it. In most derricks this is done by some form of ball and socket joint. The foot block consists of a base plate and a mast step, and the mast step is provided with a hub which fits an opening in the base plate, thereby affording a connection between the two members. Between the two members are ball bearings traveling in ball races on the respective members. Considerable stress is imposed on the foot block as the boom, which is carried by the mast, is elevated, and the horizontal thrust of the boom is transmitted to the mast, and is taken care of by the hub of the mast step entering into the base plate. Therefore, the pressure on the block from a perpendicular direction is taken care of by the ball bearings, and the stress transmitted in a horizontal direction by the boom is cared for by the hub on the mast step, so that with all the pressure and strain imposed on the foot block it is constructed to withstand such conditions without binding or creating friction, thus permitting the mast to function properly. This type of derrick is designed to be rotated easily by one man under the most trying conditions, while with other types of derricks it is necessary to employ several men for this purpose. The ball and socket type of foot block produces excessive friction and is much harder to rotate for that reason. The ball and socket joint allows the mast to tilt in any direction and is of very simple construction. The only variation in ball and socket foot blocks is in detail. In four types of derrick bases, all made by different manufacturers, the bases consisted of steel castings in two cases, and chilled cast iron in one; the other type was a combination of chilled cast iron and cast steel, but all employed ball and socket joints.

l. In all types of derricks the connection between the boom and mast is made by means of a pin. Most derricks have a pin which is removable and which must be taken out in order to remove the boom from the mast. This construction cuts down the time necessary for the "jumping" of the derrick. The boom pin fits into the slot and the locking plate is bolted over it. The time necessary for removal of this plate is slight, and the saving in the time required for jumping is appreciable. The real saving is in the time saved by the locking plate when the boom is to be stepped into the mast. This operation, when performed with the type of derrick employing a removable pin, necessitates the lining up of the holes before the pin can be placed. With a locking plate the boom pin is simply slipped into the slot and the plate placed over it.

m. The mast top consists in the main of two important parts, the spider and the gudgeon pin. The spider plate has the guy wires attached to it. In raising a load with a guy derrick the top of the mast is pulled in the direction of the boom, thus stressing the back guys, and with the usual slack in the guys the mast gets out of plumb. The tilting or inclination of the mast toward the boom causes the spider plate to bind on the gudgeon pin, making it very difficult to rotate the mast. This condition is very common in derricks, and with the use of roller bearings this problem is overcome. The ball bearings between the base plate and the spider plate equalize the pressure which is exerted on the spider plate and the roller bearings around the gudgeon pin, thereby making it possible to rotate the mast freely. (Figure 7–14.) The simplest form of a spider plate consists of a dish-shaped steel disc with holes on the edge for the guy shackles and a hole in the center for the gudgeon pin. Obviously this plate will not be very satisfactory for heavy work. The derrick spiders of five manufacturers showed that only one derrick was fitted with bronze bushings around the gudgeon pin. All of the others used a casting of iron or steel around the pin, and no attempt was made to prevent excessive wear or binding at this point.

n. It is unusual to have enough space on the site of the building operation to anchor the guys at a great distance from the mast. The anchorage is usually within the confines of the building lot, thus bringing the guys down to a point which causes them to interfere with the swinging of the boom. When the derrick is raised and placed on the steel work it is also necessary to bring the guys close to the mast. This is the reason why the derrick is built so that the boom can be raised to a perpendicular position. In order to clear the guys the boom must be raised to this position. The radius of operation of the derrick is limited to the arc between any two guys, while the boom is at an angle to the mast. When the boom is to be moved past a guy, the boom must be raised to clear it.

o. Anchorages for guy lines may be to loops of cable bedded in the concrete of column and wall footings, and wherever the use of guy derricks is contemplated below grade, provision for these anchorages should be made when the concrete for the foundations is cast. (Figure 7–16.) Another type of anchorage below grade is the dead man, which consists of a 12 x 12 timber from 6 to 10 feet long, to which 3″ or 4″ planks are spiked at right angles. This is buried in the ground at such a depth that the weight of earth will provide a sufficient resistance. A cable sling is attached to the 12 x 12 and carried to the surface of the ground. (Figure 7–17.) Sometimes it will be sufficient to use a post anchorage, consisting of a 12 x 12—10 to 15 feet long, with a cross plank spiked to the lower end, the whole being bedded in the earth at a sufficient depth to provide proper resistance. (Figure 7–18.) Above grade anchorages for the guys are made by placing cable slings, called "chokers," around the column heads, below the splices. (Figure 7–19.) By use of the choker the speed of securing anchorages is greatly increased. A loop of cable is placed about a column for the anchorage of the foot block. This is

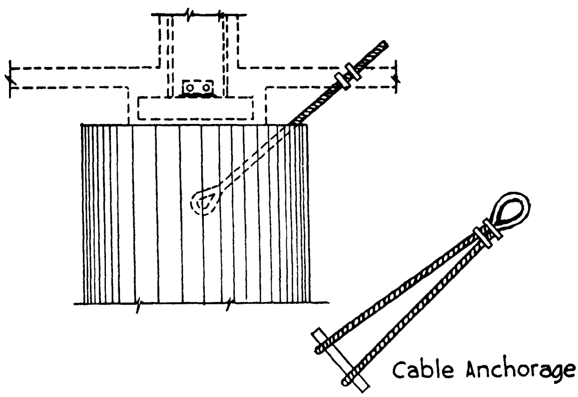


FIG. 7-16. Footing Guy Anchorage.

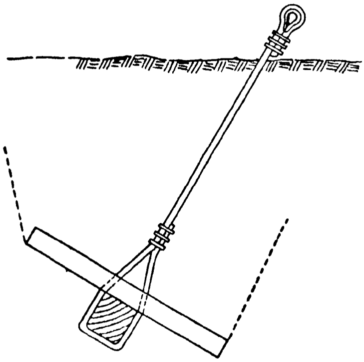


FIG. 7-17. Dead Man Guy Anchorage.

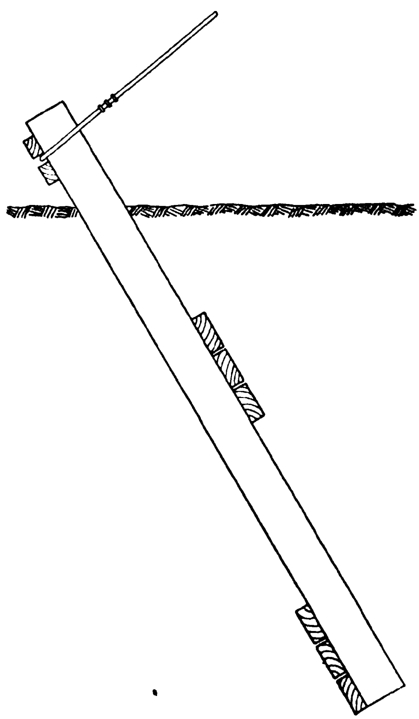


FIG. 7-18. Post Guy Anchorage.

fastened by means of wire clips. When a choker is used there is no time lost in placing and removing these clips. As there are about 6 clips on a guy wire anchorage, it may require an hour for one man to remove and replace these clips. Therefore, it is a distinct advantage to use a choker.

p. The guy tightener (Figure 7–19) consists of:

(1) turnbuckle,
(2) threaded rod with sheave, and
(3) threaded rod with loop end.

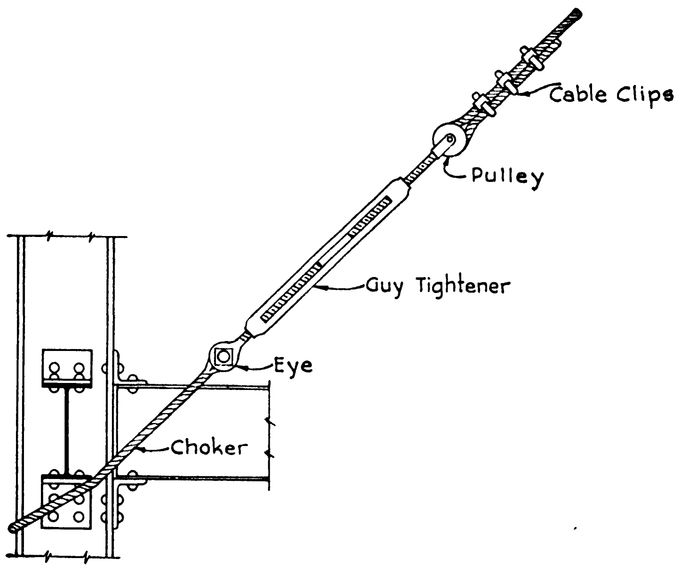


FIG. 7–19. Choker Anchorage to Steel Frames.

This device has a take-up of about 4 feet. It is designed to receive the guy cable through either a sheave or a thimble connection. The guy shackle may be:

(1) shackle with sheave,
(2) pin shackle, or
(3) screw shackle.

Shackles are used for quick connections between the guy tightener and the choker or other device used for anchorage. The first type shackle with sheave is used directly without a tightener or turnbuckle. The pin shackle has a cotter pin for securing the pin through the opening in the device. With a screw shackle one hole is threaded and the pin is screwed into this hole.

q. The hoisting tackle at the boom end consists of two sheaves, one attached to the boom and the other free to move, and has a pin or link attached to it for fastening either a hook or a down haul ball. These blocks are called load blocks, while the blocks used on the boom tackle are called topping blocks. As the steel work progresses the derrick is raised to the level from which new steel is to be erected. The hoisting engine is set at the basement level or at the first floor level of the building. For this reason there must be enough load upon the load line to balance the weight of the cable which extends down the building. This load is supplied by means of either a cast iron ball placed between the sheave and the hook, or by placing cast iron cheek weights on the cheeks of the sheave. The maximum length of line used is for about 25 stories in height. When this height is reached the weight of down haul ball needed to counterbalance the weight of hoisting line becomes excessive. At this point the whole hoisting engine is raised to the 25-story level and operated at this point.

r. The boom line is brought through a sheave in the foot block in the same manner as the load line. The line is brought through the center of the mast to the top. It is then passed through a sheave and attached to the topping. When two sheaves are used in the foot block so that there are only two lines running to the drums of the hoisting engine, the arrangement is called two-line work. This is the usual method for hoisting and is used on steel erector's derricks.

s. Operation of Derrick. Six men are usually used for the erection crew, including the pusher or man in charge of the crew. This is the most convenient and economical size of crew, as more men cannot work together efficiently, and with fewer men the output would be considerably reduced. All the men on such work are structural iron workers. The crew is composed of the following:

(1) pusher in charge of crew,
(2) bull stick operator,
(3) signal operator, and
(4) steel workers attaching loads and setting steel in place.

t. Signal Systems. Two cords are run from the point at which the derrick is placed down to the hoisting engine. These cords are run on small pulleys and are not boxed in. At the hoisting engine the cords are attached to two gongs of different size, usually 8″ and 12″ in diameter. The cords are held by the signal man, and are of sufficient length so that he can move about and watch the operations. The operation of the signal system is in the hands of the signal man. He follows the signals given to him by the pusher and the men erecting the steel. The load is fastened to the hook by means of a sling, and a manual or verbal signal given to the signal cord operator. All the work is watched by this man and he has full control over the movement of the derrick.

u. Jumping of Derrick. (Figure 7–20.) The process of lifting the derrick from one floor to a floor above is called jumping. The steel is erected about the derrick, which has been placed in a central position, so that the derrick is completely surrounded by the steel work. The outer steel, farthest away from the derrick, is placed first and the rest of the steel placed until the derrick is enclosed. Panels may be omitted so that room is left for hoisting the derrick. The timbers or steel beams which constitute the base of the derrick and which are connected to the foot block usually rest on several larger beams which are placed upon the steel work. When the derrick is to be lifted to the next level, the whole block may be raised, including the timber sills, or the boom clips which are on the timbers may be used. The boom clip consists of a pair of angles mounted on the timbers so that a pin can be inserted between them. This pin will fit the boom end and has cotter pins in the ends for easy removal and replacement of the pin.

v. In jumping the derrick several distinct steps are necessary. In Figure 7–20 these are discussed in connection with the several photographs shown.

1. Before jumping is commenced the derrick, while setting on the temporary beam grillage which rests on the building frame, erects the steel of the next two higher stories until it closes itself in. Note the wire rope kickers to hold the foot-block in place.
2. The derrick in its close quarters booms up tightly to set up the last of the steel in the floor two stories above the derrick, before the rig is jumped to this higher level.
3. Temporary grillage is set to support the derrick on the upper level.
4. The boom is then unpinned from the mast and is fastened to a steel shoe at the lower level as shown. The mast, used as a gin pole, lifts the boom through the normal topping-lift or boom falls. After being stepped out, the boom is turned through 180° so as to bring the load line adjacent to the mast. The bent corners of the 14″ square shoe plate is spiked to the temporary timber base as shown. The foot-block kickers are unhitched from the building frame and the foot-block is temporarily fastened to the mast to insure its being lifted when the mast is raised.
5. With the boom stepped out, five jumping guys at the boom tip are set up to assist the boom in functioning as a gin pole. Two guys brace the boom on the mast side while three others are splayed back.
6. The load fall from the guyed and stepped-out boom is hooked to

a choker fastened around the mast about 30 feet below the boom tie to give adequate drift for making the 25 foot, two-story jump.

7. The boom "gin pole" lifts the mast after the eight 1″ wire rope guys radiating from the mast head spider are unhooked from the building frame. The topping lift is now reversed.

8. The mast is now started up. The lifting line is the normal load line running from the drum of the hoisting engine below, passing through the mast foot-block sheaves to the boom tip and then down to the load fall at the choker on the mast.

9 and 10. Successive steps in the raising of the mast are shown in these photographs, until the foot-block is ready to rest upon the steel grillage beams at the new levels.

11. The jumped mast is then rested upon the temporary grillage after the beams are skidded into place. Planking eliminates steel-to-steel contact and prevents the foot-block from kicking out under the load.

12. Derrick guys are refastened and the turnbuckles are tightened. The blocks and falls are part of the jumped guys.

13. With the mast reguyed, the jumping guys and load falls are unhooked and the boom is raised by the topping lift of the mast used as "gin pole." The shoe is still pinned to the boom heel.

14. The boom pin holes are then lined up with the holes in the boom seat at the base of the mast, after the boom shoe is removed.

15. The boom is then repinned to the mast. The double taper on the boom and mast tends to kick the heel of the boom away from the mast as the topping lift takes strain, and consequently causes difficulties.

16. The foot-block kickers are then fastened and brought up taut.

17. The derrick is then ready to begin erecting steel at the new level. This derrick is turned by a bull-stick. This means that the rig has a ball bearing base and mast head. The bull-stick man is here aided by the use of block and falls.

w. It is important to have a man at each anchorage while the jumping of the derrick is in progress. The time required to raise a derrick varies according to conditions, but the usual time is about four hours from the time of starting until the derrick is ready for use on the next level. The height which it may be jumped is about two stories.

x. In general, a tackle is an entire assemblage of rope and block used to obtain a mechanical advantage or change in direction. The rope starts with an attachment to the becket shackle of one of the blocks and passes around the sheaves in each block in turn, and then passes from the shackle to the power. The standing part on which the pull is exerted is called the fall. Blocks are made either of wood or steel and may be either mortise

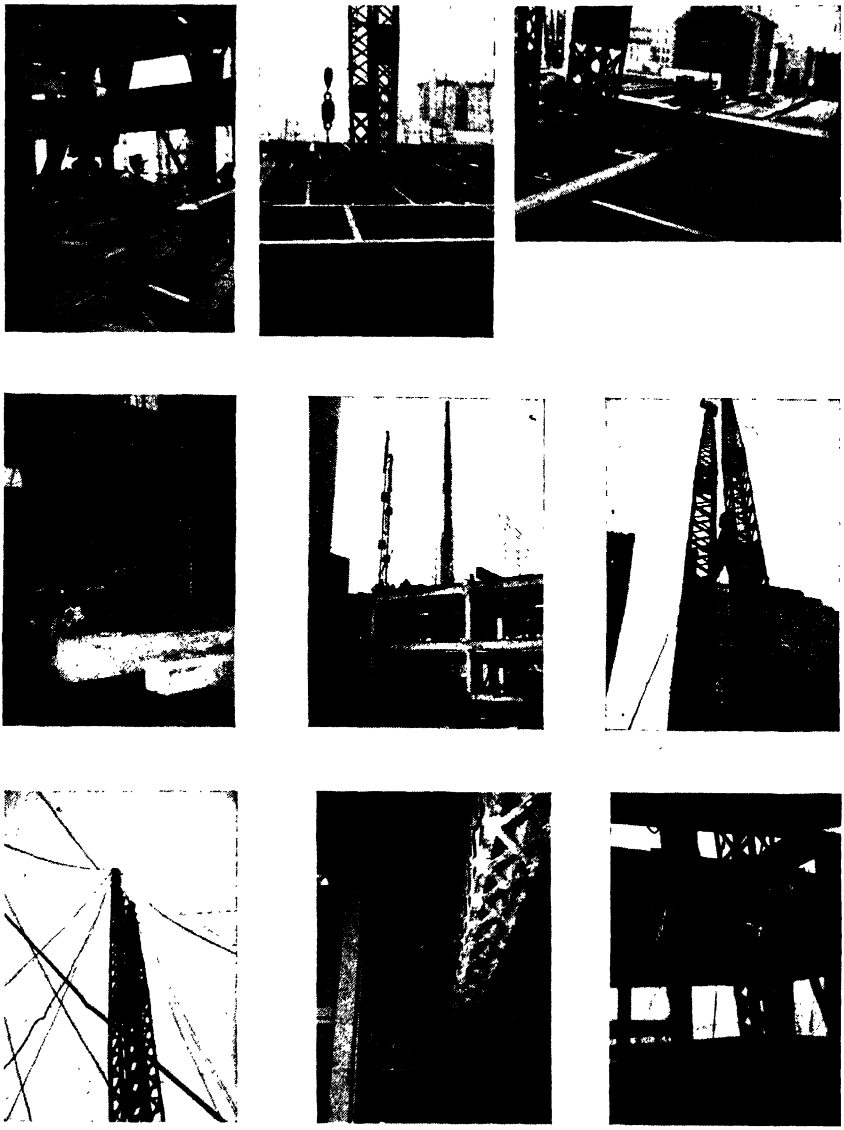


Fig. 7–20. Jumping the Derrick. (*Courtesy*

"*Construction Methods*"—*McGraw-Hill Pub. Co.*)

or snatch blocks. Blocks may have fixed or swivel hooks, shackles or rings for their attachment to hitches. (Figure 7–21.) Wooden blocks are made for use with manila rope only. The hooks are ordinarily rated in safe capacity as D^2 in tons, and shackles as $7D^2$ in tons. D in each case is the diameter of the metal from which the hook or shackle is made.

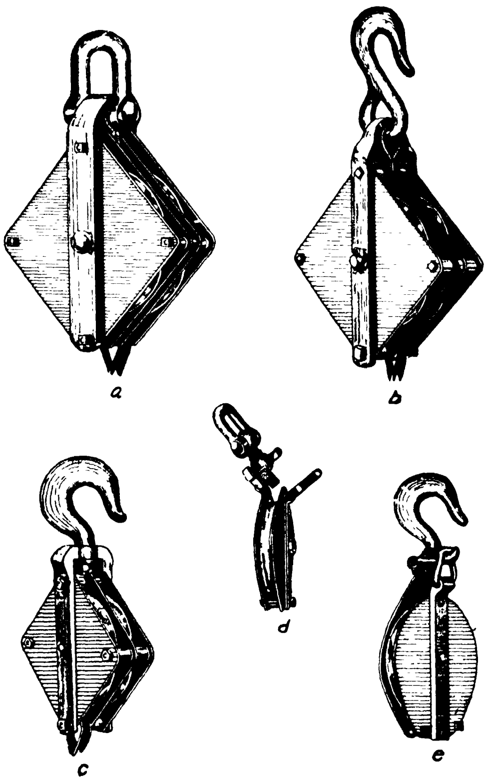


FIG. 7–21. Blocks. (a) double shackle; (b) double hook; (c) swivel hook drop-link; (d) shackle drop-link; (e) hook drop-link. (*Courtesy Boston and Lockport Block Co.*)

Wire rope blocks are usually single and double in pattern and may be had with fixed or swivel hooks or shackles. They are likewise rated by the wire rope accommodated on the sheaves and are designed to take the maximum load which may be safely imposed. Snatch blocks are also made of wood for use with manila rope and of steel for use with wire rope, although steel blocks may be obtained for use with manila rope. The snatch block may be equipped with a ball swivel shackle or eye or a drop-link hook. All of these allow the detachment of the hook, swivel or eye so that the rope may be woven over the sheave at any point along the rope. This facilitates the weaving of the cable to a block. The safe load on manila rope is about D^2, and for wire rope about $7D^2$. This allows a factor of safety of about 4.

y. Safety. The importance of constant vigilance on all work where derricks of any kind are in use cannot be stressed too much. Iron workers are frequently careless and will make fast to anything that may be secure or convenient, and, consequently, they must be watched. They should never be allowed to attach a guy to a brace or shore in an excavation on any account, and, in general, the guys should be anchored either to dead men set in the ground and thoroughly weighted or to loops of cable bedded in a concrete footing. One of the duties of the superintendent in the early stages of the job is to plan the locations of the guy derrick and see that suitable anchorages are set in the footings at the time of their construction. Particular care should be taken to see that the derrick mast and foot block are set on secure foundations. Frequently, and always as the building progresses, the derrick sets on the steel work, which is only bolted together, and often with only a part of the steel framing in place. All of the steel members should be set and completely bolted. There is room for much carelessness either in omitting beams, or in only partial or scanty bolting and a dangerous condition is set up that has been the cause of very serious accidents. Never allow the derrick to be set until the steel work is adequate and all guy anchorages are sufficient and in their proper places. Guys should be of adequate size—1⅛″ or 1¼″ are none too large on most operations; they should always be bent through proper sized eyes and at least three clips set on each connection. Each derrick mast should be provided with at least 6 equally spaced guys, and each of these guys should be anchored, by a wire cable anchor sling, to the columns of the building in course of erection.

z. When leaving the work, either for the night or at any other time, it is advisable to lay the derrick booms down, if possible, or to "top them up" (that is, raise them into a vertical position). This will prevent the booms from swinging about and fouling cables or doing other damage, in case of high winds. They should also be secured by guys or otherwise, if the conditions are such that this appears to be necessary or desirable. At least as often as every other day, all parts of every derrick should be inspected, and the moving parts thoroughly lubricated. Special attention should be given to the lubrication of the gudgeon pin at the mast head, and to the bearing at the foot of the mast, for these will wear rapidly if allowed to run dry. Every derrick should be equipped with adequate and effective mechanical brakes, and the brakes should be tested frequently to make sure that they are in good order.

aa. The hoisting engine generally includes all necessary equipment for hoisting and control of lines as the drums and hoisting apparatus. Engines are furnished with both friction drums and winch head which can be operated independently of each other. For the steel erector's derrick the engine must have two frictional drums, one for the boom line and one for the load line. Each drum is equipped with a ratchet and pawl so that the drum may be dogged. This consists of setting a pawl so that the load will not be released. This is important because of the necessity of holding the load in position. Thus, if the brake slips on the drum the pawl may be engaged and the load held in that way. When a derrick is used for 3-line work the hoisting engine has three frictional drums.

bb. The sling used in hoisting work is termed a bridle and consists of two slings of 1″ or 1½″ steel wire joined by an eye which engages the hook or shackle of the hoisting tackle. On the ends of each wire are eyes and loose-pin screw shackles, the pins being removed and replaced each time a load is picked up. A hook may be used instead of the shackles, but is not as secure a fastening. Two bridles are generally used, the ground men attaching one to the next load while the other one is used in hoisting.

cc. Chains with rings and hooks are used and probably will be used for some time to come; but wire rope slings are to be preferred as they are safer. Chains are likely to slip on beams, while cables, being made of harder steel than the structural shape, "bite" into the piece being lifted. However, failure of slings can also occur. They should be oiled to prevent decay, and tested with double loads occasionally to assure safety.

dd. Tag lines are used extensively in steel erection. They are pieces of ¾″ to 1″ hemp rope with a ⅜″ to ½″ hook spliced to their end. This line is used to swing the pieces which are being lifted by the derrick, the hook being attached to a hole or the line slung around the member and caught on the hook.

ee. Figures 7–22 to 7–26 give the details for some of the tools used in steel assembly and erection, for both the shop and the field. There are many improvised tools which each erector has, perhaps peculiar to his own gangs but, in general, the principle of their use is the same. The most used and most important are:

(1) hammers,
(2) dollies,
(3) tongs,
(4) fork wrenches,
(5) drift pins and spuds,
(6) catching can,
(7) rivet snaps, and
(8) forge.

ff. Air riveters (Figure 7–22) as used in structural steel erection are light and portable, being made in many forms to meet special requirements. They comprise a shell containing the working parts, the piston, valves and head. The ordinary riveters operate under a pressure of 70 to 80 pounds, taking about 40 cubic feet per minute.

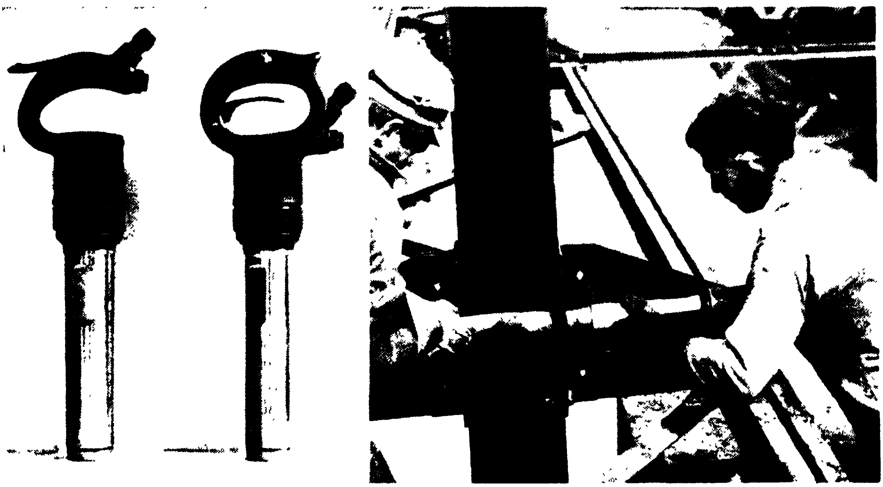


Fig. 7–22. Showing exterior and interior trigger handles and the use of the gun. (*Courtesy Ingersoll-Rand Company.*)

gg. Dollies are of many shapes and styles. (Figures 7–23 and 7–24.) Each variation is intended to make the bucking up of a rivet simpler and more direct. The ends or anvils are shaped so as to engage exactly the rivet head. The more general types of dollies are the:

(1) straight,
(2) goose-neck,
(3) bent,
(4) heel,
(5) club,
(6) ring,
(7) shackle, and
(8) joint.

The straight dolly is used in places where easy access allows of direct application to the head. The goose-neck and bent dollies are used where a flange is obstructing an axial application. All of these depend upon direct pressure. The rest of the dollies are used in places where wedge action is possible as between webs of box girders, between column flanges and beam connections and so on. The heel and club dollies are used for places where the open space between a wedging surface and

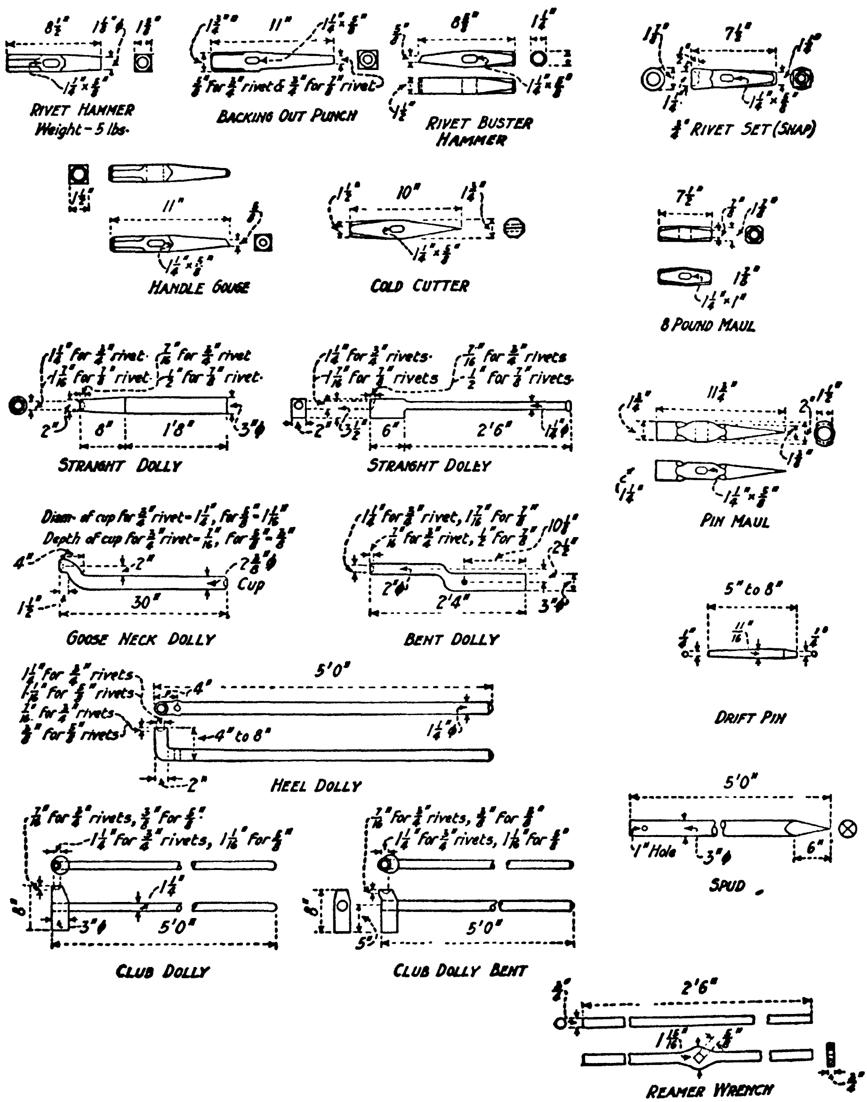


FIG. 7–23. Tools for Steel Erection. (*Courtesy American Bridge Co.*)

the rivet head is relatively small. The ring, shackle and club dollies are adjustable for angle and for wedge length as shown. All of the dollies

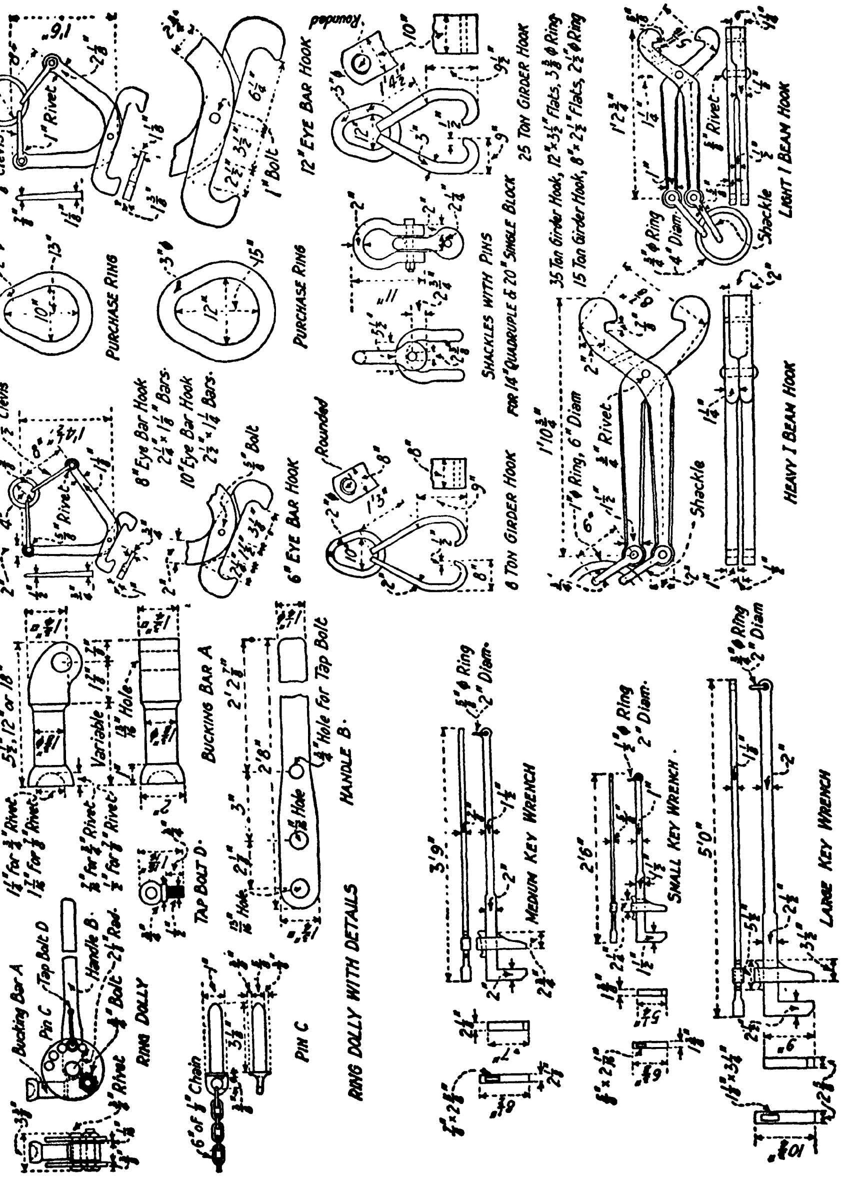


Fig. 7-24. Tools for Steel Erection. (Courtesy American Bridge Co.)

which depend upon leverage enable the bucker-up to apply considerable pressure because of this leverage.

hh. The tongs which are used by riveting gangs are of two types (Figure 7–25):

(1) pitching, and
(2) sticking.

The first are used by the rivet heater to throw the heated rivet to the rivet sticker who catches the rivet in a catching can. Note that the pitching tongs are cupped on the upper jaw only and are lipped slightly on the flat lower jaw. This is done to afford a good hold until proper direction is assured. A release of the upper jaw allows the rivet to slide off of the lower jaw easily and facilitates the work. The sticking tongs are cupped on both jaws in order to enable a rigid hold without slip. The rivet is picked up from the can close to the head and "stuck" to its full length (up to the clearance) afforded by the tongs and the application of the dolly completes the insertion.

ii. The catching cans used to be barrels or kegs of small size. They necessitated a two-hand grip or the use of the fingers into the can. Either was clumsy and dangerous in the one-hand grip because of burning. The latest cans are conical and equipped with a handle on the side. This enables the rivet sticker to reach for the throw with his left hand and use his right at all times for sticking. (Figure 7–26.)

jj. Fork wrenches (Figures 7–23 and 7–25), spuds and drift pins come into the category of "hole matchers." The shank of the fork wrench is so tapered that it may be used to match a hole and to draw a beam over. The wrench shank is called a spud by many erectors, although the real spud is used for large reamed holes such as might be used in pin-connected trusses. The drift pin is for matching holes and for securing beams temporarily, until field bolts may be stuck. The wrenches are used to tighten up the field bolts and thus serve a double purpose. Connecting bars are often used similarly to drift pins but are never left in place as drift pins are. They usually are used for matching only.

kk. Rivet snaps or sets are used to bring the roughly formed new head to a true hemisphere. It is obvious that the anvil of the hammer will become worn and cause irregularities in the rivet head. The rivet sticker reaches over to the newly formed head and a few blows of the hammer upon the opposite end of the snap forms a perfect head.

ll. Key wrenches (Figure 7–24) are used for odd size nuts and bolts and are constructed to allow of an exceptionally snug grip. Of the remaining tools required, the cuppers, clamps and "old man" are probably new.

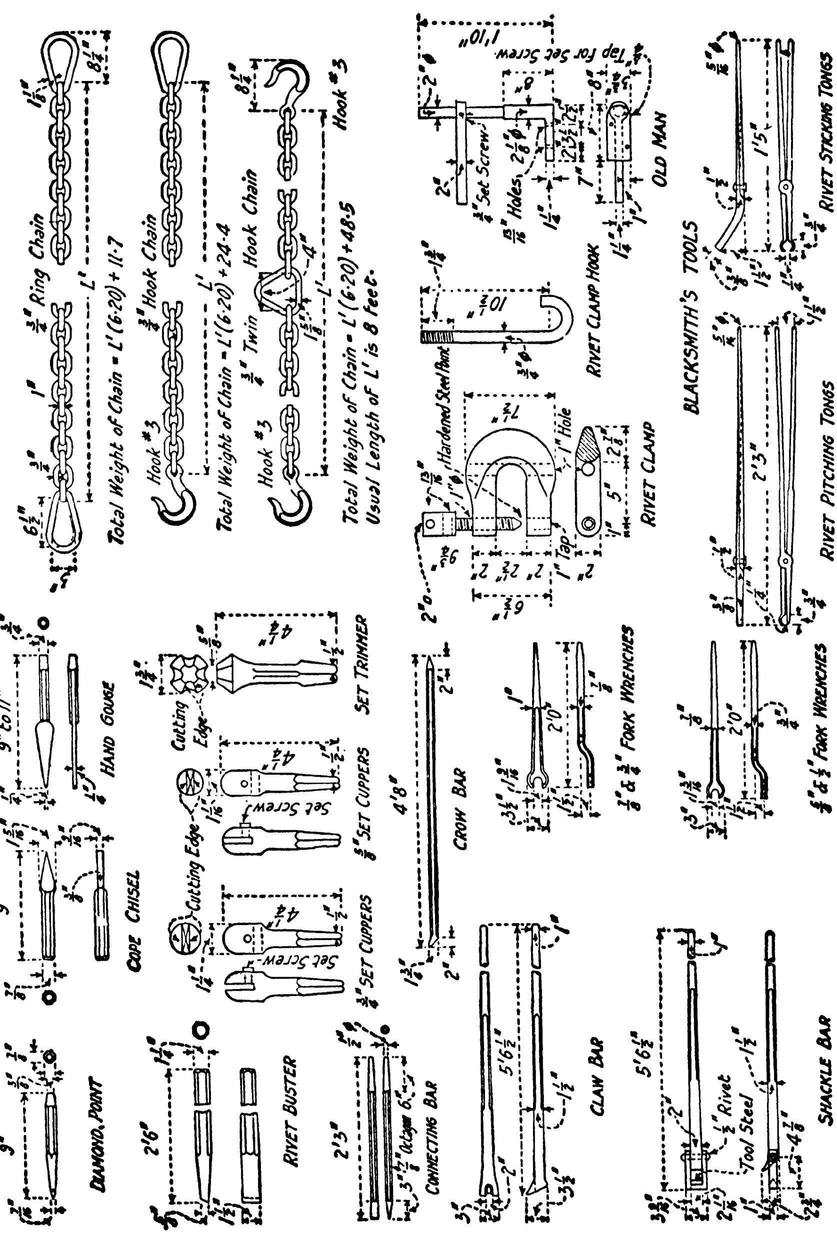


Fig. 7-25. Tools for Steel Erection. (Courtesy American Bridge Co.)

Cuppers are used for cutting out rivets, and set trimmers are used for the same purpose. One cuts the rivets down and the trimmer mashes it out, in each case removing the head. Clamps (Figure 7–25) are used to back out rivets after the head has been taken off.

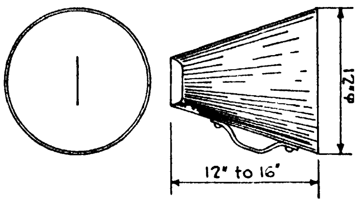


Fig. 7–26. Rivet Catching Can.

mm. The "old man" (Figure 7–25) is used to afford a purchase in reaming a hole and forms a support for the reamer shank. The reamer is turned by a reamer wrench or a ratchet wrench.

nn. For loads up to 20 tons and comparatively low lifts, where the derrick or the gin pole is impracticable, the chain block is a useful tool. They are made in three styles, the differential block, the screw-gear block and the spur-gear block. All are available in different speeds and different efficiencies and also of different costs, so the choice of the one to use depends on the character of work to be done.

7–8. Riveting and Welding

a. The various structural shapes such as plates, angles, beams and channels are connected to form structural units such as girders, trusses and columns, by the use of rivets or by welding. The units themselves are also connected to form the frame by the same methods. There are many engineers who still prefer riveting to welding because they are not satisfied that welds can be trusted as to uniformity. Welding, however, is now developed to such an extent and mechanics are sufficiently trained to justify the use of welded members and structures.

b. Riveting. Rivets vary in size from ½" to 1⅛" in diameter. The smaller size is used only for light work, but the ¾" and ⅞" rivets are most commonly used. All rivets are made of soft steel so that they may be headed easily. The distance from head to head is called the grip of the rivet. The common head used is called the "button-head" but rivets may be flattened to given depths or they may be countersunk so as to clear framing members. (Figure 7–2.)

c. Rivets are driven in the field by pneumatic riveting hammers. The gang which operates in the field as riveters consists of four men; the heater who is also the pitcher; the catcher who is also the sticker; the bucker-up; and the man with the gun, or the riveter. The heater takes enough of the proper sized rivets and places them in the forge. When they are at a white heat, he removes them with his pitching tongs and throws them to the catcher or sticker. The sticker catches them in his can. Using his sticking tongs he places the hot rivet in the open hole and drives it home by pounding it with his tongs. The bucker-up then places a dolly over the head of the rivet and the driver forms the head on the other end. This head should always be formed on the side of the thinnest piece, if possible. Rivets should never be driven when the color is darker than a blood red nor when it is brighter than a light yellow color. The bucker-up is probably the most important man on the gang. He must be sturdy enough to hold the rivet tightly in the hole so that the hole may be completely filled. If the rivet is too long, a button-head rivet results. These are objectionable because they do not create sufficiently large areas of enclosed bearing. Steel erectors often make these rivets look like good ones by using rivet snaps, which are tools that cut off the washer-shaped lip. Snaps should never be used for this purpose, but the inspector can readily detect such methods by the shear cut produced by the snap around the base of the head. When either of these are detected the inspector should mark them with a distinguishing paint. These rivets should be "burned" out or "backed" out and replaced with properly driven rivets. Loose rivets are most usually found in the field and they must be detected and replaced with good ones. Loose rivets can be detected by their dead sound when struck with a hammer. Bad rivets are usually removed by cutting off their heads and then "backing" them out with a punch. Inspection should follow closely on the heels of driving so that poor rivets can be reached and replaced by the gang before they move too far along. Careful inspection of a gang's first day's work will usually establish the extent to which inspection must be carried. The gang should be checked for a sufficient time to determine the efficiency of the crew. As the "bucker-up" and "riveter" trade off from time to time both men must be checked. The holes into which rivets are to be driven should be clean and in alignment. When the holes do not match a drift pin is used to line the hole up. If the lack in alignment is slight, this is permissible, but when they are badly centered, the hole should be reamed out and a larger size rivet used to fill the hole. Long shanks of smaller size, overheated are often "floated" into place. This must not be allowed.

d. Welding. The various processes used in welding as applied to structural steel frames are:

(1) electric welding, and
(2) gas welding.

The first is subdivided into resistance, arc, shielded arc, and atomic hydrogen welding. Gas welding is commonly called oxyacetylene welding. Arc welding is the most commonly used form of welding for struc-

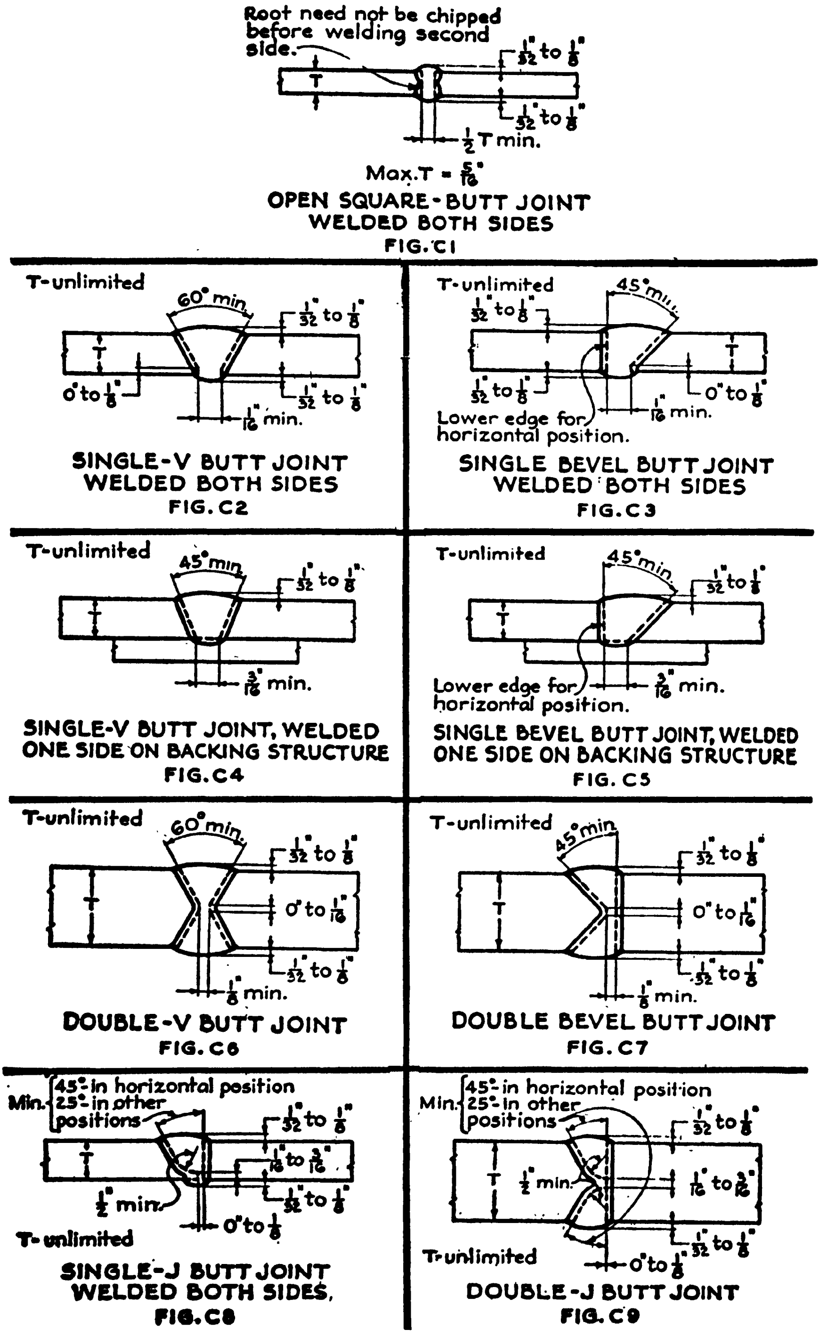
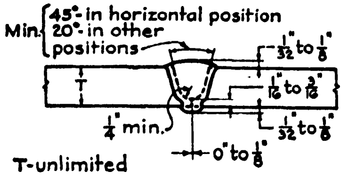
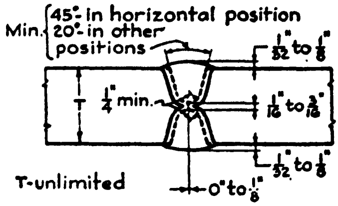


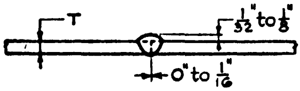
Fig. 7-27. Types of Welded Joints



SINGLE-U BUTT JOINT
WELDED BOTH SIDES
FIG. C10

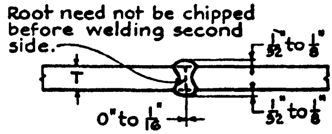


DOUBLE-U BUTT JOINT
FIG. C11



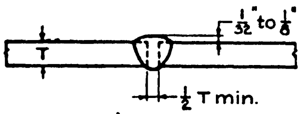
Effective Throat Thickness = ½T
Max. T = 1/8"

SQUARE-BUTT JOINT
WELDED ONE SIDE
FIG. C12



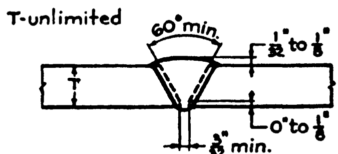
Effective Throat Thickness = ¾T
Max. T = ¼"

SQUARE-BUTT JOINT
WELDED BOTH SIDES
FIG. C13



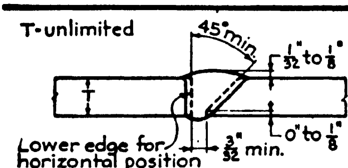
Effective Throat Thickness = ¾T
Max. T = ¼"

OPEN SQUARE-BUTT JOINT
WELDED ONE SIDE
FIG. C14



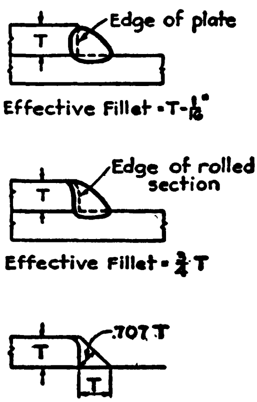
Effective Throat Thickness = ¾T

SINGLE-V BUTT JOINT
WELDED ONE SIDE
FIG. C15



Effective Throat Thickness = ¾T

SINGLE BEVEL BUTT JOINT
WELDED ONE SIDE
FIG. C16

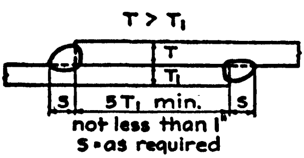


Max. Effective Fillet = T-1/16"

Max. Effective Fillet = ¾T

Max. Effective Fillet = T

EDGE FILLET WELDS
FIG. C17



DOUBLE FILLET WELDED
LAP JOINT
FIG. C18

(Courtesy American Welding Society.)

tural steel frames at the present time. When electric welding is to be used for field erection, the contractor must be sure to check the sources of electric power available to him. He may have to generate his own or he may be so located that he can buy power and transform it to suit his equipment. Although either direct or alternating current can be used, direct current is used for construction welding on nearly all jobs. The relative cost of one plan or another must be determined before an erection contractor is sure of his proposal.

e. Joints. Most welded joints are either butt or lap joints. These may be of any of the types shown in Figure 7–27. The application of this technique to the usual structural steel connections are shown in Figure 7–28.

f. In electric welding, the electrode or welding rod is the negative side of the circuit, when plates or members thicker then ¼″ are joined and the positive side of the circuit is the base metal or piece which is being welded. From average results it was found that about two feet of joint could be welded with one pound of welding rod. The current involved will vary from 125–225 amperes depending upon the diameter of the electrode and the dimension of the weld head. A good welder will lay about 4 feet of ⅜″ fillet weld per hour, and will operate with a small arc (⅛″ to ¼″) so as to avoid weld metal scattering which always occurs when long arcs are used.

g. The welding machines can usually be set in the basement or at the first floor level, from which it is possible to run leads to a considerable height without excessive voltage drop. Skyscrapers would require either "boosted amperage" or resetting of the welding machine as the frame went up. The ultra-violet rays from the electric arc are very injurious to the eyes and skin and welders should always be required to wear their helmets. Care must always be taken to prevent fires originating from sparks. As all construction jobs have a great deal of wood in the forms of staging, scaffolds and forms, this precaution becomes doubly important.

h. When shop-welded members are detailed provision should always be made for field erection bolts which, together with cables, are used to provide ease of assembly, rigidity and in bringing the parts which are to be welded, closely together.

i. Qualifying Welders. Because of the relatively recent adoption of welding for taller building frames, and the very few trained crews for this work, building departments have been very careful to insure safe work by providing qualifying tests for welders, before they would allow men to work on these jobs. The tests which are commonly applied usually involve the welding of double-lap joints, double-V butt joints and longitudinal weld fillets. The qualification tests recommended by the

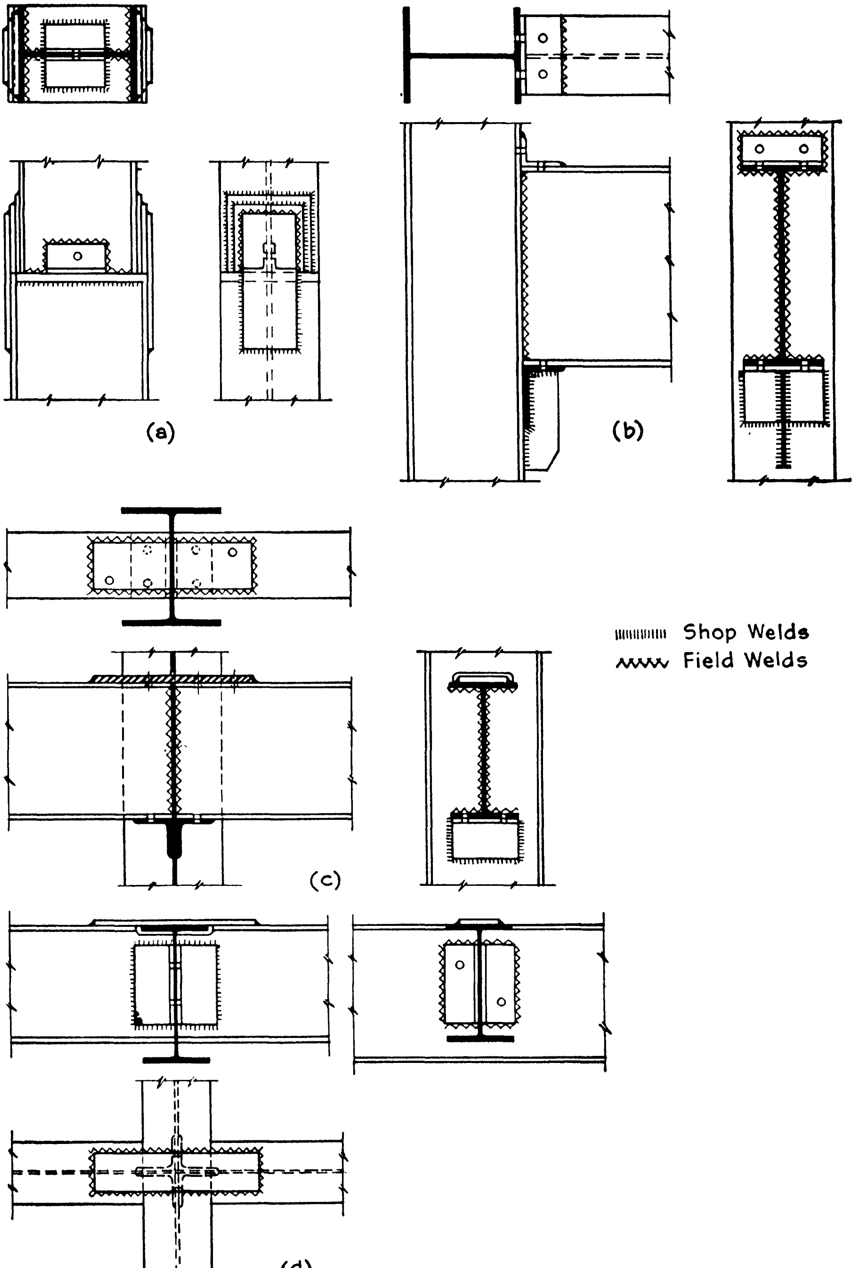


Fig. 7-28. Welded Structural Steel Connections. (a) column splice; (b) beam framing into column flange; (c) opposite beams framing into column web; (d) opposite beams framing into girder.

American Welding Society are fully described in their "Standard Code for Arc and Gas Welding in Building Construction" (1946 Edition), and the reader should thoroughly acquaint himself with these when concerned with welded frames.

7–9. Erecting Steel

a. Job Organization. In the erection of steel, the construction control or planning of the job is all important. One only has to stop a moment and think of the details involved to see why, in this part of the construction, organization plays such an important part. Here we have a framework built of separate and distinct parts: columns, girders, beams, trusses, and the like, which are required at a certain time, and for which nothing can be substituted. The work of erecting also involves expensive equipment and highly paid employees which makes it imperative to the financial success of the job, that the necessary pieces be at hand when needed. For these reasons in the consideration of the time schedule the contracts for steel fabrication should be let as soon as possible. The initial "jump" or start that the fabricator has on a job is one of the most important items affecting the time schedule and expediting of the steel. As steel may be erected much faster than it can be fabricated, a period of at least six weeks should be allowed between the letting of the contract and the first delivery. Then a check should be kept on the shop to be sure that the deliveries will come on time.

b. The steel generally comes to the site on trucks, either directly from the fabrication shop or from freight cars. In any case, in the trucking of steel, it is of extreme importance that the proper consecutive pieces be sorted out, so that the steel may be hoisted directly to the proper floor or stored until needed. The determination of the economical routing of the steel depends on the conditions of the site and the location of the job in respect to the fabricating shop. The following possibilities are to be considered:

(1) available space at the site, without congestion for storage,
(2) crowded conditions with no space for storage, and
(3) direct delivery from shop to site by truck.

Where there is plenty of space, it is advisable to keep the steel coming as fast as possible. The piling or storage of the steel will involve considerable forethought, but the routing problem will be simple. In storing the steel keep the grillage column bases and slabs in separate piles and arranged in the order they will be needed. The columns and beams should be separated, floor by floor, using 4 x 6 lagging strips between pieces to allow the grip and tag lines to be placed easily. If conditions are cramped, arrangements to hold the freight cars in the yard, paying demurrage, can be made, or the steel may be rehandled at the freight yard if the use of a freight derrick and storage space can be arranged. Both of these situations are expensive and require careful expediting. The router, in this case, will have to keep in close touch with orders and car shipments, seeing that the cars are loaded with the right steel and that they appear at the right time.

c. When the fabricating shop is near enough to the job so that the steel can be trucked directly, it is best to have fabrication proceed as fast as possible and have the pieces that are needed delivered. This is the most economical method. In this case, the only problem to be considered is the traffic problem, which is present in all cases. The steel must be kept coming to the job regardless of the time or how and yet congestion must be avoided. This problem is very important in all cities. Some contractors use a semaphore system to signal truck drivers blocks away that they may come on to be unloaded. In this way deliveries are spaced at proper intervals and unloading can be accomplished without impeding traffic. When the steel is delivered to the job in trucks the load will be picked up by the derrick and landed on the derrick floor. Every piece of steel is detailed and numbered according to the shop drawings which will be on the job. Care should be taken to ship the steel in the order in which it is required, but when it arrives on the job, it must be sorted and placed where it can conveniently be found when wanted.

d. The first operation in the steel erection is the setting of column bases on the footings. The column bases used on the mill building were very simple affairs, but for heavy steel buildings the column bases are much more elaborate. The column loads may run from several hundred tons to several thousand tons and this load must be spread over the footing so that the concrete forming the footing will not be overstressed. The column bases are usually rolled steel plates, 4″, 6″ or even 8″ thick, called billets or slabs. As these bases are heavy in themselves, wooden wedges are insufficient for leveling, and the usual method is to set angle iron screeds on the footing, bedded in cement mortar and carefully leveled. (Figures 4–2 and 7–6.) After these screeds are hard, a bed of cement mortar is spread over the top of the footing and the base or billet is lowered into it until it bears against the screeds. It is very important that the bases or billets be absolutely level, for otherwise the steel will not be plumb.

e. It is perfectly obvious that elevator shafts must be plumb. In fact, the builder's contract with the elevator manufacturer always contains a provision whereby the builder guarantees to the elevator manufacturer that the elevator shafts will be plumb to within 1″. This means that if the steel is out of plumb more than 1″, any cutting or blocking out that may have to be done in order to enable the elevator constructor to set the elevator guides plumb will be at the cost of the builder. Likewise on the enclosure walls on the outside of the building. The stone, for instance, will be detailed and cut with a certain assumed clearance of the steel, based on the supposition that the steel is plumb. But if it is out of plumb, these clearances will not be sufficient, and all of the stone that comes in contact with the steel will have to be "backed out," or recut on the job to enable the setting of the stone. This may also be an expensive item that will be charged to the builder. There are various other details where there will be additional expense as well as mechanical difficulties due to the steel being out of plumb, so it is evident that there is a serious responsibility resting on the superintendent to see to it that his steel is plumb.

f. When steel is being erected, it is first assembled by merely inserting bolts in the connections and three or four stories of steel may be erected in this way. Then cables are attached to the frame, diagonally in both directions. These cables are equipped with turnbuckles. Then plumb bobs are hung at the columns, and if any appear to be out of plumb, they are drawn up by means of the cables until they are plumb and they are held in their correct positions until the steel is riveted. This, of course, is a part of the work of the steel erector, but the superintendent should take the precaution to have his own field party check the work because he should never take anything for granted. To depend upon back-charges is of little avail.

g. The operation of setting steel is not different in principle from the setting of the members of a timber mill building. There are columns and girders and generally beams, arranged in much the same way as in semi-mill construction, but with differences in detail of connections because of the difference in materials. Columns are set first, then the girders and then the beams. The spacing of beams will be different than in semi-mill construction, because this is a frame structure with columns in the outside walls whereas the mill is usually a wall-bearing structure. There will be a line of beams on the columns and in the outside walls. These beams are called spandrel beams, and they are an important detail in this kind of structure because they carry the masonry, whatever it may be.

h. At the start of the setting of the steel, the superintendent should give notice to the trades that they will have to be ready to start as soon as portions of the steel are riveted. These trades are the fireproofer, who installs the floor system, the electrician, the plumber, the steamfitter and the stair builder. All of these trades work together as soon as the floor system starts. The steamfitter and the plumber have to set sleeves through which their pipes will have to pass and the electrician has to install conduit work for all the various services that may be required. The stair builder starts the permanent stairs. Whatever may be the type of flooring used, these trades will be required, and it is the superintendent's duty to give them ample notice, so there will be no excuse for delay when they are wanted. On some classes of buildings like hotels and clubs, where ventilating systems are installed, the sheet metal worker will also have to set sleeves for the ventilating ducts, but as a rule, this work is included with the steamfitting, so that it is necessary to notify only the steamfitter. On most jobs all of these trades are subcontracts, but where the floor system is to be installed by the builder, the superintendent at this time must see to it that his foremen are on hand and are prepared to man their jobs when the steel is ready, and he must also check up on his materials supply and see to it that it is ready for delivery when required. It is clear that the superintendent has a multitude of duties and that the better he knows his job the better he will be able to anticipate his needs and the fewer errors he will make, and as the superintendent is not supposed to make errors, he should qualify himself by knowing the job.

i. Columns, as a rule, are made in two story lengths, so that the column splices come at every second floor. Assuming that the first two floors have been set with the stiff leg derricks, the next two and all following floors will be set with guy derricks. The guy derrick can swing through an entire circle, whereas the stiff leg can swing only through an arc that is bounded by its stiff legs. Furthermore, the derrick has to be "jumped" or raised every two floors, so that all things considered, the guy derrick is a much handier and useful tool for steel erection than the stiff leg. Assuming that the first two stories have been bolted up temporarily, the guy derricks are brought on the job and erected. At the point where the derrick is to be set, the steel for the entire bay should be put in and fully bolted. This is very important because not only is the derrick heavy but it will lift heavy loads and all such loads will come on the steel directly under where the derrick is set. It is also necessary to see that all of the bolting is tight. If it is, the resistance to stress will be in shear across the diameter of the bolt, but if the bolts are loose the load may be thrown on the nuts and the resistance will be in tension against the threads of the bolts, which may strip and give away. It therefore becomes very important to see to it that all of the bolts are tight, so that the load does not come on merely a few of them.

j. All of the steel of the derrick bay having been set and thoroughly bolted, the next step is to place two heavy timbers or steel beams across the bay from girder to girder, extending well over the girders at both ends. On top of these is placed the foot block of the derrick, and on this foot block the mast of the derrick is erected. The ends of the derrick guys are passed through the eye of the turnbuckle and bent back on the standing part and fastened with at least three clips, attached as shown in Figures 7–19 and 7–29.

FIG. 7–29. Attaching Cable Clips. (*Courtesy American Hoist and Derrick Co.*)

k. The derrick is set up by the iron workers, but the superintendent should make daily inspections and see to it that none of the things mentioned have been carelessly done. It is never safe to take anything for granted, however good the reputation of the foreman in charge may be. It is a part of good superintendence to check up constantly.

l. In steel erection three groups of men are used, the erection gang who assemble the steel, the riveting gang who rivet it, and the painting gang who paint it. As soon as the derrick is ready for operation the next step is the planking of the derrick floor. This is usually done with 3″

plank and it should be thoroughly done—that is, the entire floor should be tightly planked so that no tools, loose rivets, bolts or nuts can slip through. Immediately below the derrick floor will be the riveters and the painters, and below them will be the fireproofers and the other trades. These men must be protected and the superintendent must see to it that they are. The erection gang, who are on the derrick floor, are often careless and indifferent and they will frequently let tools and materials slip through the floor unless they are watched. The foreman of a derrick gang, or the "pusher," must be careful and conscientious and take all necessary precautions to safeguard his own men and also the men below. Some pushers are indifferent, and with a man of that type the superintendent must be vigilant. The erection of steel is rated as the most hazardous of all the trades engaged in building, but not intrinsically or necessarily hazardous provided it is handled by a competent and painstaking man. Often the work of the field party is quite as hazardous as that of the iron worker. The field party has to climb all over the steel and carry instruments into all sorts of dangerous places to establish building lines and give marks and grades, and of course there is danger. A derrick is a dangerous tool and many things can happen, but whether they do happen depends primarily upon the man in charge of the erecting gang and the superintendent. Some general rules to be observed are as follows:

1. Do not attempt to set steel on a rainy day or when it is wet. This applies to the field party also. Steel is slippery when it is wet and it is dangerous to try to go about on it.

2. Don't let the men wear shoes with soles nailed on. The soles should be sewed on or they should be rubber. Exposed nails in a sole are very likely to cause a man to slip.

3. All the men should wear heavy gloves but not with gauntlets, and their clothing should not be loose. A piece of steel swinging in on the derrick is likely to catch in a gauntlet or on loose clothing and carry a man away.

4. Don't ever stand under a derrick load or a boom that is loaded, or allow any one else to do so. This applies to all kinds of derricks wherever they are used. Never allow a man to ride a load. They will frequently do this to save themselves the trouble of climbing ladders unless they are watched.

5. Use shackles and not hooks.

6. Use cable slings and not chains.

7. Inspect brakes on hoisting engines daily and caution the engineer never to operate his engine unless his brakes are in good order.

8. Watch for frayed or broken strands in all cables and guys and repair or replace them as soon as seen.

9. Don't allow men to do any stunts or take unnecessary risks. Take steps to caution them constantly to protect themselves, otherwise you cannot protect them.

10. Inspect guy anchorages and guy fastenings and foot block anchorages daily.

m. As soon as two floors of steel are set and bolted, the derrick is jumped. The boom is unshipped and is hoisted by using the mast as a gin pole. Then it is temporarily guyed as a mast, and the mast is hoisted with its foot block attached to it and set on timbers. (See Article 7–7*v*.)

n. Immediately after the steel is plumbed, the riveters begin their work. There are four men in the gang, and they frequently work together for years, from job to job. The heater works on the floor immediately under the floor where the riveters are working. The other three work on small plank platforms hung from the steel with ropes. A rope about 30 feet long with two eye splices, one at each end is used. Through these eyes are placed 4 x 6 "needle beams" of wood. Planks are spanned over these to afford a foothold and as a seat for the erectors when working at a joint. These planks are so arranged as to be about 12″ below the lowest flange of the floor steel to enable driving from below. The bucking-up is done from above where vertical rivets must be driven. The driver sits on these planks and can brace himself with his feet on the flanges of the nearby beams. This platform should be fitted with a toe board to prevent tools or dropped rivets from falling over the edge on to men working below. The heater heats a rivet, then with a tong throws or tosses it to one of the men on the platform who catches it in a catching can or similar receptacle. These men become very skilful at catching rivets, but they frequently miss and falling rivets are a constant cause of casualties on all steel structures. The worst condition arises when the men are riveting connections to the outside columns because if a rivet is thrown toward the outside of the building and it is not caught it falls outside, either on the bridge or in the street. Consequently, the superintendent should see to it that rivets are not thrown toward the outside of the building. The heater should be required to place his forge in such a position that he can throw his rivets substantially parallel with the face of the building. As it is more or less trouble to move the forge, the heater is likely to avoid doing so, unless he is watched.

o. Another precaution that the superintendent must take is to see to it that the forge fires are extinguished at quitting time. Generally, the heater dumps his fire at the end of the day and these live coals are likely to set fire to the platform. This has caused very serious fires and entailed heavy losses. These fires are often high up on the steel and difficult to reach, particularly at night, and it is dangerous for firemen to attempt to get at them. Because of the frequency and seriousness of these fires the City of New York now requires that the stand pipe for the fire lines shall be carried up with the steel and fitted with connections so hose can be attached every day as the steel rises. This is not done in other cities and in any event the superintendent should see to it that such fires do not occur.

p. Buildings are often rated in size as one derrick, two derrick, or three derrick jobs and so on. A derrick boom is 50, 60 or 80 feet long as a rule, and as a guy derrick can swing a full circle, a building 50′-0″ by 100′-0″ could be served by a single derrick. A building 50′-0″ by 200′-0″ would require two derricks. When there is more than one derrick on a job it should be an inflexible rule that one derrick should not get ahead of another. To get a building out of step by allowing one part of it to be built faster than another part is the worst of building practice, and greatly complicates the job management. It causes the trades to work on several different floors, and makes a lot of confusion that should be avoided.

q. Access to the various floors at this stage is by means of ladders. A ladder is a potential hazard and it is a part of the superintendent's duty to see to it that they are properly built, properly set and properly maintained. A properly built ladder has clear, straight grained strings and the rungs should be housed into the strings and uniformly spaced. Unequal spacing or unequal width of rungs is a dangerous condition. A man should be able to go up or down a ladder without looking at the rungs, and this he can readily do if the rungs are equally spaced. The ladder should stand on a plank platform 4 or 5 feet wide, laid on the steel beams. At the top of the ladder should be another similar platform. The top of the ladder should rise at least 3 feet above the upper platform and it should rest against a cleat spiked to the lower platform. It often facilitates the movement of men to have ladders of double width so men can pass up and down simultaneously. As the superintendent goes about the job he should take note of all ladders and see to it that they are in good condition and comply with the details. As soon as three or four floors of steel have been riveted, the permanent stairs should be started. This is the work of the ornamental iron contractor and is separate from the structural steel.

r. The painting of the structural steel is a separate trade, but this work is always a part of the structural steel contract. Steel that is unprotected will rust quickly in the presence of moisture. Thus, steel must always be protected, and one effective way of protecting it is by painting, preferably with a graphite paint. This is not, however, a permanent protection, and steel should be repainted at intervals. This, of course, cannot be done unless the steel is exposed, so that it cannot be considered as permanent protection for the steel of a building which is entirely covered. Nevertheless, it affords some protection and is always required. One coat of paint is applied at the place of fabrication and is called the shop coat. The other coat is applied after erection and is called the field coat. These coats should be of contrasting colors so that the superintendent can readily determine when the field coat has been applied.

s. The erectors, riveters, and painters should be kept as close together as circumstances will permit. The superintendent is the expeditor of the job, and he must constantly see that each trade is doing its maximum, and that each follows the other as closely as conditions will permit. He should consult daily with the foremen, lay out work to be performed and see that it is performed.

t. Setting Grillages and Rolled Slabs. In setting steel grillages the piers or concrete footings are left 2″ or 3″ below the final level to secure more accurate setting of the screeds. The disadvantage of the angle screeds (Figures 4–2 and 7–6) is the time spent while the cement is setting and even then the grillages may not be level. Sometimes the footings are capped with a smooth granolithic top to insure proper bearing surfaces. Another method is to set one foot pieces of 2 x 4 at the corners of the pier or footing to receive the grillages. Steel shims are then used to wedge the grillage to the proper level, and the concrete may then be cast.

u. Rolled steel slabs or billets have angles riveted or welded to them so that the derrick can pick them up by inserting a shackle or hook into the rivet holes. The slab must not be lowered too rapidly, as the threads on any anchor bolts may be stripped or distorted. They may be set in the same way as grillages. When the billet is finally aligned, the footing is formed and a 1 to 2 grout is poured.

v. Erecting Columns. The steel column should be picked up by a cable sling placed around it, above the center of gravity, so that the column will hang nearly vertical. The column base has clip angles on it to receive the column, and as the column is lowered into place the connection holes should be guided into line by inserting the spud end of a structural wrench or a drift pin into them. When the spud or pin lines up the holes, temporary field bolts hold the column in place. The best plan is to start setting columns in a corner of a building. By doing this, one complete bay can be framed and used as a guide for the rest of the work. The derrick, which is in the middle of the lot, sets the columns furthest away first. The first floor beams are set as soon as the columns are placed to stabilize the columns and form a frame.

w. Columns for tall buildings are usually made in two story lengths and the splice comes just above the girder connections at every second story level. This incurs some waste of material but the time saved in erection counterbalances that. There is no economy, however, in erecting structural steel columns in three story lengths for there is additional waste of material and the erection cost is increased as provision must be made at each working level to carry steel for three stories instead of two. Judgment should be used in deciding whether or not the columns which are floating free should be guyed. It may be necessary, before the foot of an upper column can be inserted between the splice plates of the lower

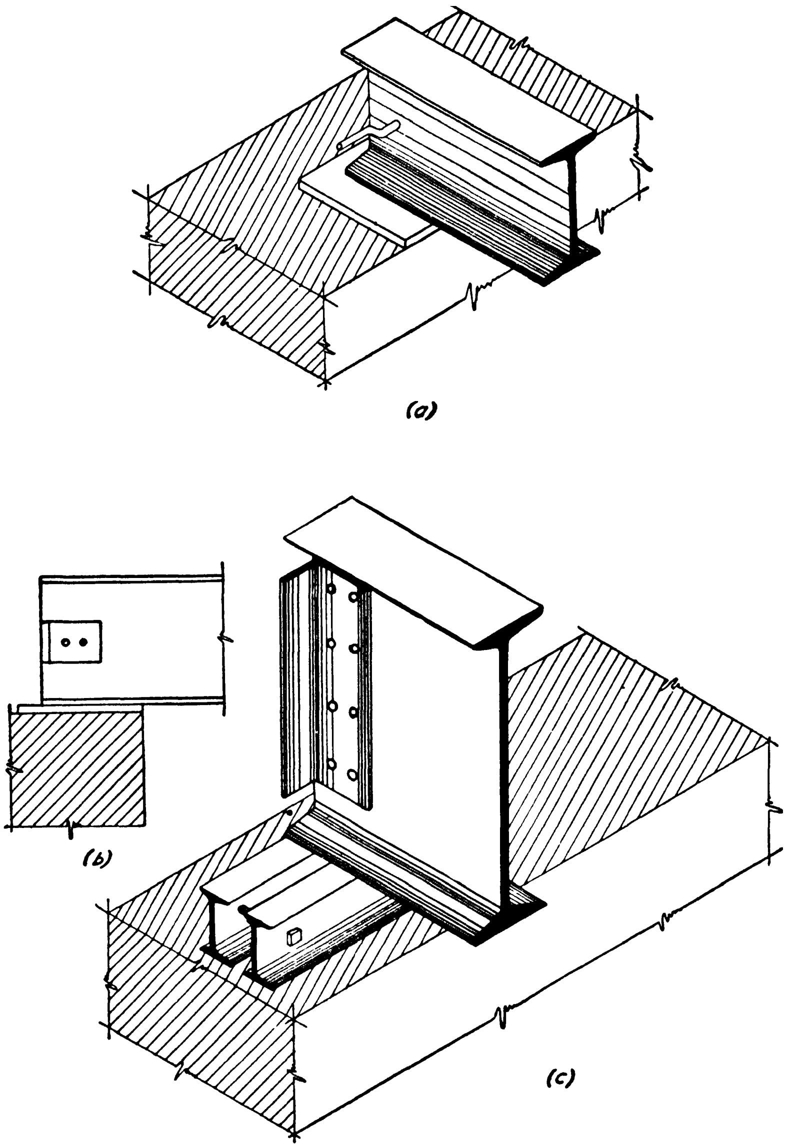


FIG. 7-30. Beams Bearing on Masonry Walls.

column, to bend the splice plates out slightly by sledging them. This may be avoided by placing one splice plate on each column. The beams are erected best with bridle slings of wire rope. The girder should travel from the stock pile to its location in the building in a horizontal position.

x. When steel beams and girders are built into masonry, as shown in Figure 7–30, bearing plates are provided to distribute the force over a large area. The derrick man picks up the beam with a center hitch or a double bridle hitch, which is better, and sets it on the bearing plates. It is then moved into accurate position by sledges. The bearing plates should be set accurately as the position of the beam is measured from them. When a center hitch is used for picking up the piece, the derrick man should raise the member about a foot and see which way the beam is going to tilt on its way into place. A tag line is applied to the end which tends to be the higher.

y. When a beam frames between a wall and a girder, the girder end of the beam is first brought into place between the two angles which are to receive it and a drift pin is shoved through the angle and beam to hold it temporarily in place. It is then set on the steel plate in the masonry. When a beam frames between a wall and a column, the end which frames into the column is set first. The upper clip angles do not have to be turned up to allow the beam to be placed, as the ⅛″ clearance is sufficient to either slide the beam into place from the side or send it in from the front. When a beam frames between the flanges of columns the beams may be swung sideways into place where connections to columns consist of top and bottom seat angles and where ½″ or more clearance usually is provided between the end of the beam and the column. When the connection is made, with the end of the girder and the column intended to be riveted up tight, for close fits, it is usually necessary to spread the columns apart to get the beam in place. One end of the beam is placed on the erection seat on one of the columns and the beam is allowed to rest against the opposite column in a diagonal position. The high end is sledged down until it falls into its proper position on the other erection seat. When a beam frames between the webs of two columns, the beam is lifted by a center hitch and a tag line. In these cases the erection clip angles come bolted to the column and the clip on one end should be removed. The low end is inserted between its erection angles and the high end is allowed to rest diagonally against the opposite column. Any rivet heads which will obstruct its downward path should be countersunk. The upper clip angle is then replaced. When a beam frames between the flanges of one column and the web of another it is necessary to place the web end first on its erection seat, as its horizontal movement is restricted. The upper clip angle of the other column is then removed or tilted upwards and the beam is swung horizontally into place. In some cases there will not be clearance enough provided and the beam is then rested diagonally as before, with the web end set as before. The high end is then sledged down. The upper clip angle is applied again and the beam is bolted up tight. If the beam is to be framed to the flange of the column at one end and a girder at the other the girder end is swung into place first. When it comes opposite the holes in the girder, drift pins are passed through both sides of the beam and it then can be swung horizontally so that it will rest on the shelf angle of the column. If the beam frames against the web of the column, the column end is placed first as its horizontal movement is restricted. The girder end is then swung around, sledged into place and the drift pins are placed. When a beam frames between two beams or girders, a center lift should be taken on the beam and the connection angles on the low side made to come opposite the holes in the flange of the member the beam is to be framed to. A drift pin is inserted and the other end of the beam is brought down and sledged into place. A drift pin is put into place and the member is field-bolted

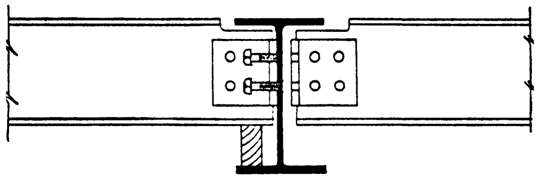


FIG. 7-31. Erecting Beams Framing Opposite.

securely until the riveting is begun. When a beam frames opposite a beam into a girder, one beam is placed as just outlined and temporarily bolted into place with the nut on the exposed side of the web of the girder. The far end of the second beam is then drifted into position. The nuts of the bolts on the first beam are then taken off and the field bolts are backed out until they are flush with the web of the girder so that the second beam can be slid into place. A drift pin is then inserted into one of the angles of the second beam at one of the holes which has not been bolted in the girder. It can then be swung or sledged into place until the drift pin comes opposite the hole in the web of the girder, and the drift pin is pushed through the web and the further beam connection angle. The field bolts can then be passed through the second beam and the nuts applied. To avoid the dropping of one of these beams, a piece of wood is driven under the beam to wedge it against the flange of the girder, but this is usually unnecessary as the flange of the girder would stop it. (Figure 7-31.)

x. A large girder may be hoisted by means of a bridle chain or cable if it will not overstress the derrick. A long plate girder which is shipped to the job in two pieces may require a false-work in its erection. This may be done by making a cribbing of 6 x 6 timber from the floor below to hold both ends of the member until it can be fastened together. It may also be erected by supporting one half on an "A" frame until the other half is brought into position and riveted into place. The wall end of one half of the plate girder is placed and the other end is supported on the cribbing or the "A" frame. The other half is brought up and rested at its wall end. The spliced end is swung into place and the splice plate is put on while the derrick is still supporting one end. One splice plate may be fastened to each half of the girder to simplify things.

aa. For heavy truss work the members are sent to the job separately and the truss is erected piece by piece. If the span is small, so that the truss will not overstress the derrick on the job, the truss may be erected as a unit. If the truss is less than two tons in weight, it is safe to pick it up with several turns of wire around the apex. If the truss weighs between two and five tons, a center lift from the apex may cause a reversal of stress in some of the tension members and result in buckling. In this case the truss should be erected in a cradle of steel or wood which gives an upward reaction at the third points and does not induce a maximum reversal of stress. When the truss is large and arrives on the job in two pieces, one half is lifted up and the wall end is set into place. The center end is then supported on a cradle or cribbing. The other half is then brought up and its wall end is placed. Usually the splice plate is on one half of the truss. The center end of the second piece is then brought into alignment with the holes of the first half and the pieces are bolted together. The truss must then be braced to avoid any motion laterally. This may be done by bracing or the second whole truss may be erected and the purlins placed by the derrick to provide lateral bracing.

bb. Riveting in the field is always preceded by temporary bolting. The erectors will place the columns, beams and girders and will fasten them temporarily with field bolts. After the column furthest away from the derrick is set it is guyed before being released by the derrick. This is continued until four columns of a bay is erected. Then the beams between the two columns furthest away is erected. A steel erector will sit on the top of each of the two columns. The derrick man will maneuver the beam so it is practically in place, slight adjustments being made by the men on the columns by the use of the shank of their fork wrenches. As soon as the set of holes are properly lined up, the steel man will insert a drift pin in another group of aligned holes. Removing his fork wrench the erector places two bolts in two other sets of holes and brings them up tight. During this action the derrick is still holding the beam. The erectors will then slip down the columns to the lower tier and complete the bolting of that level. This process is continued until the bays are all filled in.

cc. Riveting in the field cannot be done until the steel has all been plumbed because the bolts used allow movement of the members. Plumbing of the steel is done by means of cable and tackle. At the same time as the steel is plumbed, the rivets will be driven so that they will hold the members in the final plumbed position. The riveters will follow the erectors about one story behind. The "plumbers" will be between the riveters and erectors.

REINFORCED CONCRETE

7-10. Detailing

a. All reinforced concrete slabs, beams, girders and columns are conventionally indicated on the contract drawings. It will be remembered that the contract drawings give sufficient information to afford the contractor sufficient information to estimate the quantities of concrete, reinforcing steel, forms and auxiliary materials. In order to erect the concrete frame and the floor system every slab, beam, girder and column must be detailed so that every bar can be fabricated in accordance with the intent of the design.

b. The engineer's plan merely indicates the bar sizes, their spacing and often a general indication of the type of bends desired. In contrast the properly drawn erection plan would indicate each variation of this general pattern and would be like that shown in Figure 7–32. Beside this plan each bar is detailed and given a mark, if it is bent. The dimensions of such details are determined by the general practice for slab bar bends shown in Figure 7–33. The bars are scheduled as shown.

7-11. Beam and Girder Details

a. As suggested in Article 5–4g, the meticulous engineer carefully prepares a beam schedule. (Figure 5–7.) In addition to this schedule the reinforcing steel contractor schedules the tension bars and the stirrups for all beams and girders. Special variations in the beam shape affecting the bar details are shown in Figure 7–34.

*b. **Reinforcing Bars.*** Reinforcing bars are now standardized in 11 sizes. These are shown in Table 7-1. This table gives the cross-sectional area, weight per foot, the area in bond, and the data for selecting bars for columns, beams and slabs.

TABLE 7–1

	Round							Square			
Size	¼	⅜	½	⅝	¾	⅞	1	½	1	1⅛	1¼
Area—sq. in.	0.049	0.11	0.19	0.30	0.44	0.60	0.78	0.25	1.00	1 26	1.56
Weight per Foot	0.167	0.376	0.668	1.04	1.50	2.04	2.67	0.85	3 40	4.30	5 31
Perimeter Inches	0.78	1.18	1.57	1.96	2.35	2.75	3.14	2.00	4.00	4.50	5.00

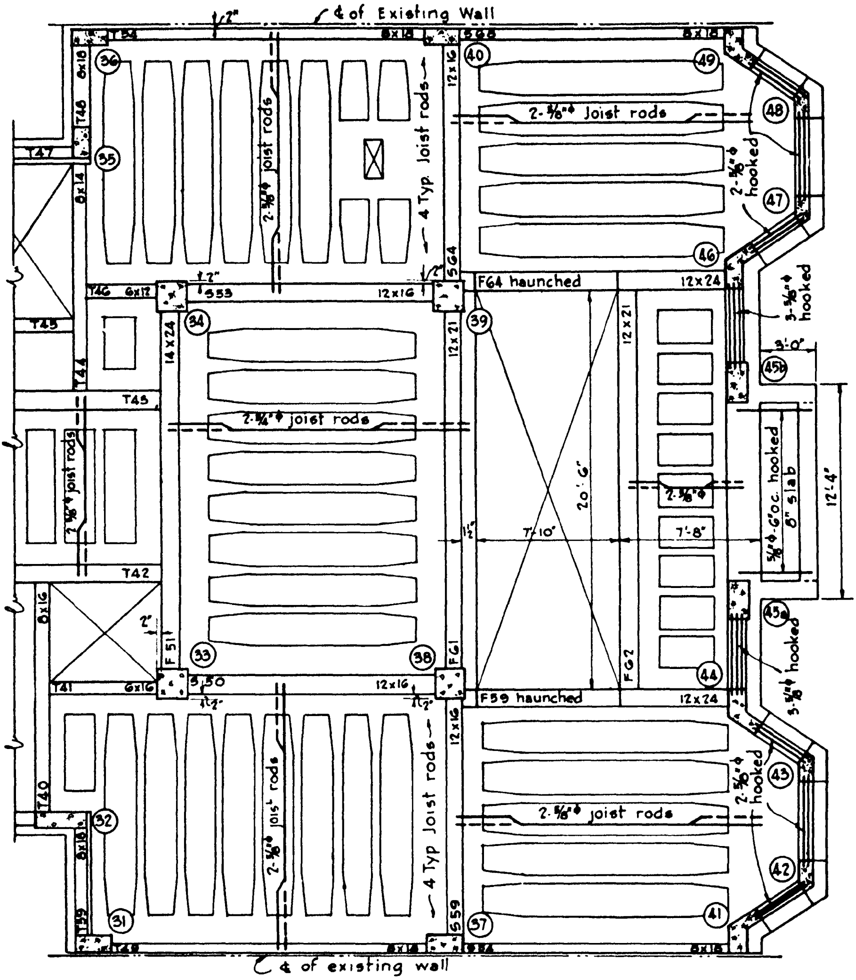


FIG. 7-32. Erection Plan for Reinforced Concrete Floor.

7-12. Column Details

a. As for beams and girders the columns are also indicated in a column schedule (Figure 5-6). The subcontractor for reinforcing prepares schedules for the column steel, which includes the vertical steel, ties or spirals, dowels and splices. In addition, as for beams and girders, he prepares special details for all columns which vary in some respects from the general pattern.

b. The details of concrete columns vary with the structural design.

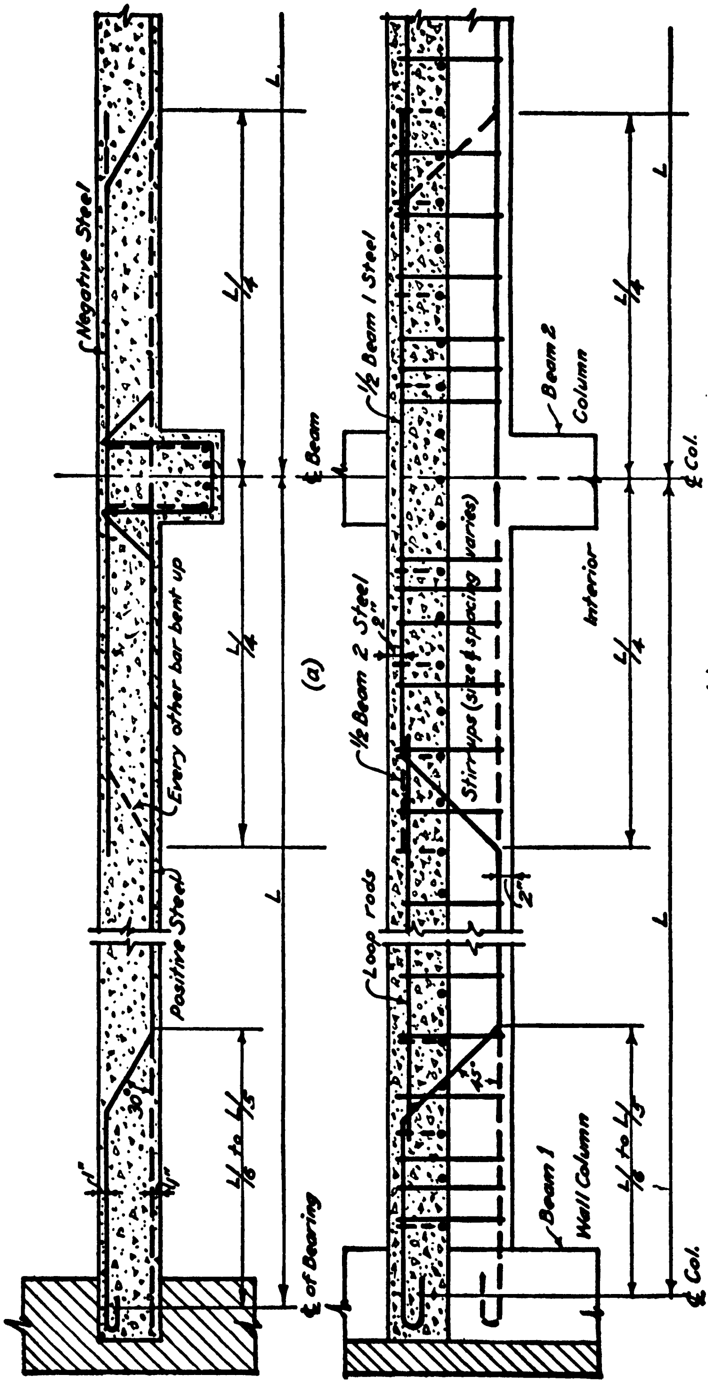
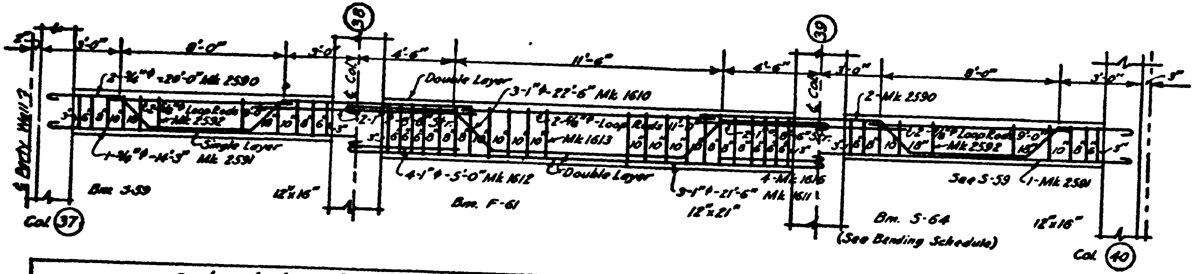
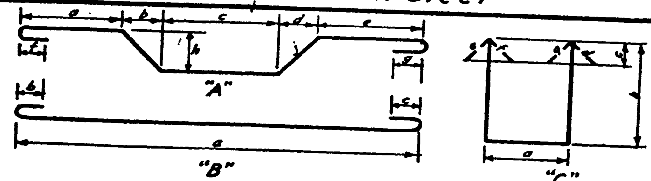


FIG. 7–33. Bar Bending for Concrete Slabs and Beams.



Schedule of Beam Steel



No. Reqd.	Size	Length Ft.	Length In.	Mk.	Sketch	Dimensions (Listed when they occur) a	b	c	d	e	f	g	h	j
4	3/4"φ	20	0	2590	A	2'-9"	12"	6'-0"	12"	8'-0"	5"		12"-	1'-5"
2	3/4"φ	14	3	2591	B	13'-9"	6"							
3	1"φ	22	6	1610	A	4'-6"	13"	9'-4"	13"	4'-6"	7"	7"	13"	1'-6"
3	1"φ	21	6	1611	B	20'-6"	6"	6"						
8	1"φ	5	0	1612	B	4'-6"	6"							
4	1"φ	8	6	Str.										
2	5/8"φ	11	0	Str.										
4	5/8"φ	9	0	Str.										
20	3/8"φ	4	7	2592	C	9"	13"	7"	10"	10"				
22	3/8"φ	5	5	1613	C	9"	18"	7"	10"	10"				

FIG. 7-34. Details for Concrete Beam Reinforcement.

Concrete columns may be reinforced by vertical steel and ties, by vertical steel and hoops or spirals, and columns which are a combination of a structural steel and concrete encasement working together. (Figures 6–12 and 7–35.) In all cases the vertical reinforcing bars are kept 2″ back from the surfaces of the finished concrete. The ties, hoops or spirals are placed outside of the vertical steel and are thus about 1½″ back from the face of the concrete. In this way the ties, hoops or spirals

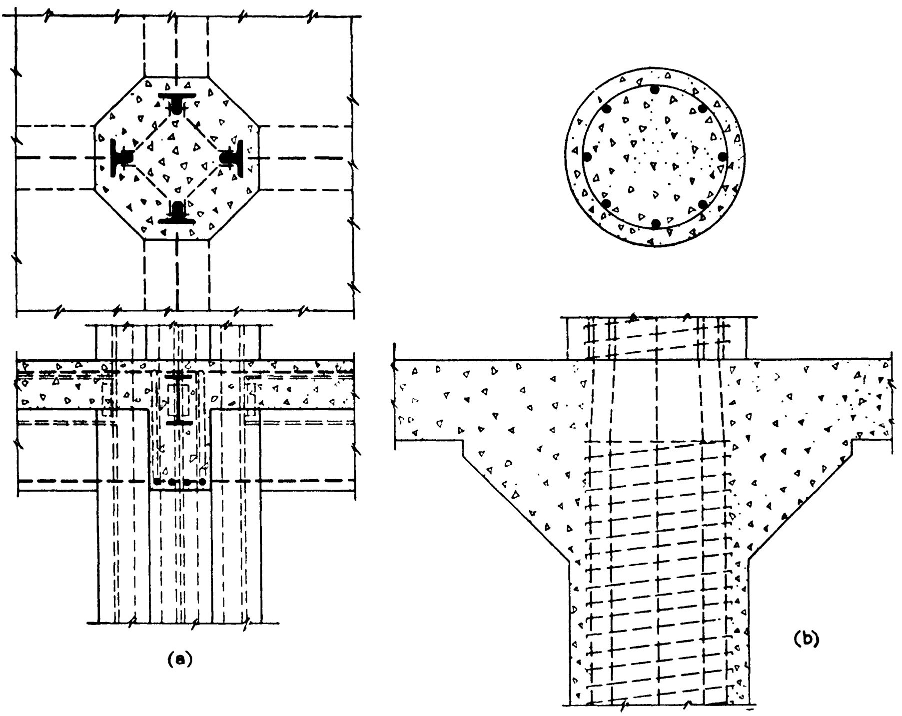


FIG. 7–35. Reinforced Concrete Columns. (a) structural steel reinforcement; (b) vertical steel and spirals.

assist in stabilizing the vertical steel. The principle involved is the confinement of the concrete of the core so as to increase its resistance to load. The ties are of lighter rods and form complete rings around the column at each spot. The spacing of the ties is specified by local code and is limited by column size, vertical steel size and other details. The spacing of the hoops or spiral is called the "pitch" and is related to core diameter by code specifications. Reinforced concrete columns are spliced as shown in Figure 7–36.

c. Column shapes are determined by their position in the structure and the design. Thus, corner columns may be L-shaped; intermediate wall columns may be square or rectangular, or they may have the irregular shapes due to set-back at the column center line; interior columns may be square, rectangular, or circular. The general disposition of the vertical steel and the ties, or spirals, is similar to that shown in Figures 6–12 and 7–35.

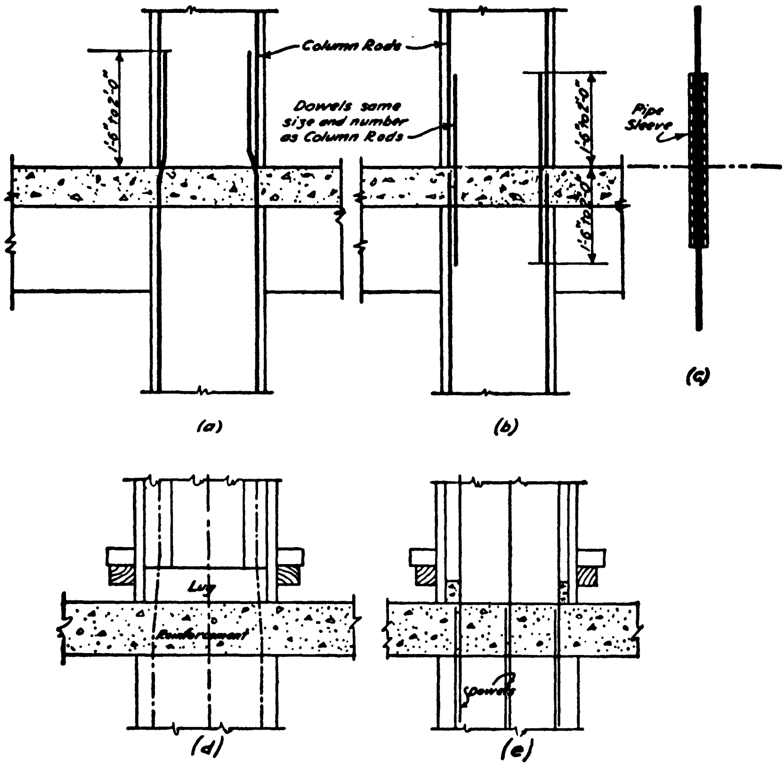


Fig. 7–36. Reinforced Concrete Column Splices. (a) extended vertical steel and dowels; (b) separated dowels; (c) pipe-sleeve splices; (d)&(e) lugs for forms.

d. Composite columns, or those using structural shapes and concrete encasement, are of many types. The most common involves the use of light angles and batten plates, as shown in Figure 7–35. Columns of this kind lend themselves admirably to connections with concrete beams or structural steel beams when required.

7–13. Spandrel Details

a. Reinforced concrete has the advantage of being economically varied in shape to meet specific details. This is particularly applicable to the details of spandrel beams. The spandrel, which is that section of an exterior wall between the sill of windows in the story immediately below, may take on a great variety of shapes and design, depending upon the architectural treatment. Figure 7–37 shows some of the variations of spandrel beams in the concrete frame. (See Article 8–3*f*.)

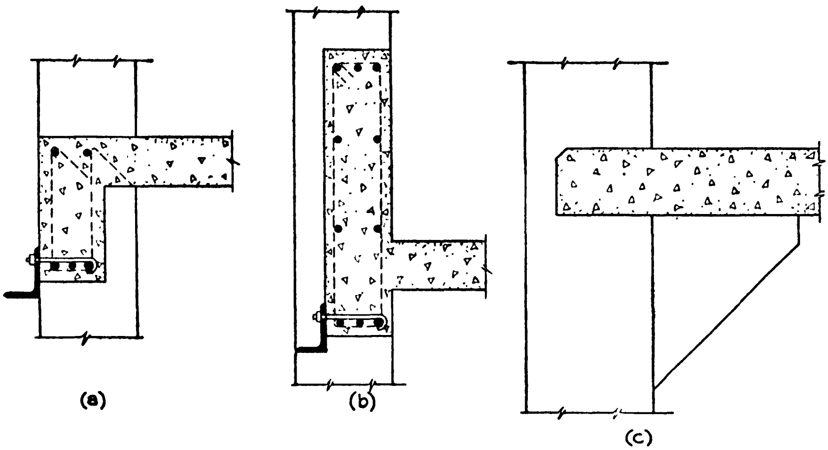


FIG. 7–37. Concrete Frame Spandrels. (a) turn-down beam; (b) turn-up beam; (c) flat slab support.

7–14. Placing Concrete

a. The placing of concrete for first-class buildings is essentially the same as that for second-class buildings except that multi-story buildings present problems of hoisting and organization. As large structures involve large yardages of concrete it becomes economically possible to use mechanical devices of many kinds to expedite placement.

b. Forms. The forms for slabs and beams have been discussed elsewhere (Chapter 6). In forming columns various schemes are used. Square and rectangular columns are formed by using panels which confine each side of such members. (Figure 7–38.) Circular columns are formed by using steel cylinders or bent plates. The panels are easily demountable and therefore re-usable, with only slight changes. Where beams frame into columns a pocket must be left in the column panel to allow the concrete to flow from the beam to the column and vice versa.

c. Plant. There are many variations of plant arrangement. These are related to each job and the equipment available to the contractor. Much can be learned from the catalogs of the manufacturers of equipment. The important element in plant efficiency is pre-planning. The plant should be well balanced. No part of the scheme—the charging, mixing and handling—should be made larger or smaller than the others. The size of the job and the plant layout will be determining factors in the size of these units. At times it will be more economical to use a single large unit,

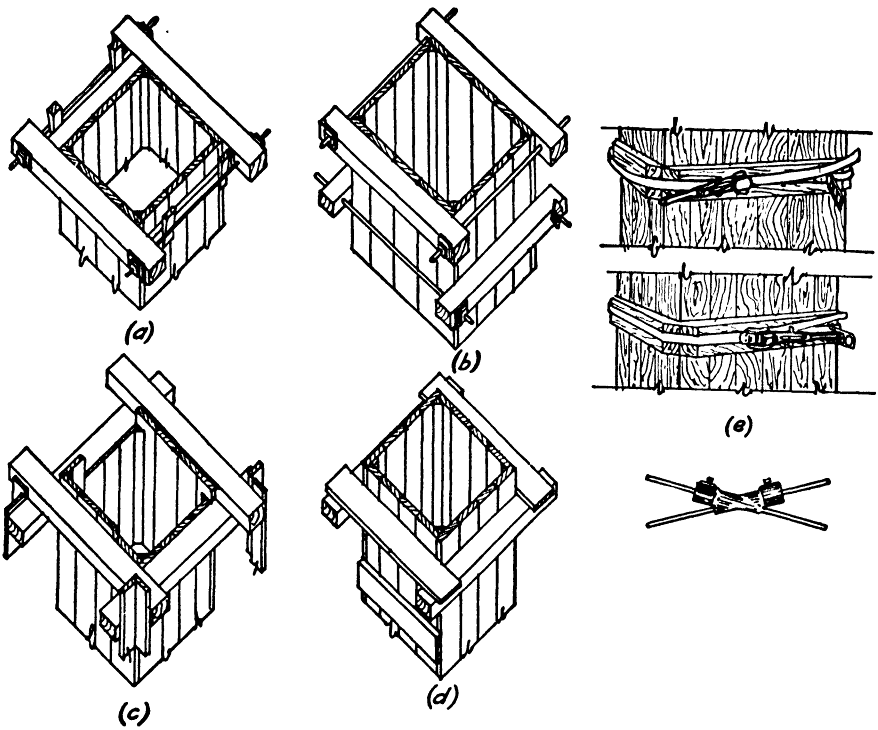


Fig. 7–38. Forming Reinforced Columns.

while at other times several smaller units, placed at advantageous points, are more economical.

d. The principal divisions of concrete placement are (Figures 7–39 to 7–42):

(1) stock piles and transport to mixer,
(2) mixing,
(3) hoisting,
(4) distribution, and
(5) spreading, spading and leveling.

The increasing tendency to use ready-mixed concrete in metropolitan areas has greatly reduced the use of job mixing of concrete and where this is still used it may well be confined to such localities as are not served

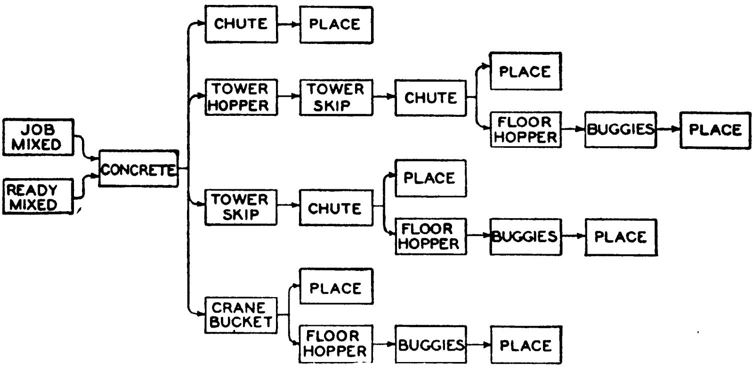


Fig. 7-39. Table of Casting Methods.

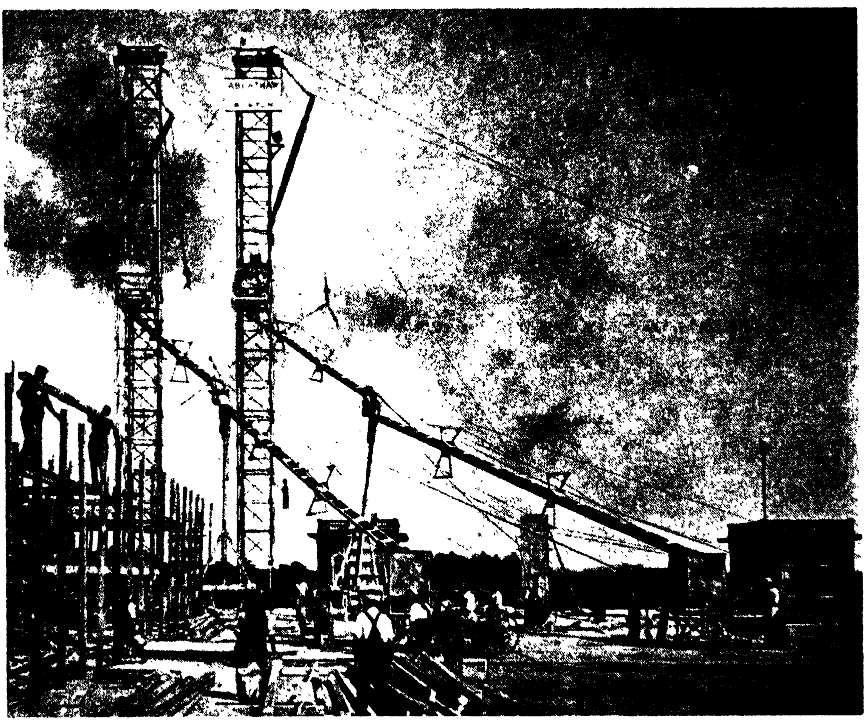


Fig. 7-40. Chuting from Towers to Floor Hoppers. (*Courtesy Aberthaw Construction Co.*)

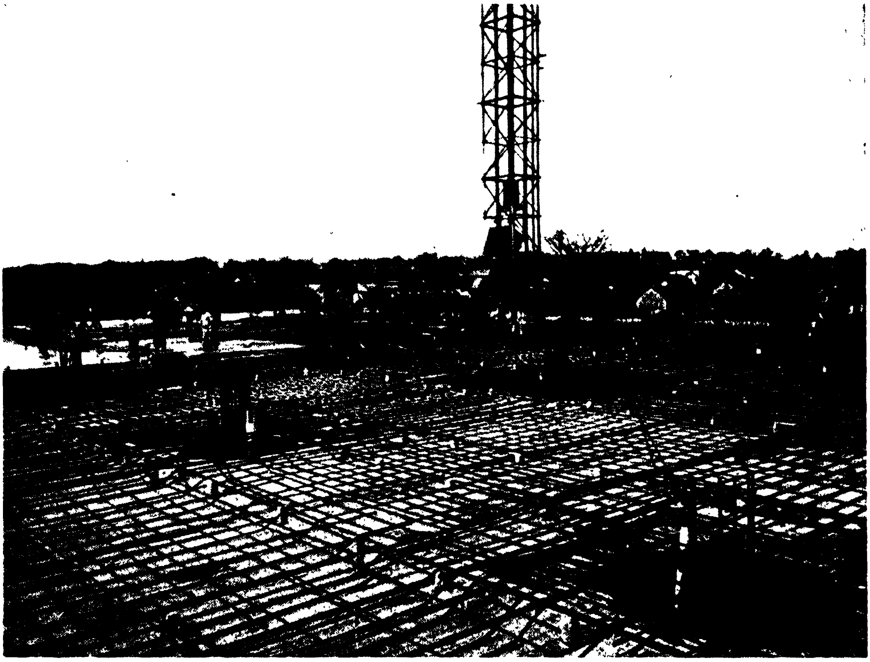


FIG. 7–41. Tower Skips to Buggies. (*Courtesy Aberthaw Construction Co.*)

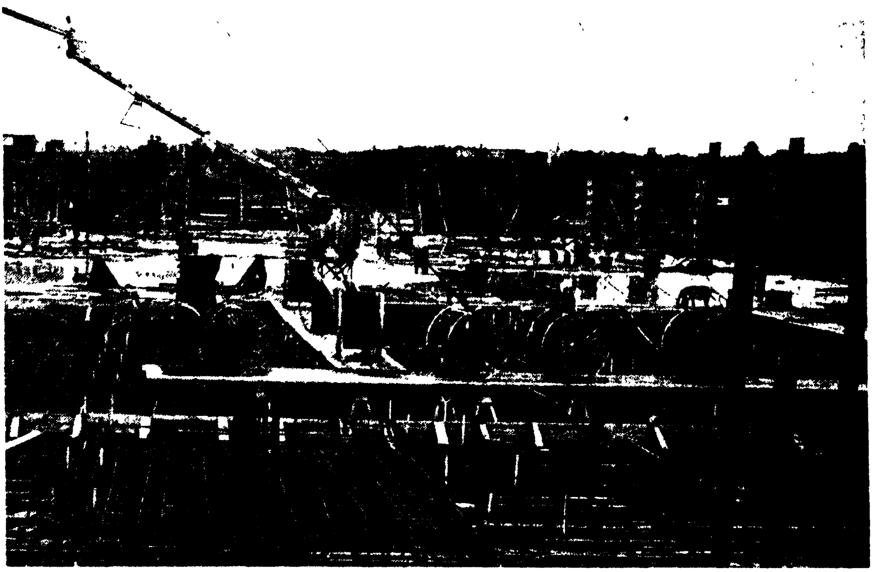


FIG. 7–42. Chute to Floor Hopper–Buggies to Place. (*Courtesy Aberthaw Construction Co.*)

by ready-mix concrete plants. Hoisting is effected by towers carrying skips which can be elevated to any level desired. When the height of the structure is not too great, cranes may elevate the concrete in buckets to the level where the buckets are discharged either directly into place or into floor hoppers, whence the concrete is carted to place. Distribution can be effected by:

(1) chuting to place,
(2) carting from floor hopper to place, or
(3) chuting or bucketing to floor hopper, thence carting to place.

The spreading, spading and leveling of concrete is similar to that for any concrete in any case.

e. The concrete for columns is placed either by spouting, direct bucket dump or from buggies or barrows. When buggies are used, runways are led to the various parts of the floor, resting upon horses or bents for support. The columns are cast to the bottom of the beam or slab, as the case may be; or they are cast to the bottom of the column capital in flat slab construction. The important factors in the placing of concrete in columns are continuous deposition to completion and the proper spading to produce a dense concrete and smooth column faces. Localized placing is, of course, necessary in this case and the type of form lends itself naturally to such deposition. In order to get well bedded reinforcement the spading should be carried on continuously with the placing and the concrete should not be run to the form faster than this work can be done.

f. The concrete in floor systems may also be placed by spouting. In most buildings it is probably more reasonable to cart the concrete over runways leading from floor hoppers located in strategic places and which are supplied by the hoisting skips, chutes, or crane buckets. The runways are stripped back as the work nears the hopper or tower. Concrete which is cast continuously to completion always results in a better appearing job and, because of the absence of cleavage planes, in a more dense concrete which should wear well. If work must be stopped, the stoppage plane should occur at right angles with the tension reinforcement and at a point of low shear. Such stoppage boards should be inclined and placed as shown in Figure 7–43.

g. Winter Construction. The importance of protecting concrete during freezing weather cannot be emphasized too often. The precautions which are taken against freezing are varied by contractors, but all of them aim to keep the concrete materials warm while it is being placed and then to keep the cast concrete at a sufficiently high temperature to insure hardening without freezing. The materials are protected by heating and the cast concrete may be protected as shown in Figure 7–44. It is always good practice to enclose the structure in tarpaulins and then heat the enclosure with salamanders or by steam heat if this can be made available from existing sources. It will be noted that the horizontal tarpaulin over

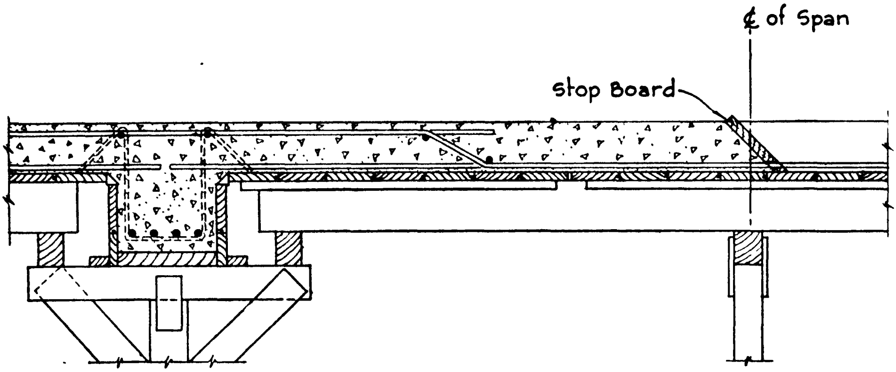


FIG. 7–43. Stop Boards for Construction Joints.

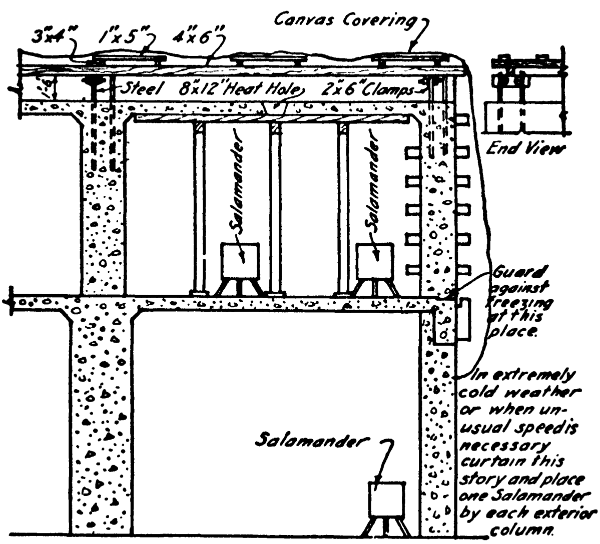


FIG. 7–44. Winter Protection for Concrete Frames.

the freshly cast slabs and beams is raised above the concrete and holes are left in the slabs to allow complete circulation of the heated air around the concrete.

h. Form Removal. The removal of forms is always important, regardless of the temperature. The sequence of removal of the form panels is usually column sides, beam sides, and then slab panels and beam bottoms. When the slab panels and beam bottoms are removed, reshores are usually set to give the fresh concrete additional assistance during continued hardening. A great deal of experience has been gained on the time of form removal and Table 7–2 shows the periods customarily recommended.

TABLE 7–2
FORM REMOVAL (DAYS)

Form Panel	Temperature		
	>60°F	50°–60°F	40°–50°F
Column Sides	≦ 3	5	≧10
Beam Sides	≦ 4	6	≧10
Beam Bottoms <14′-0″ Span	≦14	18	≧14
Floor Panels <6′-0″ Span	≦ 4	8	≧14

For beam bottoms and floor panels add one day for each additional foot of span.

i. To recapitulate the important elements of successful concrete placement we may list the following:

(1) continuous and even placing,
(2) placing in even horizontal layers of not too great a thickness,
(3) plant to be such as to avoid segregation of the constituent parts of the mix,
(4) bond new and old concrete properly at construction joints,
(5) the concrete should be spaded, puddled and tamped to bring the mortar in contact with all form faces and reinforcement, and
(6) the concrete should be amply protected in freezing weather.

CHAPTER 8

EXTERIOR WALLS

8-1. Wall Types

a. The exterior walls of first-class buildings are always built with 4 hour fire ratings and thus would be composed of noninflammable materials such as brick, stone, terra cotta, metal panels, or fireproofed steel panels. For architectural effect we may have an exterior face of brick, stone, metal or terra cotta. As a backing we may have brick, tile, lightweight concrete block, or some type of fireproofed metal panel.

STONE FACING

8-2. Stone Coursing

*a. **Rubble.*** In general, stone masonry is divided into two classes, namely, rubble and ashlar. Rubble masonry is composed of stones or stone fragments irregular as to any one or all three elements of size, shape and jointing. The irregularity may be somewhat ordered, to be sure, in any one of these particulars and the degree of such ordering has given rise to two classifications of this type of stone masonry, random rubble and coursed rubble. These are generally illustrated in Figure 8-1(a), (b). In random rubble little attention is given to ideas of coursing but each layer should contain stones bonding through the wall in sufficient number to produce a closely knit structure. The remaining interstices are filled with smaller stones of such size and shape as prove to be convenient or characteristic of the stone chosen. The most attractive random rubble is composed of generous stones, chosen for some interrelationship of shape among contiguous pieces so as to avoid an excess of small chips used as fillers. The pointing should be kept well back of the outer surface. Builds need not be vertical, but beds should approximate horizontality both for stability and better appearance. Coursed rubble is so assembled of roughly squared stones as to produce, at intervals, an approximately continuous horizontal bed joint separated by such vertical distances from similar neighboring joints as the natural cleavages of the material and convenient handling suggest. Such masonry may either be irregularly coursed and squared and the angles and quoins of the same or of a different stone may be introduced for a more precise ranging of the wall surface work. Both

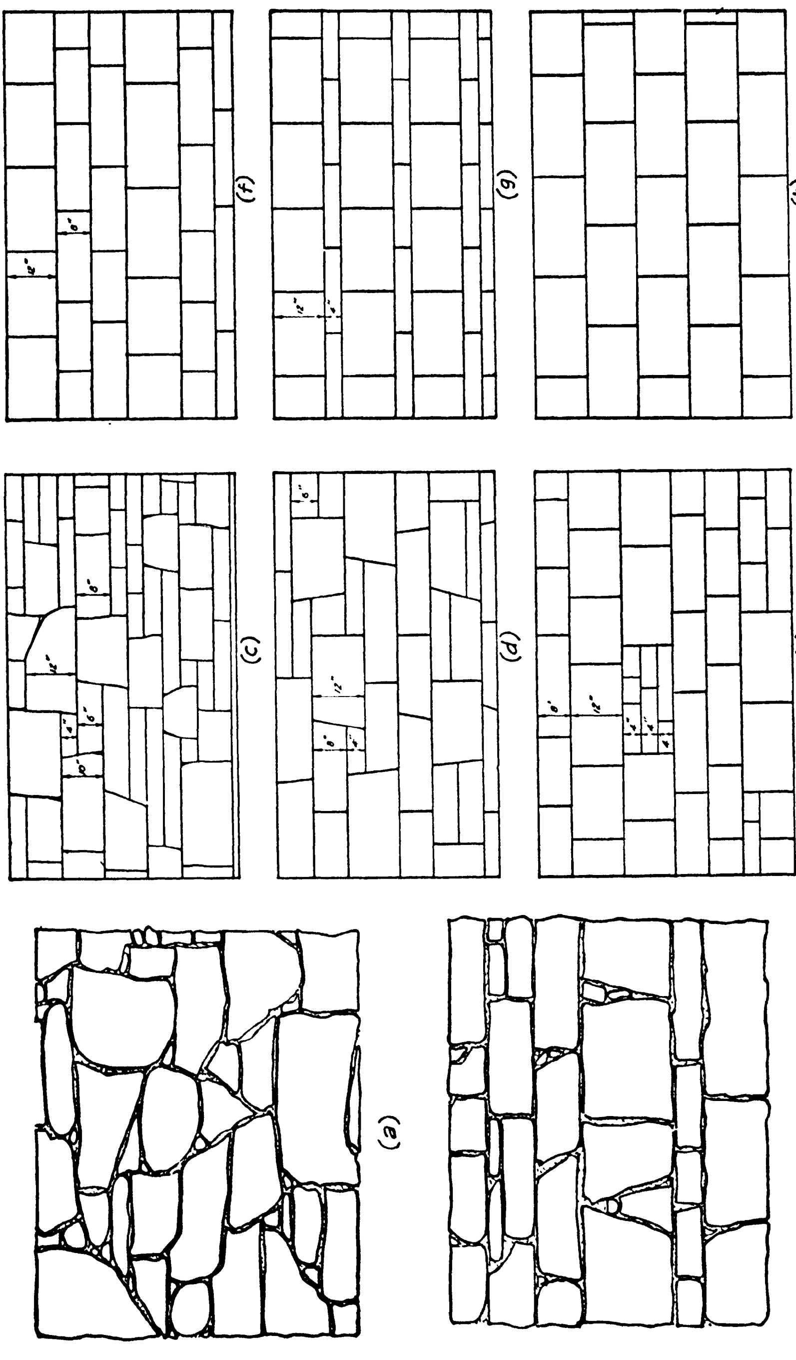


Fig. 8-1. Ashlar Stone Coursing. (a) random rubble; (b) coursed rubble; (c)&(d) broken ashlar; (e) to (h) regular and irregular coursed ashlar.

types are usually used in solid stone walls, although some walls faced with rubble have been backed by other masonry units.

b. Ashlar. Without regard to the surface finish of the stones, the term ashlar is usually, though not invariably, applied to stone masonry forming merely the superficial finish of the wall where the horizontal bed joints, vertical builds and the backs of the component stones are more carefully dressed to true planes at right angles to each other, thus permitting their assembly with beds of mortar of uniform thickness. In the more precisely ordered examples of ashlar the thickness of the mortar joints will vary with the stone chosen and the texture required by the design. For granite ¼″ to ½″ is usually a minimum. For granite column drums 3/16″ may be required. In limestone, sandstone and marble, joints may be decreased over these dimensions, but for exterior work ⅛″ is a reasonable minimum. Ashlar may be laid up as broken ashlar (Figure 8–1(c), (d) or it may be regularly or irregularly coursed as shown in Figure 8–1(c) to 8–1(h). The dimensions of the coursing of ashlar masonry and the lengths of stones between vertical joints are matters determined almost wholly by considerations of style and architectural scale. Regularly coursed ashlar may be subdivided by horizontal beds as close as 10″ or 12″ apart or expanding to 15″ or 20″. In monumental public work, particularly in granite, horizontal beds of coursed ashlar are frequently separated by dimensions of 3 to 5 feet. As a general rule, no stone in a facing should exceed a length of three times its depth in order that bending stresses, tending to cause cracks, may be avoided. Ashlar facing, regardless of the material, may be anchored, as a thin skin of uniform thickness, to the back-up material, or it may be, and normally is, cut in courses of varying thickness in the wall to promote the stability of the wall by mechanical bonding. Marble, sandstone and limestone may be thus bonded in courses alternately 4″ and 8″ thick, but in a material as coarse in texture as granite, courses alternately 8″ and 12″ thick are quite economical in cost. The extra labor and hazard of splitting granite to thinner courses than 8″ is far more costly than the material saved thereby.

8–3. Openings in Stonework

a. Sills. When windows and doors are provided with stone sills, these elements serve as washes for the protection of the opening and are usually pitched outward with a wash of at least 1″ in 1 foot. They are also usually provided with a drip on their under faces, as shown in Figure 8–2. In buildings where the loads are not very great and when the sills are not very long, the sill ends may be extended into the walls at the jamb, not more than 4″. Such sills are called "lug" sills. In heavy load bearing masonry walls where the pier loads are great, consolidation of the masonry and pier settlements may tend to crack lug sills and the so-called "slip" sills are used. The lug sill produces a more finished appearance and should ordinarily be used except where protection against settlement cracks from unusual weights demands the slip sill arrangement. In all cases the sills should be bedded at their ends only, when they are set,

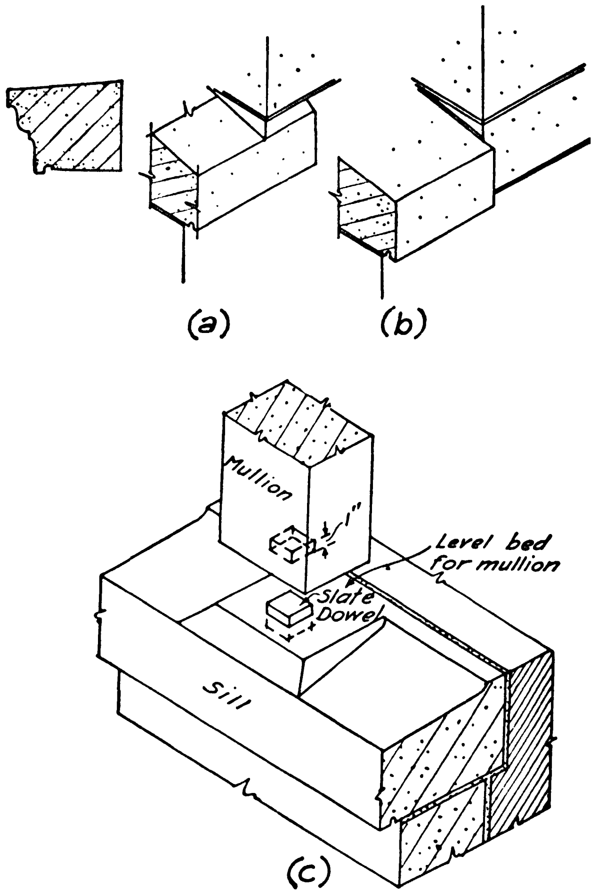
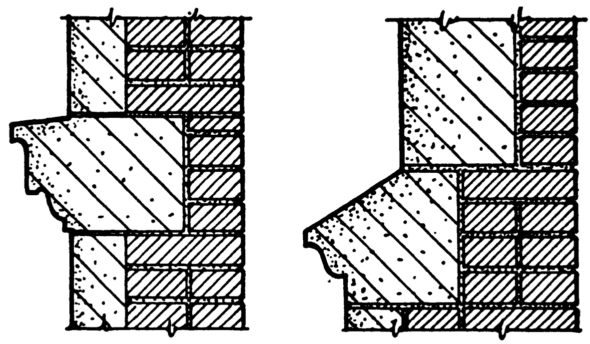


FIG. 8–2. Stone Sills. (a) lug; (b) slip; (c) stone dowel for mullion.

and pointed up later. This provides sufficient clearance for the anticipated consolidation of the pier masonry.

b. Belts. The horizontal divisions in the design of stone buildings and in brick buildings with stone trim are effected by the use of belt courses. Such belt courses often form the sill or lintel courses for wall openings and for that reason are considered here. They often are used at floor lines to reduce wall thickness. This may be done by increasing the wall thickness on the exterior of the wall as shown in Figure 8–3. The belt courses are usually moulded and provided with washes and drips. Care must be exercised in determining the heights of these courses, as well as of the ashlar courses, to assure proper bonding with the backing when brick is used. If the depth of a course does not allow a regular



(a) (b)

FIG. 8–3. Stone Belt Courses. (a) architectural break; (b) wall thickness change.

number of brick courses in the backing, the bricks must be clipped to fit into the ashlar toothing. This should be avoided as being uneconomical and a study of common brick sizes will assist in eliminating the difficulty. The moulded belts and base courses are designed partly to decorate, partly to give appearances of adequate strength and to throw off water quickly from upper slopes and to prevent discoloring drip by providing sufficient projection.

c. Arches. The tops of windows and doors are closed in for proper bearing by either arches or lintels. When the arch is used and is made up of stonework, the joints should radiate from centers, the location of which will depend upon whether the arch is segmental, semicircular, elliptical, pointed or flat. All stone arches are made up of cut stones called voussoirs and all the voussoirs taken together are called the arch ring, to differentiate it from secondary courses called ring courses. (Figure 8–4.) As the stability of stone arches may depend more upon the stones than upon the joints, more attention must be given to their detail than is usually given to brick arches. Elliptical and pointed arches of low crown are apt to open up at the crown or they may bulge at the haunch. A flat, elliptical arch should not be used for openings of over 8 feet nor where abutments of sufficient mass are not provided. In all the arches, based upon the ellipse, each joint should be perpendicular to the tangent

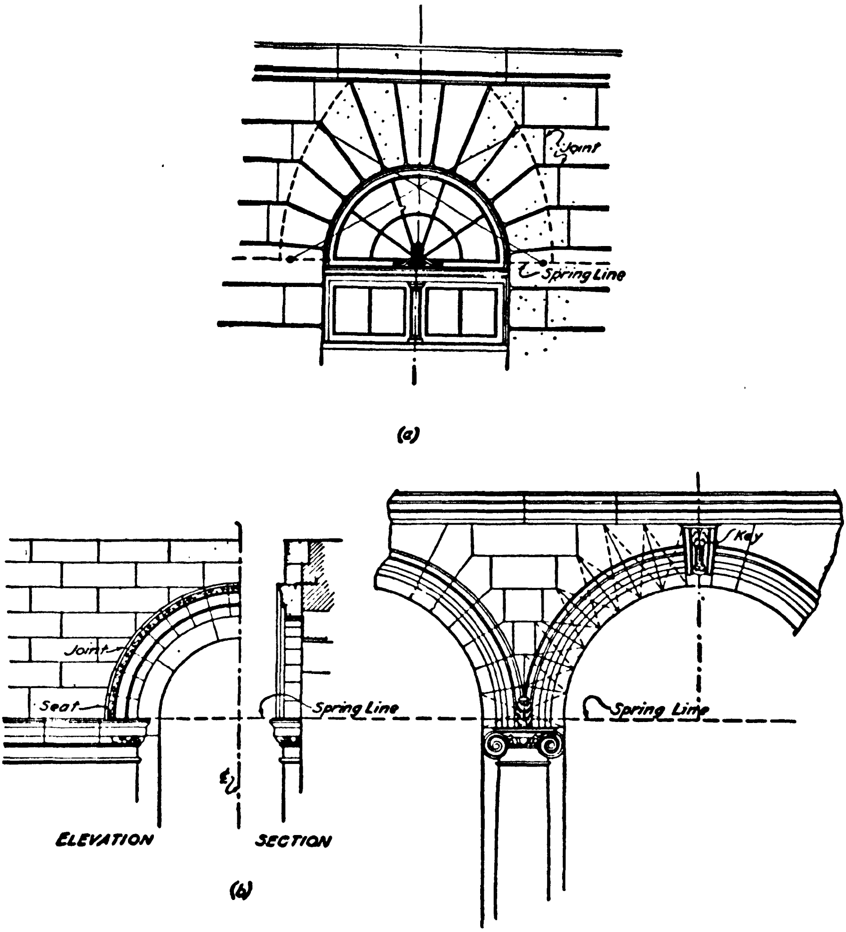


Fig. 8-4. Arch Coursing.

to the curve of the soffit at that point and radiate to definite centers. From the viewpoints of strength and stability the following items must be considered:

(1) ample thrust resistance in the springings,
(2) relief by brick arch or steel beams, and
(3) proper bonding of voussoirs into backing.

The relief of a stone arch by steel beams is shown in Figure 8–5. Flat arches must develop thrusts across the stone joints and slippage due to shear must be prevented. Thus the arch must be deep enough to develop the thrust ring with reasonable rise.

d. Mullions and Tracery. Proper jointing of the component parts of arches, jamb stones, mullions and tracery are essential to stability. All bed joints should therefore be at right angles to the resultant pressure coming upon them to prevent sliding. All joints should be so arranged that no bending or torsional stresses are set up in the adjacent stones. This condition may arise if mullions or tracery members are butted upon the spanning length of other members. In tracery work it is always necessary to arrange the joints in such a way that no inclined pressures can be transmitted. Figure 8–6 illustrates the jointing of the stones for a window with curvilinear bar tracery. Where heavy pier loads are encountered the intersection of the sill with the reveal should be separated by a slip joint. Where exceptionally heavy mullions are used, the mullion stone should pass through the sill to the underlying masonry to avoid setting up bending stresses in the sill stone. If the mullion is light, a continuous sill may be used. The areas enveloping intersections of tracery members should always be made of one stone, as shown. Mitres should never be used, as it is almost impossible, when used, to make a creditable execution of the carving at these points. By using a single stone the pressures in the tracery may be transferred at right angles to the joints, as is obviously desirable. The tracery of such windows should be set after the main arch has seasoned and its centers have been removed. This order of procedure insures against internal strains in these light members due to arch settlement or other causes. It will be noted that in the curvilinear example chosen for illustration, the tracery curves are, most of them, simple circular curves merging normally into each other at every change of curve motion.

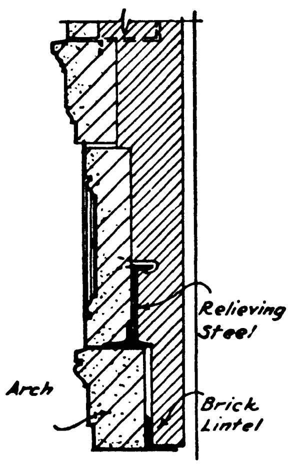


FIG. 8–5. Relieving Stone Arches with Steel.

e. Weathering Details. As previously described for sills, all projecting edges of stonework should be provided with drips and all the flat surfaces of projecting courses should be provided with washes so as to shed water and accumulated dust with facility. The tooling of such washes should be finer than that of the vertical surfaces unless the finish is rubbed or polished. Figure 8–7 illustrates a cornice with its drips and washes. When belt courses are returned around pilasters the washes and drips may be provided for as shown in Figures 8–3 and 8–12.

f. Spandrels. The spandrel construction in ashlar-faced walls presents many variations. As already discussed the spandrel extends from the sill of the window in one story to the head of the window of the story just below. In multi-story buildings the structural elements of the spandrels are often used for wind bracing. The facing, whether stone or brick, is supported by shelf angles, lugs or brackets attached to the structural

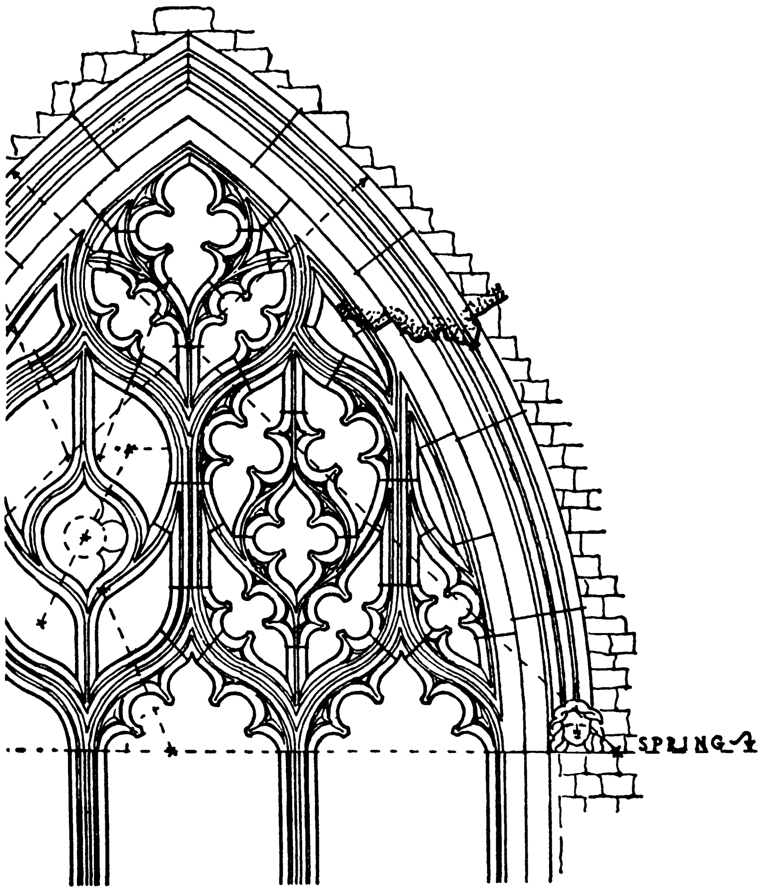


FIG. 8–6. Stone Tracery.

spandrel beams and to the wall columns. Figures 8–8 and 8–27 show several variations in spandrel construction.

g. Parapets. Walls extended above the roof level have been the cause of considerable trouble in the buildings where they have been used. Due to the small load imposed upon such shallow walls, the tendency to loosen is accentuated. Figure 8–9 shows a suggested means of increasing

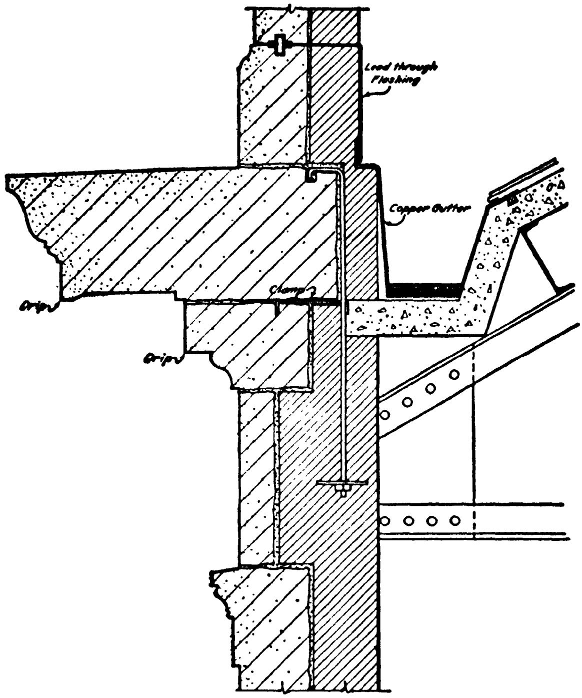


FIG. 8-7. Stone Cornice showing Drips and Washes.

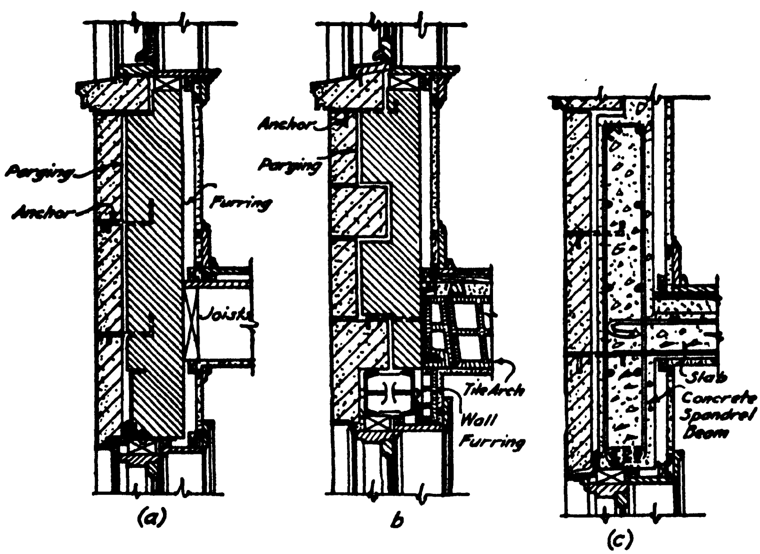


Fig. 8-8. Stone Ashlar Spandrels. (a) uniform thickness; (b) variable thickness; (c) concrete backup.

the stability of such parapet masonry. In this case the parapet is laid up, capped with a flashed steel cap or with a wooden cap and the masonry consolidated by bringing up the stress in the anchor bolts. This process is expensive but effective.

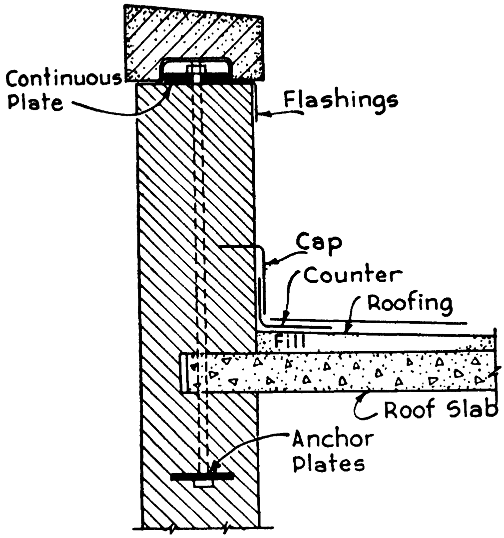


FIG. 8–9. Producing Compression in Parapet Walls.

8–4. Steps and Platforms

a. Entrance steps should always be of some hard stone which will resist abrasion. Granites, Potsdam sandstone or Tennessee marble serve very well. The tread stones should be solidly bedded upon walls at either end and if the span is more than 6 feet a central support should also be provided. A detail in which the tread is bedded its entire length upon a concrete slab spanning the entrance area is often employed. The details of setting are shown in Figure 8–10. The horizontal surfaces of steps should never receive a smooth finish because of the hazard from ice coating in winter. Fine-pointing or bush-hammering gives a surface of good texture, prevents slipping and wears to a smooth surface only after long and continuous usage. These surfaces may, of course, then be refinished as before.

b. The grouting of vertical and horizontal joints is illustrated in Figure 8–11. Cold lead wool is preferred to molten lead for caulking horizontal joints, as the hot lead is likely to crack the stone and its subsequent contraction on cooling loosens the pointing and destroys its efficacy as a weather stop and joint filler. In grouting the vertical joints of ashlar the

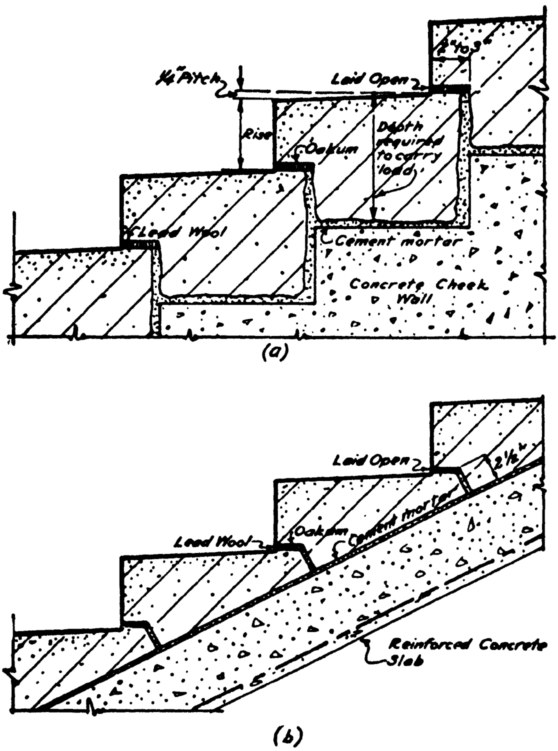


FIG. 8–10. Stone Stairs. (a) squared treads on concrete walls; (b) trimmed treads on concrete slab.

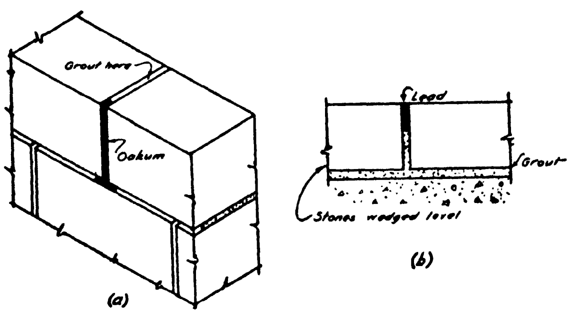


FIG. 8–11. Grouting Stone Joints. (a) ashlar; (b) flagging.

face should be caulked with oakum to provide a dam for the grout and prevent staining.

8–5. Special Details

a. Columns and Pilasters. Columns are either free or engaged, according as they stand isolated from or attached to the walls. A free column less than 8 feet high is actually made of one block of stone with separate pieces for the cap and base. It is not to be supposed that 8 feet is the limit of height for monolithic columns in any such materials as granite, limestone or marble. In fact, for columns up to a height of 20 feet, in limestone, the monolith is not only far handsomer but is less costly than the same column cut into drums. The present limitations of the granite lathe are such as to make columns, or drums, exceeding 12 feet difficult to obtain in this material, but the obvious economy of the monolithic over the subdivided shaft lies in the comparative ease of turning the entasis in one operation and in the elimination of the added bed cutting. This saving more than offsets the cost of transporting and setting the larger piece. As a general limitation to size of monolithic shafts, aside from the foregoing considerations, the architect should bear in mind the transportation limits of weight imposed by public authority—usually 12 to 15 tons over the highway bridges of average strength.

b. If a column is engaged, the shaft may also be made of one piece, but it is preferably jointed with the ashlar, as it, properly speaking, is a portion of the wall. Pilasters, used in connection with free columns, are rectangular engaged piers without entasis and of proportions dependent upon the design. They are jointed similarly to the engaged column. The pilaster width usually is a mean between the lower and upper diameters of a free column of corresponding design.

c. In setting large column drums it is important to keep the non-staining cement mortar, if mortar is used, raked back from the face of the joint about ¾″ to prevent the edges from spalling off, due to the great weight. Lead discs are frequently inserted in the mortar beds to take the weight before the mortar has set. Mortarless joints are not infrequently used in fine monumental work. Engaged columns should be cut with a rectangular back which extends into the wall at least as far as the ashlar facing. In addition, the shaft should be anchored into the backing by means of galvanized steel clamps. Figure 8–12 illustrates the details of jointing for small engaged columns and pilasters and gives the details for the drum column and coursed pilasters. The pointing mortar for stone columns should contain the material of the column powdered to a sand and the pointing should be as nearly flush as may be, still keeping the joint at

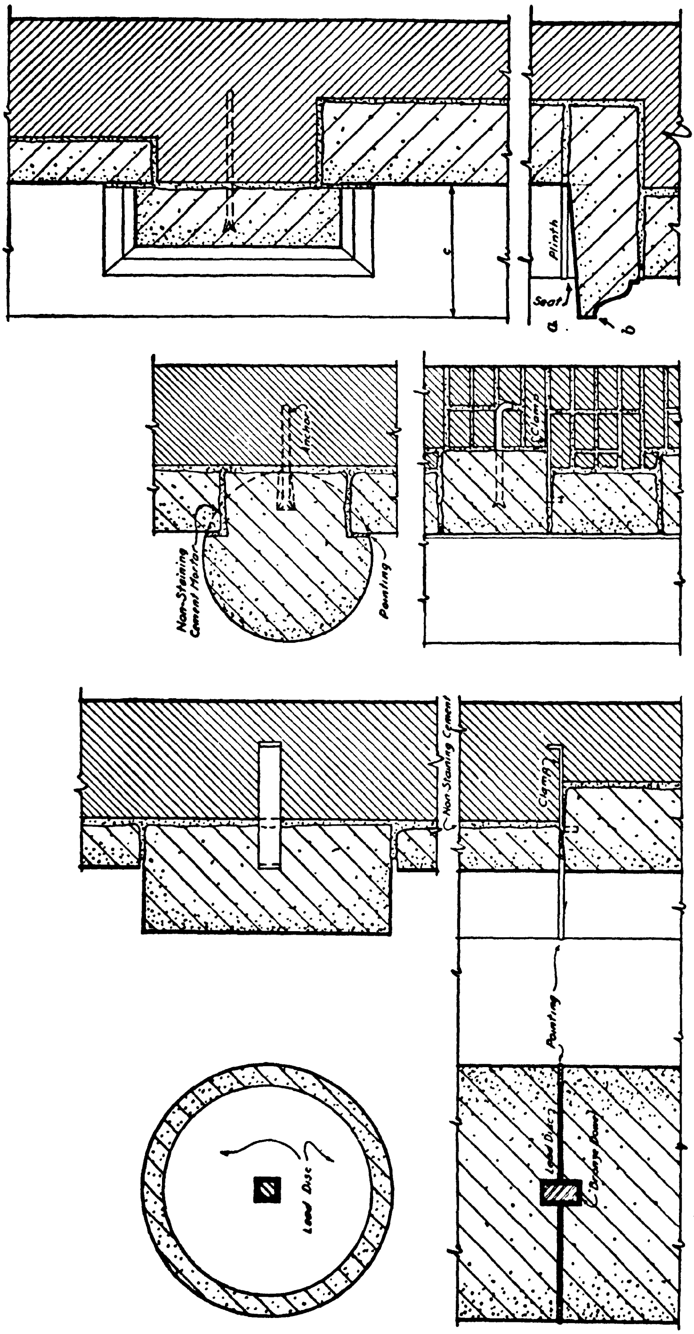


Fig. 8–12. Stone Columns and Pilasters. (a) free-standing circular columns; (b) pilaster; (c) engaged circular column; (d) pilaster bearing on belt course.

uniform thickness. The joint should always be made as inconspicuous as possible.

d. ***Entablatures and Cornices.*** Aside from the architectural features of the design, the important elements, structurally, are:

(1) the proper balancing and support of the stone, and
(2) the jointing and cutting to provide protection against the elements.

Cornices constructed so as to be self supporting as structural masonry must be made up of stones in permanently stable equilibrium upon the center of gravity of the immediate wall section. Prudence dictates that they should be carefully anchored down in addition, and they should never depend upon superimposed masonry for stability. Figure 8–7 illustrates a typical cornice section which emphasizes the lack of self support, where equilibrium may be assured only by verifying that the weight of each portion of a stone inside the vertical line through the center of gravity shall predominate over the weight of each portion outside of this line. Such is not the case here.

e. The preparation of proper weathering details, both as to joints and drips, is often seriously slighted. The horizontal joints should be well caulked and leaded with cold lead wool or filled with an impervious and elastic cement mortar well forced into the joint. Nearly all of the cornices of the historic architectural styles provided arrises for drips and, in general, it may be said that every soffit contiguous to a vertical surface receiving water from a wash above should be arranged with a back-cut or drip to stop the travel of the water toward the main vertical surfaces of the building in order to provide against the unattractive discoloration otherwise sure to occur on the vertical surfaces of the stone.

f. ***Balustrades and Copings.*** Figure 8–13 shows sections through a typical balustrade and coping. Solid copings do not present a problem very different from the main wall, but the balustrade calls for careful attention to attachment and waterproof jointing. The customary procedure is not to rely upon mortar joints and superimposed weight for stability but to provide all joints with dowels to secure the parts against movement.

g. Stone details which come into contact with, or which operate with, the roof surface in the shedding of water must be carefully flashed. Copings and parapets of any form of masonry are notorious trouble makers when improperly flashed. They should always be "through flashed" with copper or some approved type of fabric, and the bond thus broken should be rectified by the introduction of soldered cups to fit the dowel anchoring, as shown in Figure 8–13. All masonry mortar joints are to some extent porous and will absorb and transmit moisture. The through flashing is an effectual stop to its progress toward the interior of the building, and should be introduced wherever the masonry absorption and transmission occur near any soffit closely related to interior finish as, for example, the masonry heads of door and window openings, or walls carried on steel over rooms or bays.

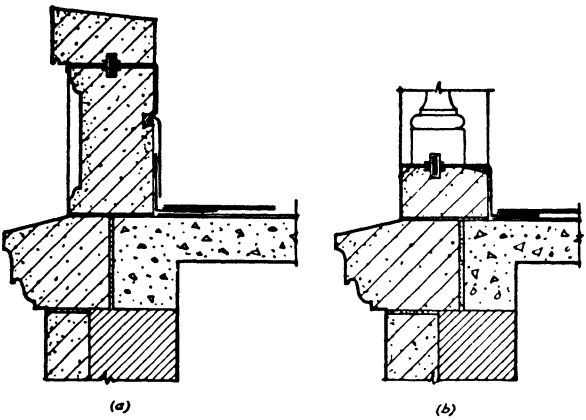


FIG. 8–13. Stone Parapets and Balustrades. (a) parapet; (b) balustrade.

h. Stone Cutting. The fitting of cut stone around structural members, insofar as it may be determined in the shop drafting room, is the task of the stone detailer. The most important phase of this work is that of providing adequate support and anchorage for the several pieces composing the detail. The proper adjustment of thickness is also important where it is restricted by the thickness of the fireproofing which must provide a covering for the spandrel steel. Stones must not be so radically back-cut as to make them awkward for crating and shipment, and consultation with a stone specialist familiar with the practical details of pattern preparation and the natural limitations of the material in question, will save time to the architect and cost to the owner. Anchorage may be provided by direct connection to the frame or by use of the usual stone anchors into curtain-wall brickwork. When portions of the cornice are formed by balance stones, two-thirds of the weight of the stone should come inside the face of the main wall or the stone should be securely anchored to sufficient dead weight to insure absolute stability. (Figure 8–7.)

i. The holes or recesses cut in stone are usually either for the purpose of ease of handling during setting or for bond. The Lewis hole is used, as shown in Figure 8–14(f), for stones of such weight as cannot be properly

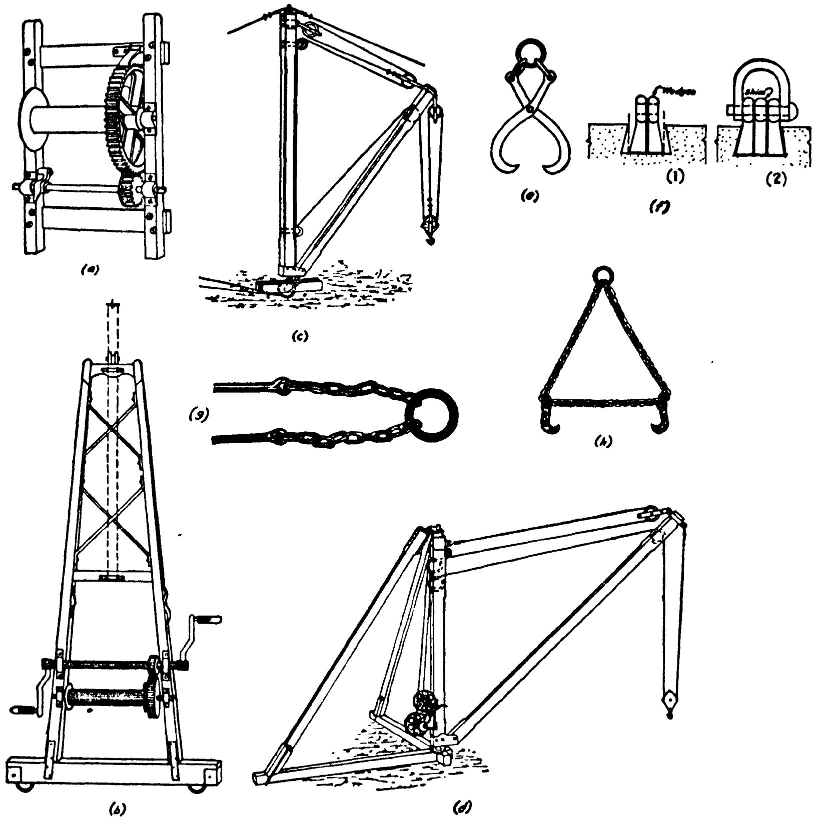


Fig. 8–14. Stone Erection Equipment. (a) winch; (b) setter derrick; (c) guyed derrick; (d) stiff-leg derrick; (e) tongs; (f) Lewis; (g) chain Lewis; (h) grab-chains.

handled by two men and must be lifted and swung into place by a derrick. The principle of the grip of the Lewis bolt lies in the shape of the expansion shim. The hole is shaped like that in (1) of this figure and the two wedges are slid into it. The space will just accommodate the maximum wedge width at its top as shown. The shim is then forced between the two wedges and the pin is put through the eye of the triple-leaved device,

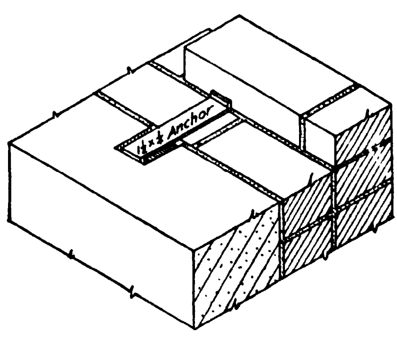


Fig. 8–15. Anchoring Stone Ashlar.

as shown in (2). The recesses for the anchors are usually cut on the job so as to insure accurate adjustment with the backing, or frame. Anchors should always finish flush with the top of the stone, as shown in Figures 8–7 and 8–15, for the purpose of preserving a flush surface to form the bed for the next course. These rabbets also act as an additional protection to the anchor. The use of mortise holes and stone tenons for details which otherwise would be, or might tend to become, unstable due to insufficient course bonding or superimposed weight is a precaution which should always be taken. The tenon may be cut on one stone and the mortise in the other, or both stones may be provided with mortises, the tenon action being supplied by a separate cubical dowel stone as shown for a mullion in Figure 8–2(c).

j. The provision of a level seat for a stone superimposed upon a member which has a wash should always be made. Seats should likewise be cut upon platforms for the receipt of the bases of pilasters, columns and other similar forms. This feature is illustrated in Figures 8–2, 8–12, and 8–13.

k. The cutting of reglets for cap flashing can be done before the stone is set provided such work is properly detailed. Otherwise it had better be left until after setting. In spite of the care in preparation it is often found necessary to do considerable cutting in connection with this work on the job, and the stone cutter employed must, of course, be familiar with the flashing methods specified. Figure 8–13 shows the two usual cases met with in practice, that of the cap flashing let into a low parapet capstone and where a high parapet or open balustrade necessitates a reglet in the back vertical face of one of the stones or in one of the joints. The latter method is open to criticism since the exposed horizontal stone surfaces absorb water which ultimately finds its way to the interior of the building. To overcome this it is wise to carry the flashing over the next adjacent, exposed, horizontal surface above or to pass the flashing through the next bed joint above. In general, it is wise to place "through" wall flashings where horizontal soffits like the heads of windows present opportunities for moisture to find its way back into the interior of the building.

8–6. Backing Stonework

a. Ashlar stonework is usually a veneer upon brick, stone, or concrete walls. When backed with brick, as is generally best, the backing is set consecutively with the face stone, each course being set and then backed up. The same method is followed for stone backing and in each case the face stone is protected against the staining of the backing mortar by plastering, or parging, it with a non-staining mortar before the backing is set. When concrete is used for backing, the concrete is cast first and should be well set before the stone veneer is applied. In this case the ties used for the wood forms are made more numerous or are inserted at frequent intervals. These are in turn used to tie the stonework into the building wall. In this work it is important to protect the ties with mortar so that they will not be subject to alternate ventilation and moisture. Many architects specify that the back of all stone facing shall be waterproofed with either a waterproof paint or pitch or a parging of non-staining cement mortar. When this is done it should be applied to thoroughly

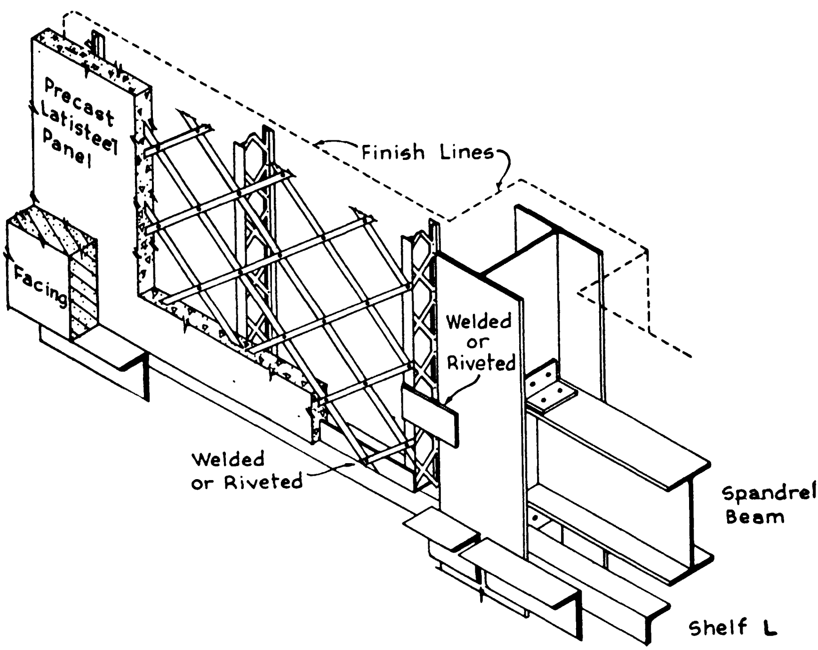


Fig. 8-16. "Latisteel" Backup for Ashlar.

seasoned stone only, as the face of the stone affords the only direction of escape for quarry sap, and staining from this source is possible.

b. A recent innovation in structural backing for masonry walls and which may be used equally as well for brick facing, stone ashlar facing, architectural terra cotta, is the use of steel frame panels. This method involves the use of lightweight steel members, the outer members of which are encased in a fireproof and stiffening slab of concrete reinforced with a lattice which provides skinstress resistance to help in carrying the loads. The result is a lighter exterior wall capable of carrying its own weight in low buildings and of imposing lighter loads upon exterior wall columns and spandrel beams in multi-story buildings. This form of construction, known as Latisteel and which may be the forerunner of other innovations effecting reductions in cost, is illustrated in Figure 8–16.

8–7. Setting Stonework

a. Erection Drawings. When coursed ashlar is to be used it is a common practice to show each stone on the elevations of the buildings. The lengths of the stones are indicated and the heights of the courses are dimensioned so that the cut-stone contractor may produce the desired jointing. From these general drawings the cut-stone contractor makes his quarry drawings which show each stone numbered and the section of the walls given to illustrate the jointing and bonding which he proposes to use. Such a quarry drawing is given in Figure 8–17. The stones later arrive on the work numbered in like fashion on the end or back.

b. Mortar. The mortar used for cut stonework will depend upon the loads imposed, the type of stone used and the architectural pattern of the stone coursing. Dense stones must be set in mortars which are non-bleeding and which will flow freely into the joints. Such a mortar should contain at least one part of hydrated lime to each part of cement used in the mortar. In each case the sand used should not exceed two and one-half parts, by volume, of the gross volume of the cement and lime. More porous stones can safely be set in a mortar containing at least two parts of lime per volume of cement. In case limestone or marble are to be set the cement should be of a non-staining type such as white portland, slag cement or La Farge. Granulated aggregate of the same material as the stone is often used to make the mortar more nearly like the stone itself.

c. Setting Stone. Stones should, with very few exceptions, be set in a full bed of mortar. When the stones are too heavy for one man to lift, they should be set by means of a derrick. In order that all the joints may be of like thickness, small wooden wedges are set along the joint bed and are driven up or released, as may be necessary, to align the stones carefully. As the stone settles upon its mortar bed these wedges carry the weight of the stone until the mortar has hardened. They are removed later when the joints are pointed.

d. The setting of stones by derricks involves the use of chained grab-hooks, cushion clamps, chain and link dowels, Lewises or some similar device. (Figure 8–14.) The grab-hooks and clamps necessitate the cutting of pockets or depressions in the stone and are awkward to use when setting a stone in place between other parts of the structure. The cushion clamp, with wood or lead cushions, prevents the marring of the finished face and was devised for this reason. With long stones two points of attachment are required to avoid breaking the stone and the dowels and Lewises are used in this case. Three types of derricks may be employed.

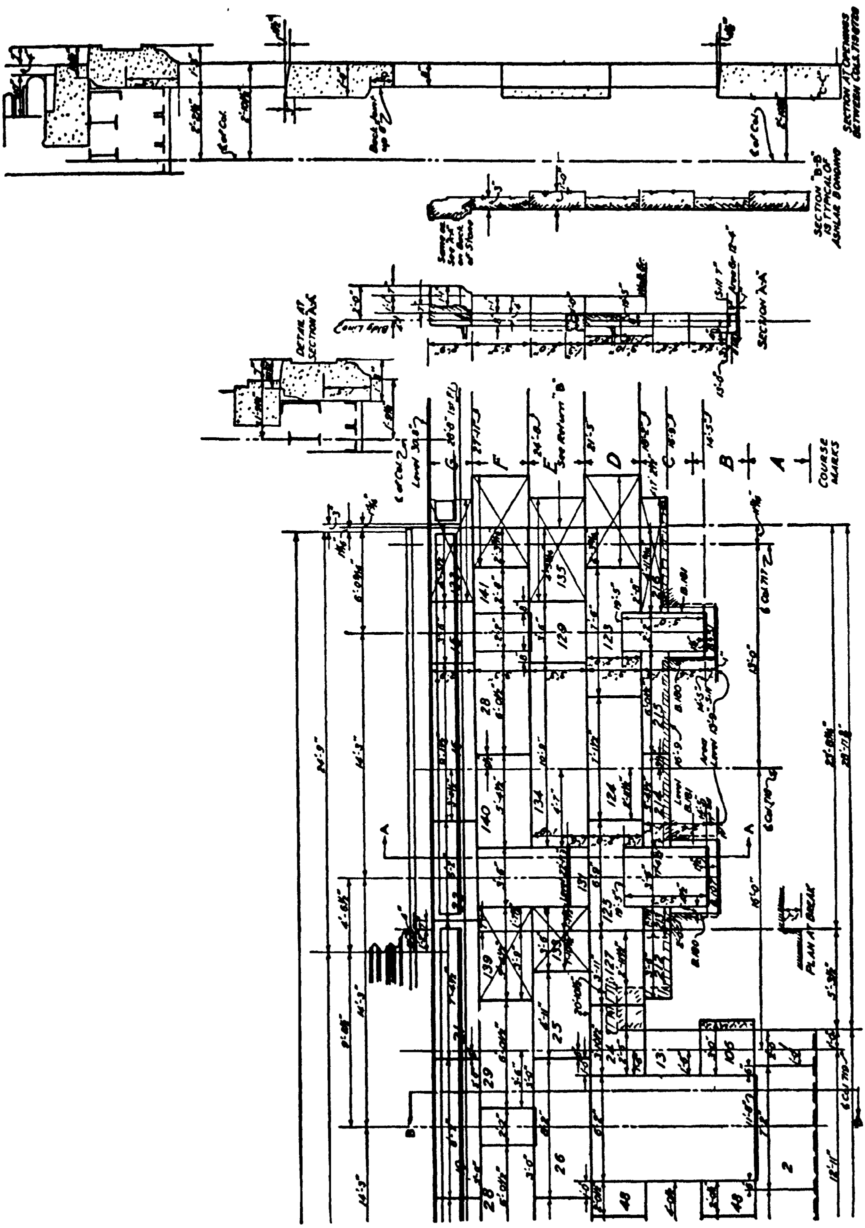


Fig. 8-17. Quarry Drawing for Ashlar.

These form a complete unit piece of equipment. Rudimentary derricks are often made up on the job by attaching the winch to a timber gin pole.

e. Each stone should be eased into as nearly its final position as possible, and a good stone-setter will manipulate the stone into its exact position before the grip is released. If this is not accomplished it must be sledged into position by light blows with a piece of timber, an operation which tends to disturb the adjoining stones already in place. In setting sills, and other stones which span openings, the bedding is prepared at the ends only, the joints elsewhere being flushed up with mortar after the original mortar has set. If this precaution is not taken the settlement of the piers, however slight, will almost invariably crack the stone. If wedges are used for sill setting, they must be removed as soon as the bedding mortar has set, for a similar reason.

f. The waterproofing of the first stone course with asbestos felt for the joints and a colorless liquid on all the exposed surfaces is worthy of note. It protects them during the first years of the life of a building when leaks and consequent efflorescence are likely to occur. In this same connection note that the use of salt for thawing out erection and anchor holes should be avoided. Any of the mineral salts, if they are allowed to remain in the walls, will later find their way to the surface of the stones and cause efflorescence.

g. The use of parging to insure a positive protective coating for all stones is advised. Very often a waterproof of dampproof paint is used to accomplish the same purpose. This parging, plaster coat is applied before the backing is laid. If the mortar used for the setting will not stain the stone, it may also be used for this work.

h. The grouting of vertical joints in face stonework is considered good practice. Where this is specified, the exterior face of the joints is closed in with oakum to avoid the waste of grout and possible staining of the exposed stone face. (Figure 8–11.)

*i. **Breast or House Derricks.*** In building construction, derricks of this type (also called "setter" derricks) are principally used for setting stone, and are usually operated by hand. They consist of a winch mounted on an "A" frame. The hoisting cable is wound on a drum mounted on the lower shaft, and the loads are hoisted by means of handles attached to either end of the upper shaft—the necessary leverage being obtained through reduction gears. In many cases the handles are also used for lowering the loads, and this is probably the safest and most efficient method. At other times, however, the loads are lowered by using a "bulltail" as a brake. A bulltail consists merely of a length of rope which is wrapped about the upper shaft several times. One end is then secured to the frame of the derrick, and the other end, or "tail," is held by a workman. By pulling on the rope sufficient friction may be brought upon the shaft to stop and hold loads of considerable weight. The most efficient bulltail is made by separating the strands of a 3-strand rope, and braiding them together so as to form a flat surface to bear against the shaft. The men sometimes have their hands and fingers crushed or bruised when using these bulltails, and the bulltails sometimes break and allow the loads to drop. In view of these possibilities it would be desirable to install a mechanical brake on the winding drum (or lower) shaft of every breast derrick. Stone setting derricks are rarely equipped with mechanical brakes, but other derricks of a closely similar type are often provided with them. A mechanical brake eliminates the possibility of crushed hand and fingers, and, if it is kept in good working order, it also keeps the load under control at all times. Even if one or more of the gear teeth should break, or the small gear should slide on its shaft and become disengaged from the large gear, there would be no danger of the load dropping because the brake is mounted on the shaft on which the hoisting cable is wound.

j. As a rule, breast derricks are guyed from only one direction, and under ordinary circumstances this would be sufficient. When moving the derricks, however, they are straightened up, and are then likely to tip over backward; the same trouble will occur if a heavy object should drop on the guys, or if the hoisting rope should suddenly break while raising a load. To guard against a possibility of this kind, a front or head guy should be secured to the derrick and to some fixed object on the floor above. If there is no higher floor, the derrick should be made secure against falling backward by some other method. All breast derricks should be set on heavy planks or timbers, of sufficient length to extend from one girder or floor beam to another. They should never be allowed to rest directly upon floor arches—this counsel being specially important when the arches are newly laid. The base of each derrick should be secured in a suitable manner by means of ropes or cables, or by timber bracing, so that it cannot become displaced.

k. Arch Centers and Overhanging Course Supports. In setting the voussoirs of stone arches and the brick of relieving arches, wood centers are used. For a small span, a center, such as shown in Figure 8–18, is employed. The planks are cut to the exact curve of the arch and are fastened together with ⅞″ cleats. They are tied across the springing line with ⅞″ boards and the whole center is rested upon 2 x 4's or stronger scantlings, as the case may demand, at the jamb lines. The top of the center is lined with 1 x 2 strips, laid about 1″ apart. Overhanging courses of stonework occasionally require bracing during erection. This is especially true where stones are used which do not have an adequate counterbalance in the wall to produce stability. A safe margin of excess wall stone is advisable for all such cases. As a rule, the volume of the stone is not the gauge of its expense, the cost being centered in the exposed shaped portion which is largely a matter of labor cost. In the cornice shown in Figure 8–19, the stones are supported by means of braces and liners which are allowed to remain in place until the mortar has set and sufficient weight has been placed upon the construction to counterbalance it.

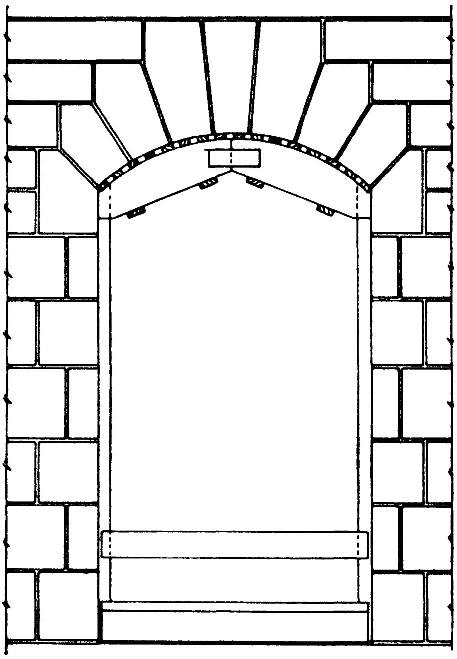


Fig. 8–18. Arch Centering.

l. Bonding of Stonework. The bond in stonework, as in brickwork, is indispensable in order that the wall may have tenacity or cohesiveness approaching the monolithic character. The bond ties the wall together both longitudinally and transversely. On this account, it is obvious that, in coursed work, no vertical joint in one course should be directly in alignment with a joint in the course immediately above or below. This insures that each stone bears directly upon at least two stones below and that it, in turn, bears parts of two stones above. The alternate thicknesses in courses contribute to this same end in another direction. In shallow ashlar the use of bronze or iron cramps is essential. These tie the backing and the face work together firmly and tend to avoid any cleavage in the wall due to load. No part of such an anchored facing may be included, however, in calculating the essential thickness for strength. The difference in thickness of alternate courses in the bonded wall generally differs by a common brick dimension, such as 4″ or 8″ for ease of laying and bonding with the backing. The thickness or depth into the wall, back of the ashlar line of the stone itself, will depend both upon the material used and the scale of the stone coursing in the design.

m. As has been previously observed, coarse textured stones like the seacoast granites cannot be split into thin 4″ slabs for stones exceeding 18″ to 20″ in course height, with any assurance of regularity nor, consequently, with economy. Alternate thicknesses of approximately 8″ and 12″ are therefore more common in granite work. Fine textured stones like the limestones and marbles, which are sawn rather than split, may be made in 4″ and 8″ thicknesses alternately, and where not exposed to extreme climatic changes, anchored veneers of limestone and marble 2″ thick are

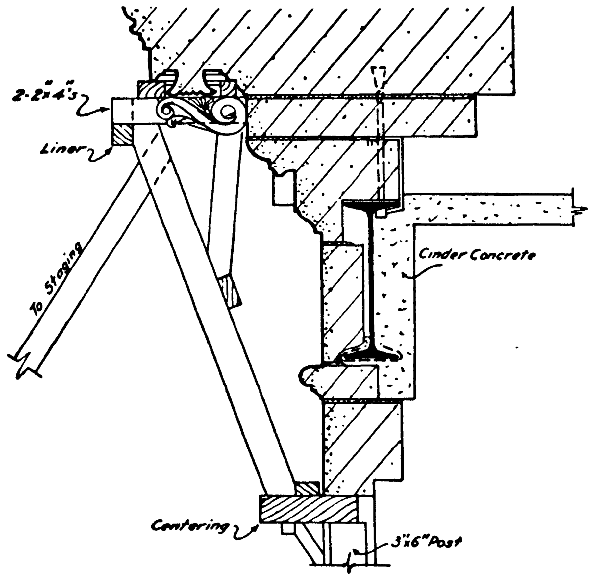


Fig. 8–19. Cornice Setting Support.

quite common. When varying course depths are encountered in the design of the elevation, the shallower course is usually the thicker, as in Figure 8–8. Where the backing is of reinforced concrete the ashlar is usually of uniform thickness in any one panel, the bond being secured by metal anchors.

n. Joints and Pointing. In setting stones the bedding mortar should theoretically be kept back from the face of the stone about 1″. This is seldom done, in actual work, whence the stipulation that the joints should be raked out immediately after each course is set. If the mortar has had time to set it is difficult to rake the joint out and as a result it cannot readily be set back far enough to insure a sufficiently deep pointing bond. Stones which are not stained by portland cement mortar should be pointed with retempered 1-1-4 mortar, in order to obtain a good caulking action and a good finish. If the stones are stained by portland cement, a non-staining cement is used in place of the standard portland.

o. The pointing mortar is forced into the joint, as shown in Figure 8–20, by means of a jointer. Several types of joints are used in pointing. The most desirable, in their order of preference, are the groove joint (b), the flush joint (c), the ruled flush joint (d), and the ordinary weather joint (e). The ruled flush joint is struck exactly as the ordinary flush joint and then ruled with a small V-groove at the edges. Projecting joints are apt to break off, while recessed or raked joints offer opportunities for frost to disintegrate the mortar or spall the stones. The most desirable joint to insure the maximum of weather protection is the concave joint. The mortar should be laid into the raked joint in at least two stages, the final

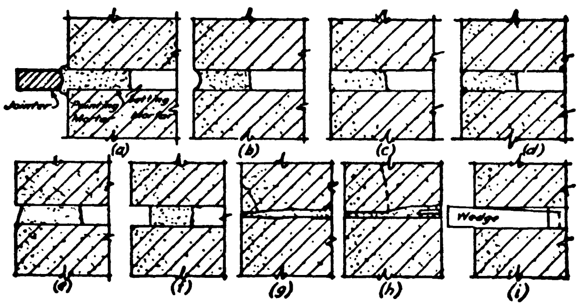


FIG. 8–20. Mortar Joints for Ashlar. (a) jointing; (b) concave joint; (c) flush flat joint; (d) jointed flush joint; (e) weather joint; (f) raked joint; (g)&(h) dangers in poorly cut beds; (i) wood wedges used in setting.

stage being cut flush with the face of the stone. When this final mortar has become thumb-print hard, the joint should be ruled with a round jointer about ⅛″ greater in diameter than the joint. This action compresses the joint surface and forces the mortar tightly against the joint interface of the stone.

p. In stone cutting supervision, it is important to make sure that all of the stones are cut square with the faces and in true planes. Hollow joints cause cracks such as shown in Figure 8–20(g),(h), while bed joints which are cut tapered or "slack," as it is called, cause other cracks. The following table suggests reasonable limits within which finished joint thicknesses may be kept for the various textures of stone finish indicated.

JOINT THICKNESS

Material	*Rough Face*	*Tooled Face*	*Polished or Smooth Face*
Brick	3/8 to 3/4		1/8 to 1/4
Granite	1/4 to 1/2	3/16 to 3/8	1/8 to 1/4
Limestone	1/4 to 3/8	3/16 to 5/16	1/8 to 3/16
Sandstone	1/4 to 1/2	1/4 to 3/8	1/8 to 5/16
Marble	1/4 to 3/8	1/8 to 5/16	1/8 to 3/16

q. In monumental work in any of the above stones where there are large surfaces to be ornamented by carving, modern work follows the precedent established by the Greek architects of setting the various stones forming this surface without mortar, the stones being carefully surfaced to true planes so that they bear directly on each other, stone to stone. Sometimes a back-cut joint accomplishes the same end and aids in properly bedding the stone and protecting the joint against leakage.

r. Metal Anchors and Dowels. The anchorage of cut stone is accomplished in several ways. The use of bronze is advised although galvanized iron is often used for economy in buildings of minor architectural importance. The iron cramps and dowels are apt to deteriorate and weaken the structure, while the bronze is almost non-corrodible. The use of sheet lead plates for setting column drums is commonly accepted modern practice. It is far superior to mortar and wedges. The joint is readily kept uniform in thickness and contains no elements tending to stain the stone surface. Another distinct advantage lies in the setting of fluted columns. The lead plate keeps the sharp arrises apart and prevents the cracking and spalling of this delicate architectural detail.

8–8. Protecting and Preservation of Stonework

a. The dampproofing of the backs and ends of cut stone which is non-crystalline in structure, and therefore often impregnated with the impurities of the water operating in its formation, is a questionable protection against efflorescence and stains. Limestones and sandstones, both coming in this category, contain a quarry "sap" which usually is not completely expelled from the stone before it is set. This expulsion must, therefore be completed while the stone is in the wall and, if dampproofing compounds are used, must force its way to the exposed or finished surface as its only outlet. The limestone quarrymen advise that no dampproofing be used, and that the brick backing be laid in the same non-staining cement which is used for the stone facing. If this cement is capable of producing strong masonry work, this method is undoubtedly a good one for protection against stains. Granites and marbles are not as apt to stain and are not often subject to the presence of quarry sap.

b. The cleaning of stonework after setting and before pointing should be done with consideration of the quality and character of the stone used. Acids when applied to limestones and marbles tend to dissolve the stone to some extent and injure its texture. Wire brushes, if vigorously used, wear away the arrises and ornament and disfigure the surface when the stone is soft, as is the case with the limestones, marbles and sandstones. Polished stone of any kind should not be touched with acid solutions or wire brushes for evident reasons. Sylvester's and Ransome's processes are used in coating stonework for protection and preservation after it is in place. Paint, oil, and creosoted paraffine have also been used for this purpose, but the paint injures the character of the stone, the oil discolors it, and the third is too expensive for ordinary work. Sylvester's process consists in using the solutions of soap and alum consecutively. About ¾ pound of castile soap dissolved in a gallon of water is first applied hot

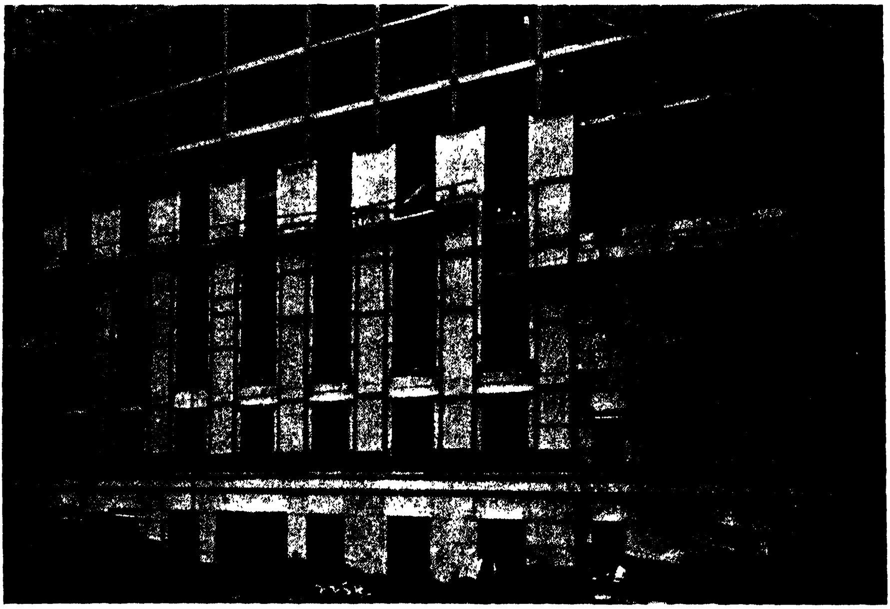


FIG. 8–21. Protection of Stonework in Place and in Transit. (*Courtesy George A. Fuller Co.*)

with a flat brush. After about one day the alum solution, about ½ pound of alum to 4 gallons of water, is applied at a temperature of about 70°F. This is allowed 24 hours to dry. These washes are then alternated until the wall is considered impervious by the formation of an insoluble compound. The latter, Ransome's process, considered by some the more derisable, consists of a coat of silicate of soda and a subsequent coat of calcium chloride, after the former has thoroughly dried. The two solutions interact chemically to form an insoluble calcium silicate which clogs the pores of the stone and prevents water action. Both of these processes must be repeated at intervals of 4 or 5 years to be effectual. If such stone as is known to be capable of resisting the climatic conditions of the locality in which it is erected be carefully chosen, in the first instance, artificial means of protection are both unnecessary and undesirable.

c. **Care of Stones.** An unusually complete specification for the protection of the stones during transit and after arriving on the site should always be prepared. The detail to which special attention is called is the boxing of set stones. Figure 8–21 shows representative practice in connection with several details. The wood which should be used for this work is white pine. In brief, the portions requiring protection are projections and arrises. Each building will present a different problem in this respect, due to the differences in architectural style and the degree of elaboration in detail. The iron strapping used in boxing the stones for shipment may be advantageously reused for securing the protecting lumber of the finished work. Thorough protection is admirable insurance against accidental damage, and all intelligent builders are quick to appreciate it as a measure of economy. It should, however, always be specified.

d. One must not overlook provisions for the protection of stonework during erection. All protecting ledges should be lined with pine or other non-staining boards to protect these surfaces from mortar drip, accidental dropping of materials or other possible damage.

ARCHITECTURAL TERRA COTTA

8–9. Setting and Anchoring Terra Cotta

a. Joints in Terra Cotta. Where the elements of subdivision and decoration are not of massive scale, terra cotta as a medium is appropriate and altogether excellent. The parts should nowhere be larger than can be executed without excessive distortion in the baking process and so that the material as a whole is expressive of the fundamental thesis which the architect seeks to develop, namely, for example, a frank and honest architectural expression of the fireproofing of the modern skyscraper skeleton.

b. In resemblance to all other products of baked clay, terra cotta shrinks in the process of drying and burning. This shrinkage has also a tendency to produce warping and variation in size with some attendant difficulty in the production of accurate moulding alignment. By careful modeling with shrinkage rules and by careful selection of clays and mixes, these difficulties are, to a sufficient degree, corrected for practical usefulness. Nevertheless, the terra cotta should be so jointed that some adjustment may be possible. This is occasionally accomplished by using back-joints as shown in Figure 8–22 for a pier. Where possible the joints should be concealed in reentrant angles, quirks, flutes or at points of natural joint transition.

c. Terra cotta blocks are made in moulds usually of a fixed size and in this element of repetition lies their economy. Although a partial stultification of design, windows of the same height and reveal, pilasters of equal width, stories of equal height and similar duplications make their respective contributions toward cost economy.

d. The mortar for terra cotta should always be of portland cement, lime hydrate and sand, usually in the proportion of 1-1½-6, and the joints should be raked out about ¾″ to receive the pointing mortar. After the

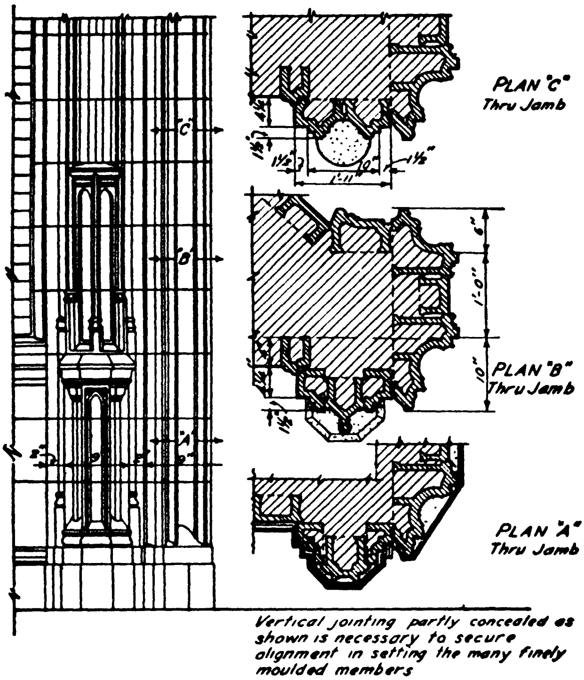


Fig. 8–22. Jointing Terra Cotta Piers. (*Courtesy National Terra Cotta Society.*)

walls are all up the joints should be pointed with the same mortar with a mineral pigment coloring satisfactory to the architect. All joints in horizontal surfaces exposed to the weather should be raked out about 2″ and the joint should then be caulked with oakum, filled with elastic cement in which a weather cap is embedded as shown in Figure 8–23.

e. When terra cotta is shipped by rail it should be packed in straw and the whole shipment stabilized in the car so it will not shift during transit. At the site the blocks should be carefully laid out on planking in the proper order of use. The erection drawings, furnished by the manufacturer, will indicate the method of assembly and each piece is numbered to correspond to these erection drawings.

f. Anchorage. The anchorage of terra cotta is accomplished by the backing and by the use of J-bolts, clamps, rods, plates, dowels and, in some cases, additional rolled shapes such as tees and angles. In such overhanging elements as cornices, balconies and balustrades, the arrangement of supports and anchorage is proportionately more complex and, under their respective headings, is more fully discussed. The anchorage of a simple wall facing of terra cotta is nearly always done by using flat anchors let into the tops of courses or into holes cut into the withes of the blocks. Every second or third course should be so anchored. The

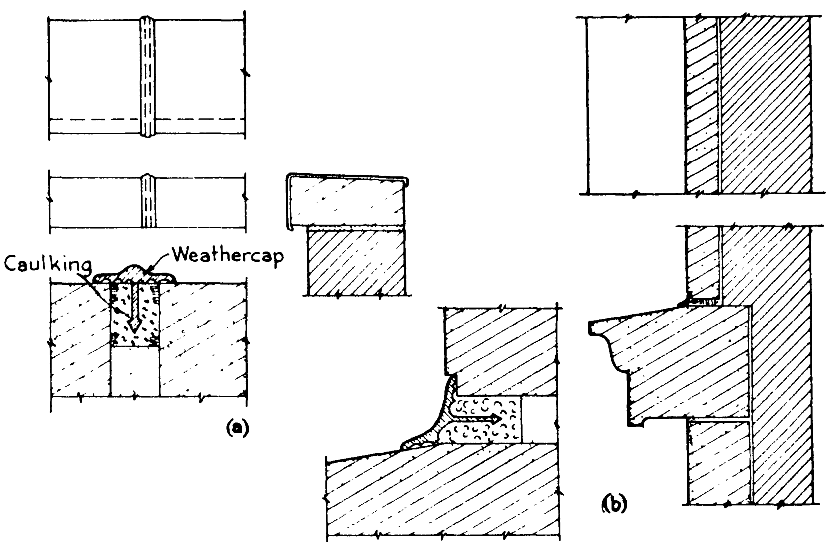


FIG. 8–23. Minwax Weather Caps. (a) joints in horizontal surfaces; (b) joints in vertical surfaces at belt courses.

detail is such as shown in Figure 8–24. Window and door heads are usually tied into the spandrel frames as shown. In these cases rods which pass through the withes of the soffit block are hung from J-bolts which, in turn, are fastened to the angles or channels riveted to the spandrel girder. Any pieces which are hung from rods are tied with other hooked rods into the backing, or to the flanges of the steelwork, so that two intersecting strains are brought to bear on the piece as shown. Figure 8–25 illustrates the anchors used for terra cotta.

g. Wherever possible, the backing should be built into the voids of the face terra cotta. The anchors themselves may be of wrought iron or soft steel, galvanized, sherardized or cadmium plated. Ordinary painting will not suffice.

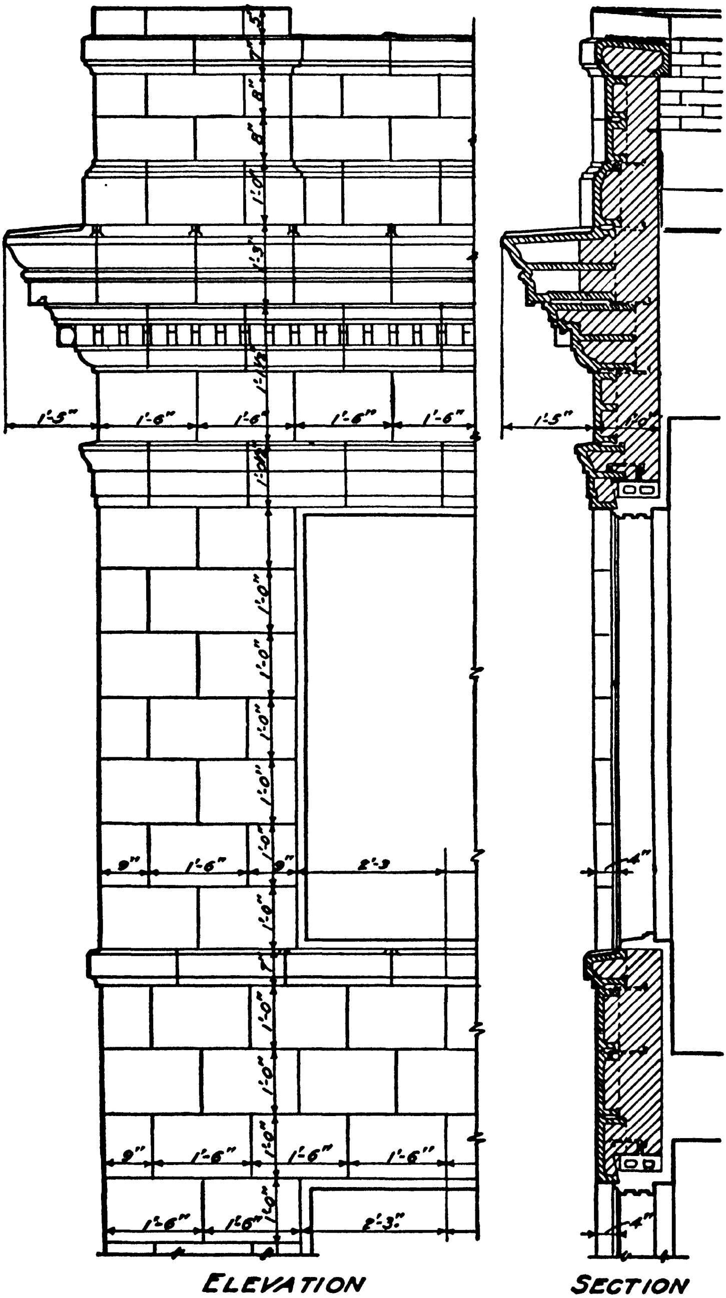


Fig. 8–24. Anchoring Terra Cotta into Backup. (*Courtesy National Terra Cotta Society.*)

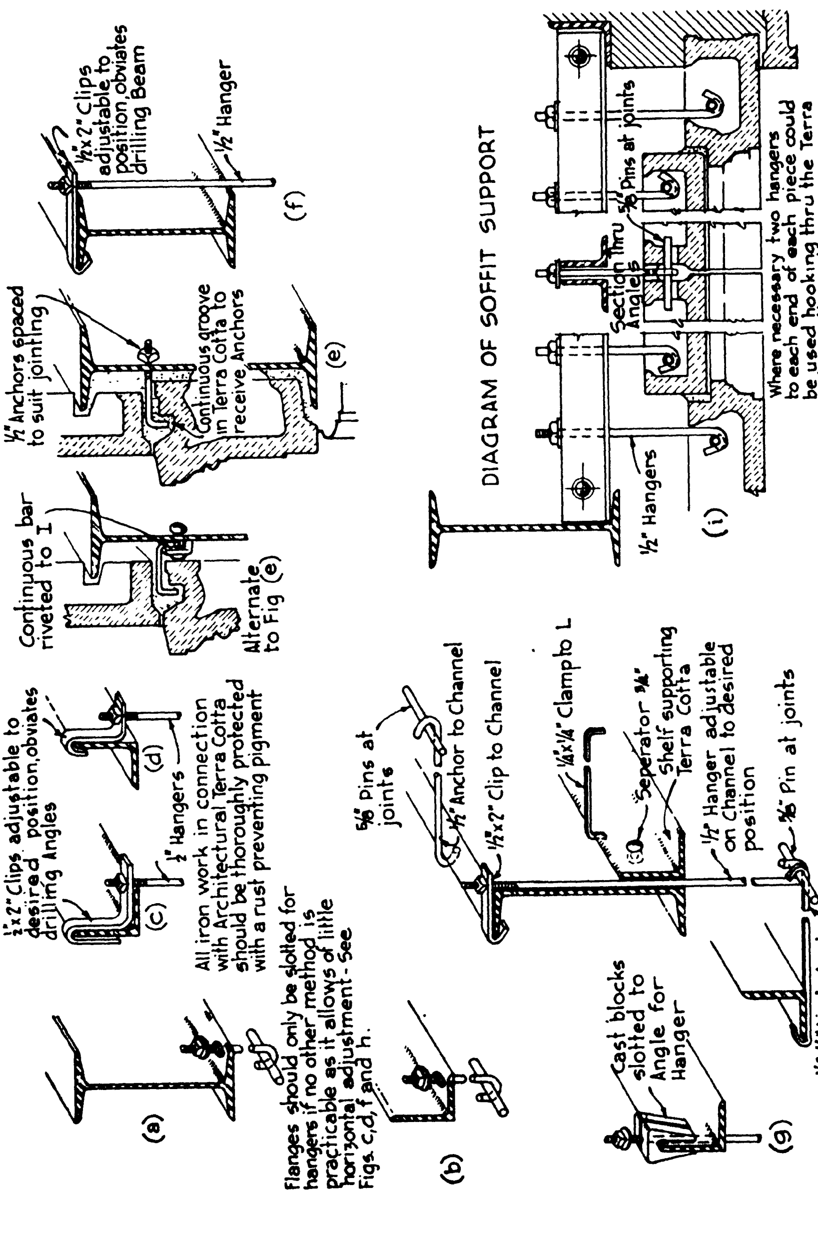
8–10. Backing of Terra Cotta

a. The course blocks of terra cotta are made so that open pockets for the insertion of brickwork are provided. The brickwork should be clipped so that these voids are completely filled. The weight of the brickwork, together with the natural bond between the mortar and terra cotta, assists in holding the facing firmly in place. Where courses project any great distance, as in cornices and balconies, the brickwork should be kept back sufficiently to allow it to corbel itself, rather than to cause additional overturning tendency in the cornice blocks, as shown in Figure 8–24. The blocks should be built up in advance of the backing and the voids should be well slushed with mortar, after which the brick should be carefully but firmly tamped into the back so as to fill all voids completely.

8–11. Terra Cotta Details

a. Terra cotta cornices, balconies, balustrades, sills, columns, arches and pilasters all present problems in special structural detailing requiring particular investigation. The use of terra cotta for heavily overhanging cornices is economical because of the great saving in weight over corresponding cornices of solid stone. A consequent economy lies in the proportionately decreased weight of both supporting walls and steel frame. The pieces adjacent to the wall are built into it from 4″ to 12″, and the pieces farther out are supported upon angles anchored back into the frame. The structural steel is usually fitted with double channel or angle "lookouts" as shown in Figure 8–26, and a continuous channel and angle or double angle is riveted to these to support the cornice between columns. From this beam are hung the J-bolts, pipes, rods and similar devices to carry the soffit blocks. Wherever possible a direct tie should be established with the spandrel steel as shown. When concrete frames are used the terra cotta is anchored as shown in Figure 8–27 for special spandrels.

b. The combination of a cornice and balustrade is shown in Figure 8–26. Here the cornice is supported by a bearing wall. The balustrade is held down by bar and channel rails and the top rail of terra cotta is set upon this as a protection. The channel should always be placed with flanges down in order to shed water. The lookout in this case is anchored to enough masonry wall to counteract the overturning tendency of the cornice. Copings are made in one or several pieces. The raised flush joint is advised as the roll joints are likely to crack. Terra cotta sills are customarily provided either with roll joints or raised joints. Either of these joints may be had with a flush front or a cutback as shown. The usual diameter of the roll is 1½″. Sills may be made so that they lug into the wood sill or they may be made with a reglet into which the water bars are set. Belt courses are similar in their details to sills.


(a)
Flanges should only be slotted for hangers if no other method is practicable as it allows of little horizontal adjustment - See Figs. c,d,f and h.
(b)
1"x2" Clips adjustable to desired position, obviates drilling Angles
(c)
(d)
1/2" Hangers
All iron work in connection with Architectural Terra Cotta should be thoroughly protected with a rust preventing pigment
Continuous bar riveted to I
Alternate to Fig (e)
1/2" Anchors spaced to suit jointing
Continuous groove in Terra Cotta to receive Anchors
(e)
1/2"x2" Clips adjustable to position, obviates drilling Beam
1/2" Hanger
(f)
5/8" Pins at joints
1/2" Anchor to Channel
1/2"x2" Clip to Channel
1/4"x1/4" Clamp to L
Seperator 3/4"
Shelf supporting Terra Cotta
1/2" Hanger adjustable on Channel to desired position
5/8" Pin at joints
(h)
1/4"x1/4" tie to Angle
Cast blocks slotted to Angle for Hanger
(g)
DIAGRAM OF SOFFIT SUPPORT
1/2" Hangers
Section thru Angles
5/8" Pins at joints
(i)
Where necessary two hangers to each end of each piece could be used hooking thru the Terra Cotta omitting pins.

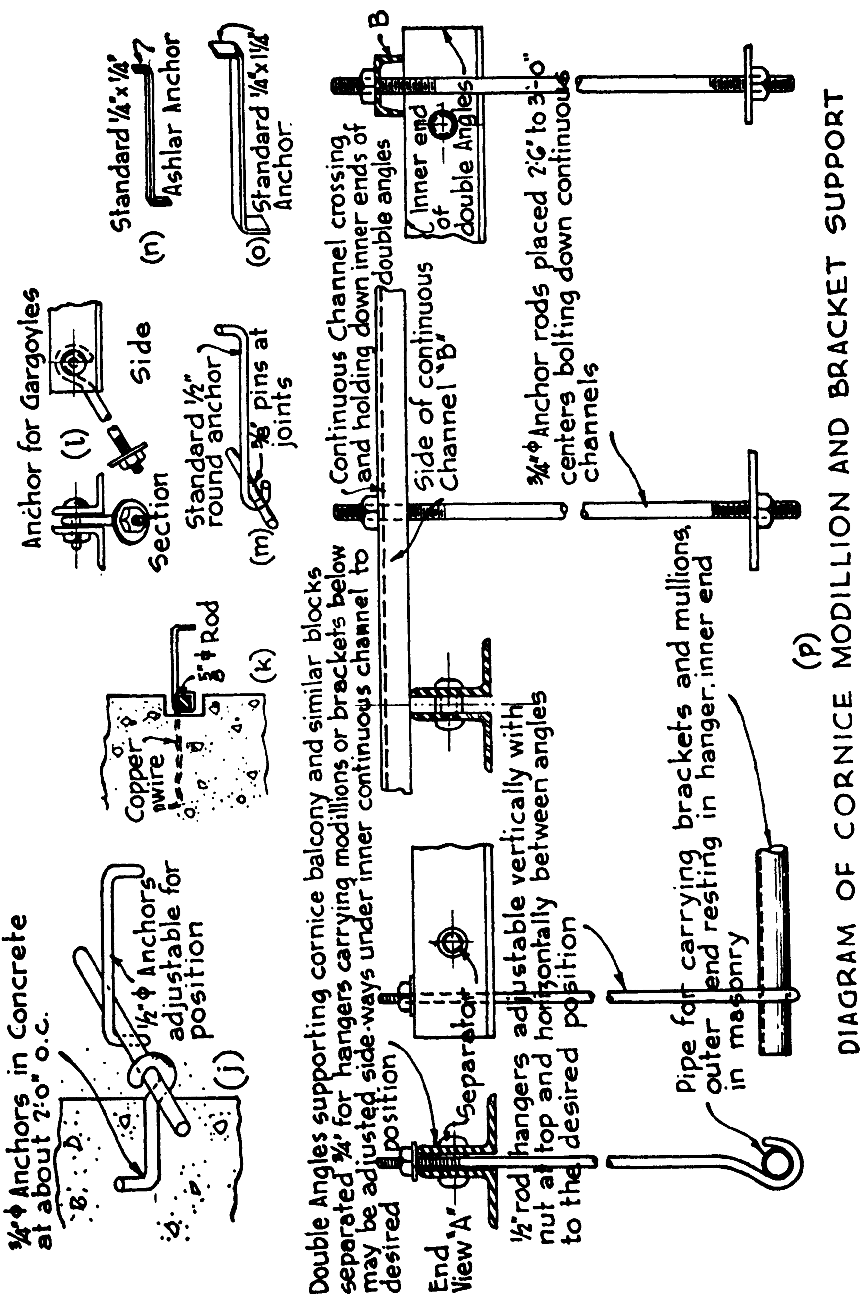


FIG. 8-25. Anchors for Terra Cotta. *(Courtesy National Terra Cotta Society.)*

c. Columns and pilasters present some of the most perplexing jointing problems in terra cotta work. When the column is free standing and under 20″ in diameter it may be built up in drums. When diameters over 20″ are necessary, each drum must be built up of separate blocks, varying in number with the periphery of the columns, so that each of the component pieces shall not exceed a size capable of true baking. The vertical

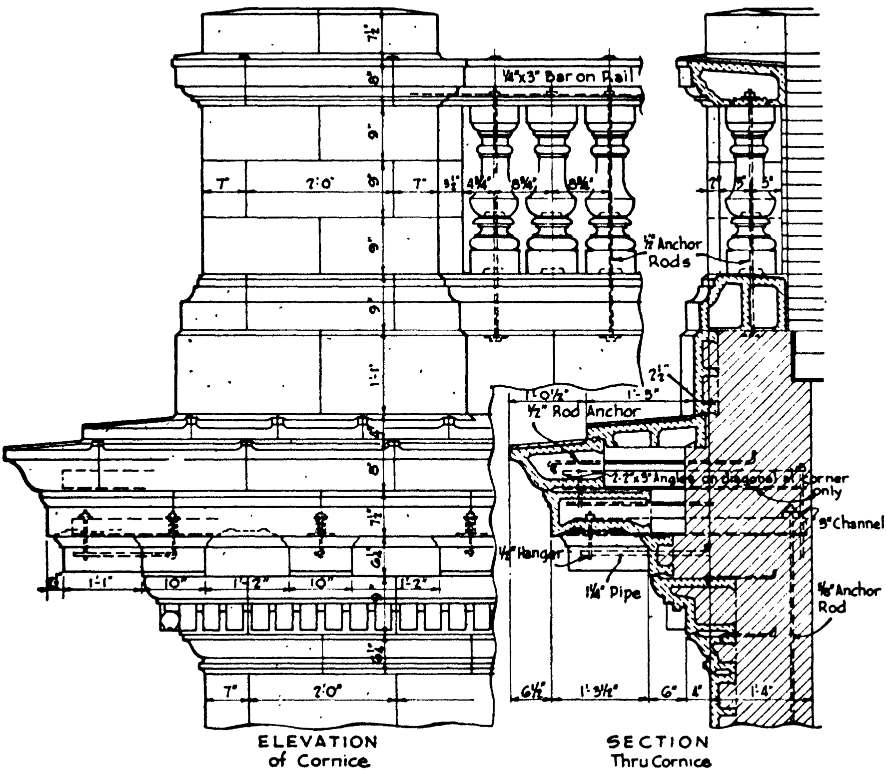


Fig. 8–26. Anchorage of Terra Cotta Cornice and Balustrade. (*Courtesy National Terra Cotta Society.*)

joints may be concealed in beads or flutes, but should never be made on the fillet of a flute, unless the fillet is ornamented for the purpose of concealing the joint. (Figure 8–28.) At best it is a difficult problem to solve, creditably, the execution of large columns in terra cotta. Acute angles formed by continuous terra cotta shells should be avoided. It is always wiser to keep the circular portion of the column in one piece and to make the wall portion in separate blocks. The tying is accomplished by hooked rods.

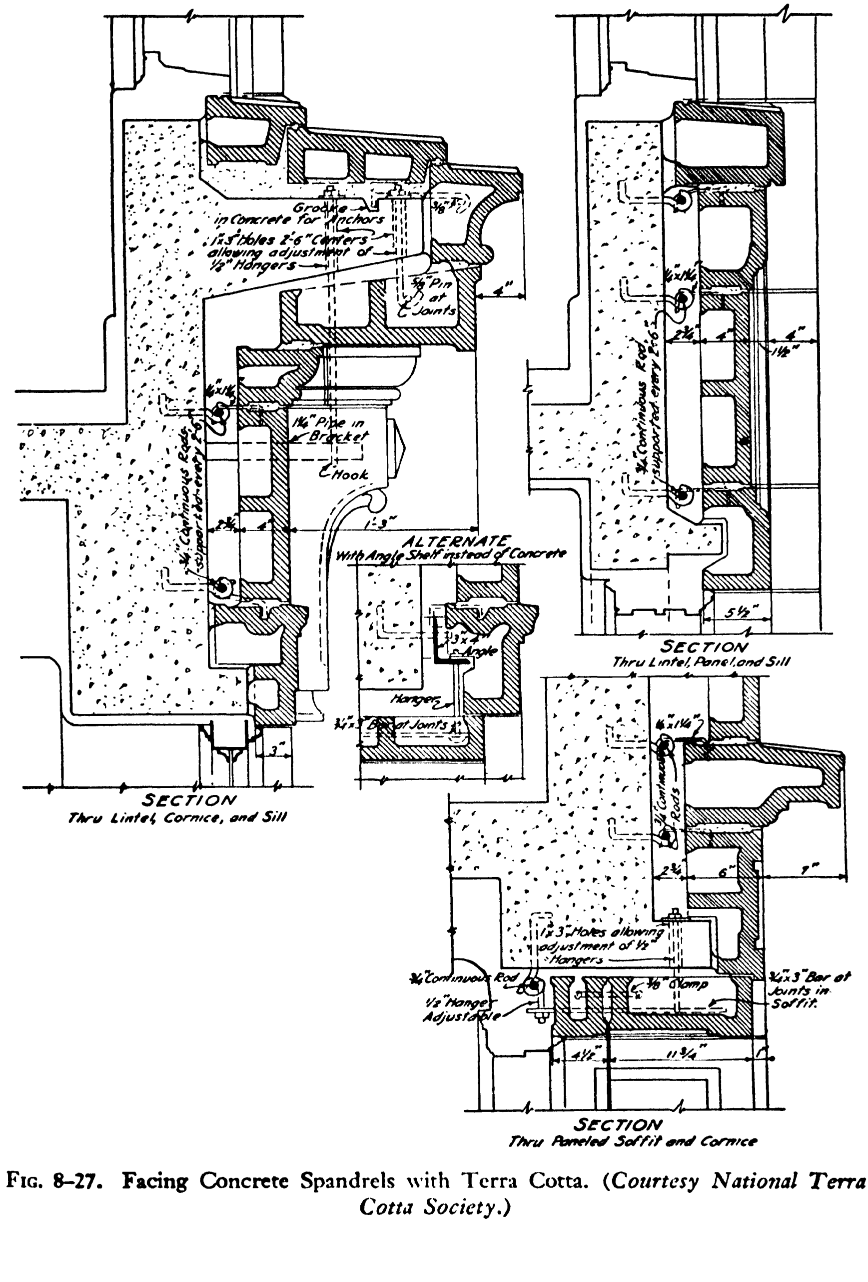


FIG. 8-27. **Facing Concrete Spandrels with Terra Cotta.** (*Courtesy National Terra Cotta Society.*)

d. Arches turned to a curve should be built up so that they allow cutting and fitting. Each of the main arch rings should be separate from its neighbors. Where flat arches are indicated the voussoirs should always be straight-jointed as shown. Joggled joints should be avoided as they almost invariably result in cracked arch blocks, due to the difficulty of producing continuous bed-to-bed contact among the voussoirs; a condition precedent to the proper transmission of thrust through the arch to its supporting abutment.

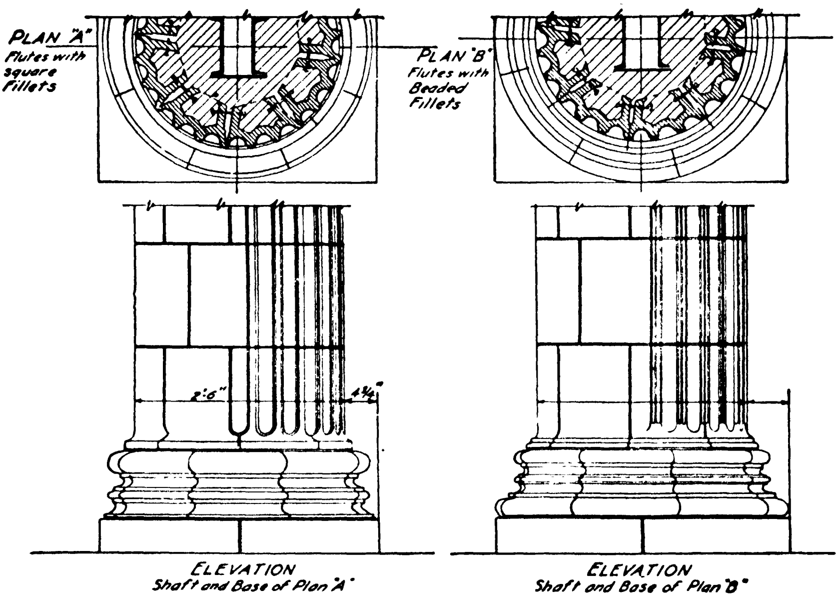


FIG. 8–28. Jointing Terra Cotta Columns. (*Courtesy National Terra Cotta Society.*)

e. Where metal flashings are provided for terra cotta, the edges of these flashings should be let into reglets formed in the terra cotta blocks where required. These reglets should be caulked with oakum and lead wool to keep the flashing from pulling out, due to wall movement.

INSULATED METAL PANELS

8–12. Paneled Walls

a. The tremendous dead weight imposed upon structural frames by heavy masonry walls has led to the serious consideration of the use of lighter panels. These panels may serve the threefold purpose of excluding the weather, providing architectural features and stiffening the frame by the plate action of the panels when properly fastened to the frame.

b. The panels may be prefabricated from insulated laminates which can be welded or otherwise fastened to the structural frame. (Figure 8–29.) If the panels form the exterior and exterior facings of the frame,

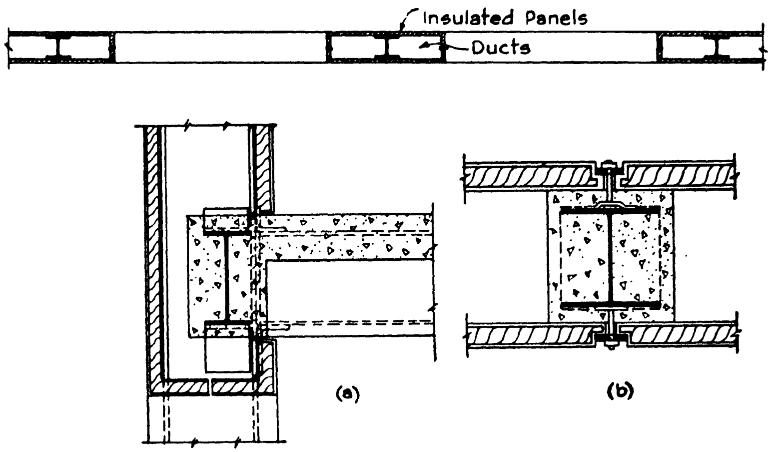


Fig. 8–29. Insulating Metal Wall Panels. (a) spandrel section; (b) column section.

it is possible to use the wall void for ducts or direct radiant heat. The exterior panels may have the final finish desired or may be used as a backing for other materials. Similarly, the interior panels may be used for final finish or a base for other finishes.

CHAPTER 9

FIREPROOFING AND PARTITIONS

9-1. Column Fireproofing

a. The modern steel-framed building is most usually fireproofed with concrete. The exterior columns which are an integral part of the exterior curtain walls may be fireproofed with concrete and then encased in unit masonry by using the backup material as protection. (Figure 9-1.) The free standing columns or those which form a part of the partition arrangement may also be encased in concrete first, similar to the exterior columns, or they may be protected by the terra cotta blocks used for the partitions. (Figure 9-2.) At times the free standing columns and the

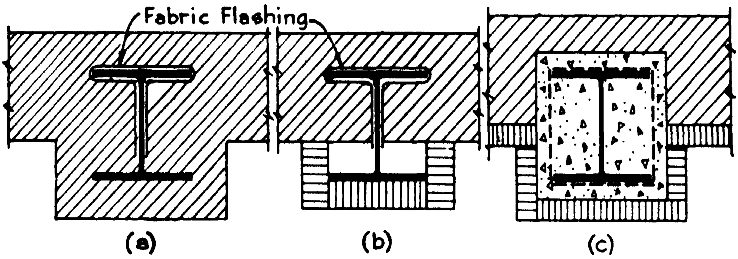


FIG. 9-1. Encasing Exterior Wall Columns. (a) brick; (b) brick and tile furring; (c) concrete, brick and tile.

projecting flanges of the exterior wall columns are protected by wrapping them in wire or expanded metal mesh which is given two coats of cement plaster, as shown. This method reduces the weight and affords a void for the installation of the mechanical and electrical services.

b. The combination of terra cotta and concrete for the fireproofing of steel columns is considered good construction. The use of rim terra cotta blocks only leaves a void between the flanges of the column and forces an inferior method of protection of the steel. The same is true of the wrapped and plastered casing. The dead weight of the combined block and cement plaster is less than the solid concrete encased structural member and serves as well under ordinary conditions. Attention should, however, be called to the varying coefficients of expansion of tile and concrete, and it is probably wiser to use either all terra cotta or all concrete. Where the casing of the columns is to be exposed as the

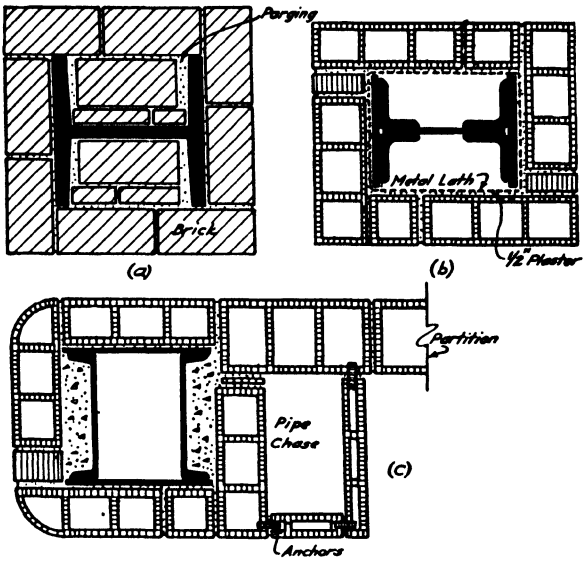


FIG. 9-2. Encasing Free Standing Columns. (a) brick; (b)&(c) terra cotta with metal lath and plaster or concrete.

finished surface, the terra cotta is less good looking than a well finished concrete surface. In detailing and specifying this kind of work it is well to consider:

(1) fire resistance,
(2) weight,
(3) finish, and
(4) cost.

9-2. Beam Fireproofing

a. The haunches of structural steel beams and girders may be protected by cast concrete, but it is possible to fireproof them with clay tile or gypsum tile. When terra cotta tile is used it may be combined with tile arches, as shown in Figure 6-1, or it may be used as complete encasement as shown in Figure 9-3. Often, however, concrete and tile are combined. When this is done the lower flange must be formed for the protective slab of concrete. Upon this clay tile, gypsum blocks or concrete tile are laid. These, in turn, are used to support the concrete slab. Where concrete slabs are used it is common practice to encase the beams in concrete at the same time the slab is cast.

9–3. Fire Resistant Plasters

a. Fire resistant plasters have been used for some time. Asbestos plasters have been used frequently but it has always been found that such plasters should be reinforced with mesh to prevent collapse due to loss of bond.

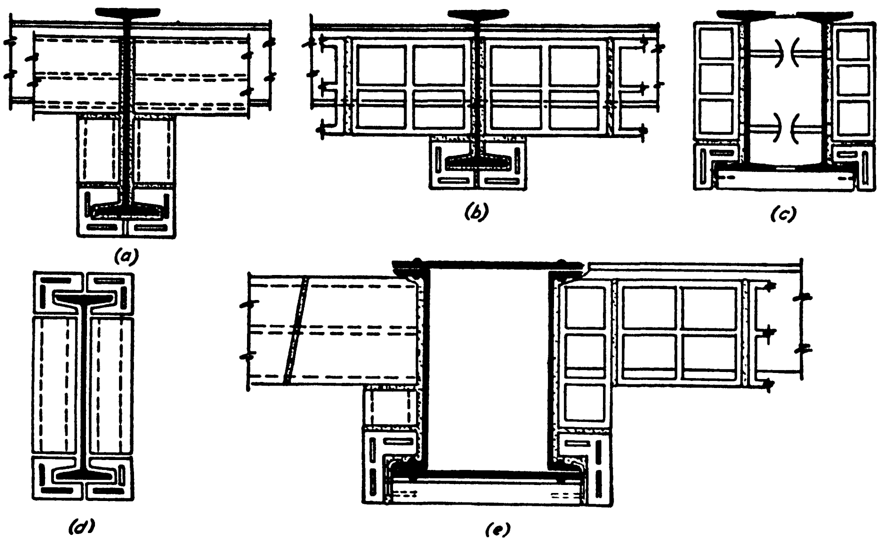


FIG. 9–3. Fireproofing Structural Steel Beams. (a),(b)&(d) single beams; (c)&(e) box girders.

Recently a vermiculite plaster which uses expanded zeolite as an aggregate with a cement matrix has given excellent results. Fire tests have shown that this material has more effective fireproofing qualities than ordinary concrete or mortar, because this material has heat insulating characteristics coupled with its resistance to fire.

9–4. Partitions

a. Partitions may be built of:

(1) terra cotta block,
(2) cinder concrete tile,
(3) gypsum block,
(4) metal lath and plaster, or
(5) light metal frames.

Of these, the clay and gypsum tile are most commonly used. The cinder concrete tile is installed in a manner similar to terra cotta. The gypsum block is hollow and usually is made with a face area of 12 x 30 as against the usual 12 x 12 face of the terra cotta block. The gypsum block is lighter in weight, is laid up much more speedily, is easily cut and fitted, and affords a better mortar bed. It is, however, not quite as resistant to fire as the terra cotta tile, if plastered. Neither do partitions built of gypsum tile possess as great lateral stability.

b. The advantages of thoroughly baked hollow tile over solid brick are:

(1) less cost per cubic foot of masonry,
(2) less weight per cubic foot of masonry,
(3) less labor to lay up the wall, and
(4) more economical delivery costs.

c. From a structural point of view the most effective method of laying terra cotta blocks is with the openings and webs vertical. This is not always done, but the strength of tile when set horizontally is much less than when set vertically. The manner of setting is somewhat different from brickwork, however. The horizontal joint mortar is placed upon the tile already in position and the vertical joint mortar is then faced upon the next tile as it lies in a horizontal position. When the openings and webs are set vertically the surface upon which the mortar can be lodged is very small and sometimes a layer of metal lath is placed upon it before the tile is set. This is a little more expensive, but gives the wall great lateral strength. It supplies a better mortar bed for the tile.

d. In order to make sure that the masonry partitions are properly secured it is customary to wedge in the last courses with brick courses if the tile coursing does not permit the use of a whole tile, or if the space remaining is smaller than a final brick course, with slate. These methods are shown in Figure 5–20. A certain amount of cutting and fitting is always necessary at the beams and girders.

e. Exterior walls are often furred with tile in order to carry the same rough construction around each room. (Figures 9–4 and 9–5.) Where terra cotta furring is used the tile are usually of split tile. Other forms of furring are used and these will be discussed later. The furring around an exterior window is illustrated in Figure 9–6.

f. Where tile partitions intersect, the courses must be properly bonded. The jointing and bonding of intersecting partitions should be arranged as shown in Figure 9–7. This method insures the interaction of the two partitions in case of strain on one and also promotes the lateral stability of both.

9–5. Door Bucks

a. The use of bucks, in some form, in terra cotta or other types of partitions is necessary where openings occur. These may be either of

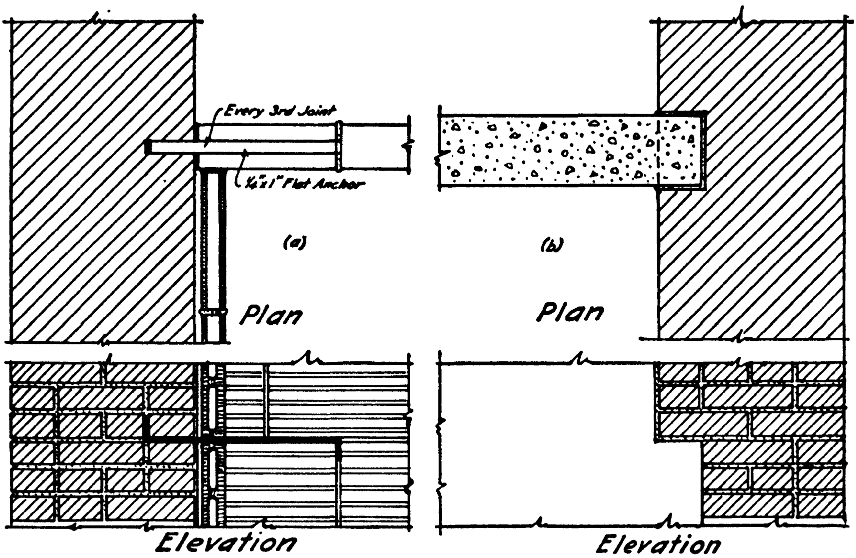


FIG. 9-4. Furring Exterior Walls. (a) terra cotta partition and furring; (b) concrete partition.

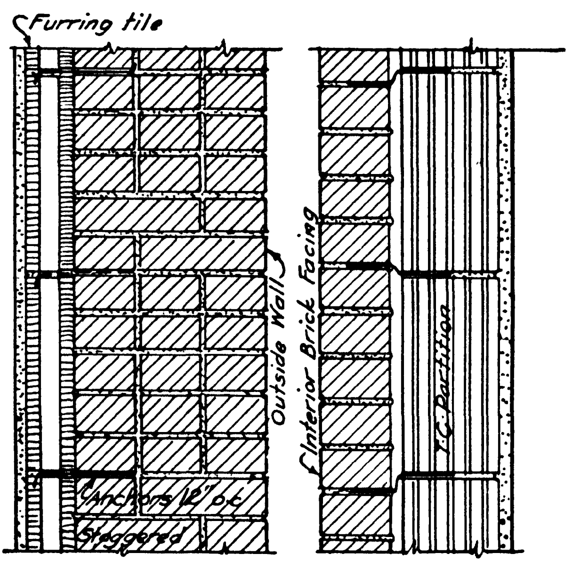


FIG. 9-5. Wall Facing. (a) exterior wall furred with terra cotta; (b) interior wall faced with brick.

wood or of steel, and the steel members may be structural angles, channels or pressed steel shapes. When wood bucks are used they may be nailed into wood brick set into the tile or brickwork or may be anchored by means of strap anchors, depending upon whether the bucks are set after or before the masonry work is erected. The building in of bucks is preferred as it gives the mason a means of preserving true alignment

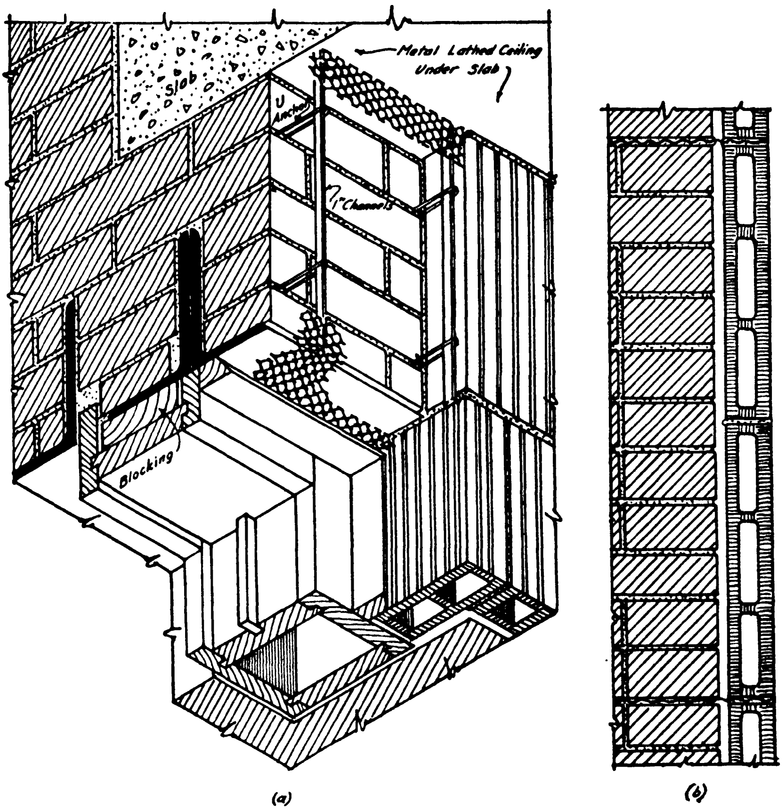
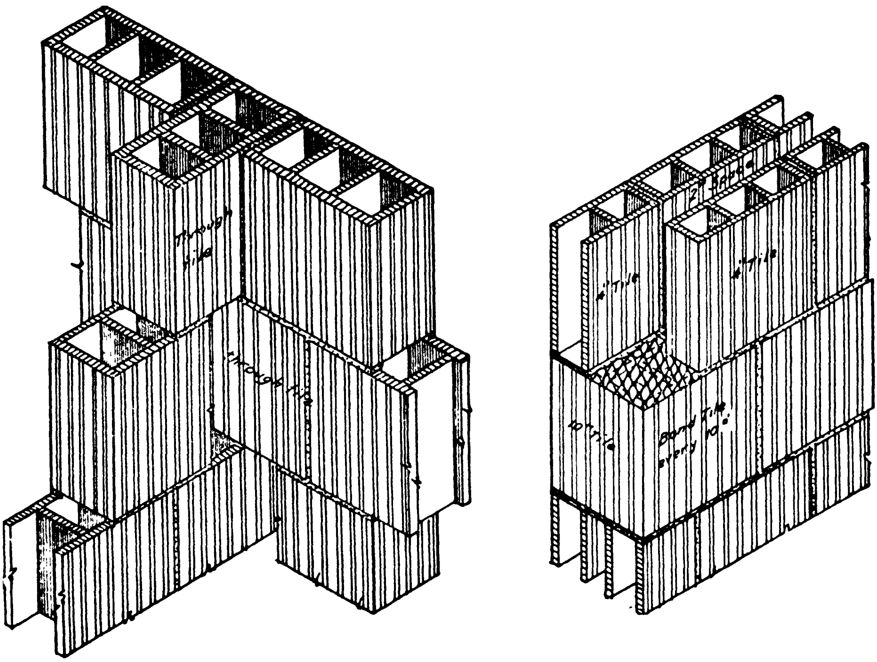


Fig. 9–6. Furring around windows.

and a much more stable anchorage. Steel bucks may be structural only and necessitate the attachment of final finish later or the pressed steel bucks may be the final finish. Figure 9–8 shows the variations often used for steel buck construction. Where the head of the buck is used as a lintel it should be reinforced with a structural angle or tee welded on to the buck head. Where the story height is high through bucks are often used. These provide greater resistance to impact caused by the slamming of doors. The jambs are extended either by means of flat bars built into the tile work or the stiles of the buck are run up to the slab above. Where the flat bars are used the door buck is usually a finish buck. When the structural channel buck is carried up the entire structural elements are usually covered by moulded sheet metal trim as shown in Figure 9–8. Where this method is not used, the buck is known as a circumferential buck.



(a) (b)

FIG. 9–7. Terra Cotta Partitions. (a) intersecting partitions; (b) hollow partitions.

9–6. Metal Studs, Lath and Plaster Partitions and Furring

a. Many times partitions are made of solid plaster or are formed as double plaster walls with a hollow space between them. These partitions are framed on steel channels or other shapes, covered with metal lath and then plastered. Figure 9–9 shows a variety of framing details of such partitions together with the bucks used for doors. Such partitions should not exceed a height of 12 feet in order to provide sufficient rigidity. When solid plaster partitions are used the wall thickness is much smaller than in the conventional case and special details for trim and openings in the partitions are required.

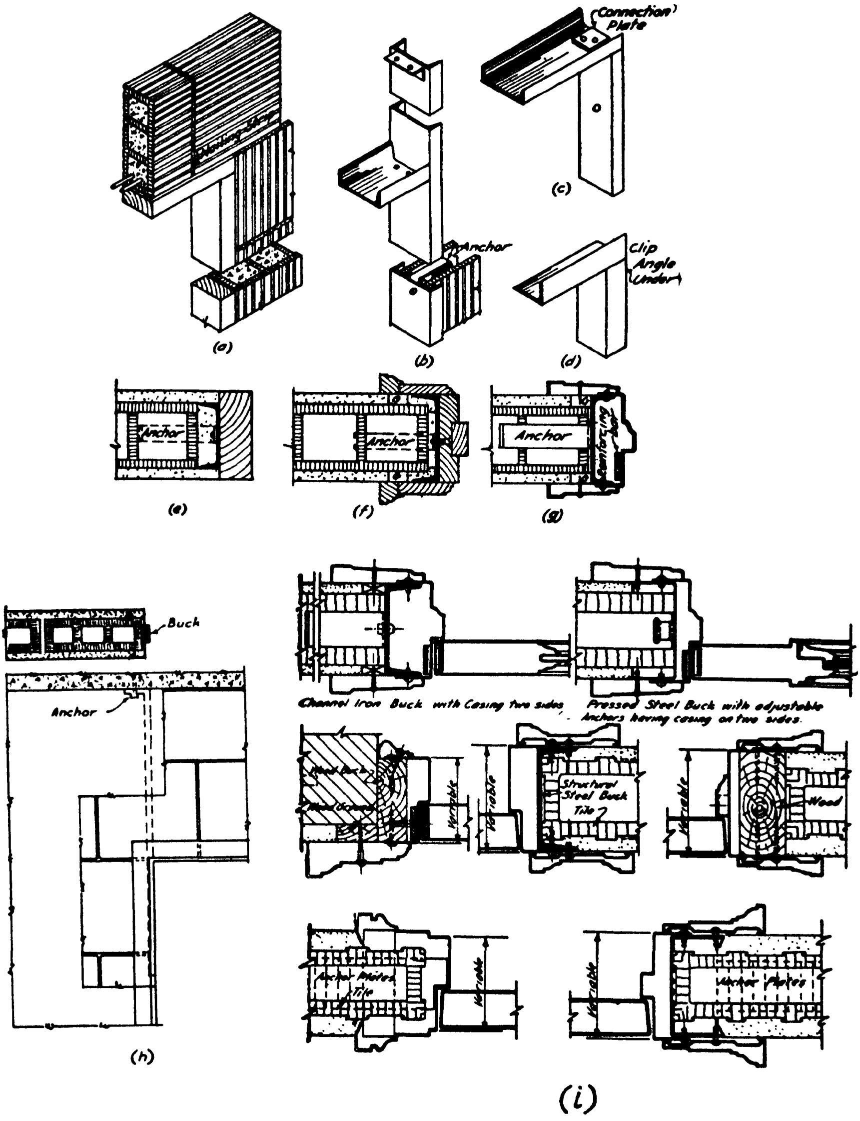


FIG. 9-8. Door Bucks. (a) circumferential wood; (b) through channel; (c)&(d) circumferential channel and angle, (e),(f)&(g) channel buck details; (h) circumferential channel with bar extension; (i) pressed steel bucks and trim.

b. The studding for partitions usually consists of channels, angles, tees or flats of such size and strength as will produce and maintain a stiff and rigid partition with a minimum size of ¾″. In solid partitions the furring usually consists of a single line of vertical studs set plumb to proper lines. In hollow partitions a single or double row of studs is used. When the double row is used clip spaces are provided to maintain the proper thickness of the finished partition. The studs are fastened to the floor and ceiling by bent knees, slotted clips or runner plates. When runner plates are used they should be not less than 1 x ⅛ flat steel or 1 x 1 x ⅛ angles. These plates are rigidly connected to the floor beams or celing slab.

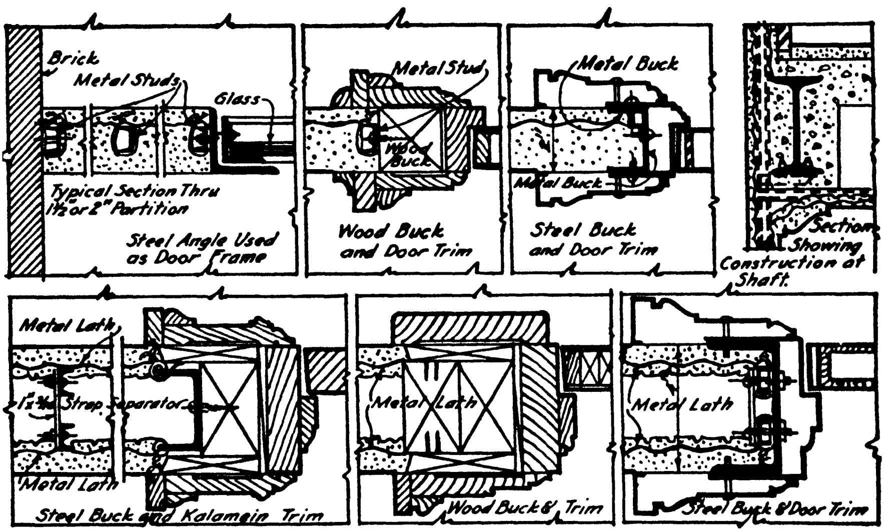


FIG. 9–9. Metal Lath and Plaster Partitions.

c. Light metal channels and metal lath are also used for furring exterior walls and around structural columns.

d. In many buildings there are many conduits and electrical outlets as well as some other service pipes. In these cases it is often possible to install all of the piping and runout stubs and then erect a double metal lath and plaster partition so as to accommodate the pipes and prevent a lot of cutting of terra cotta tile, when this material is used. This detail is shown in Figure 9–10.

9–7. Light Metal Frames for Partitions

a. Aside from finished ornamental metal partitions, treated in Chapter 10, light frames are also used for prefabricated partitions. These partitions

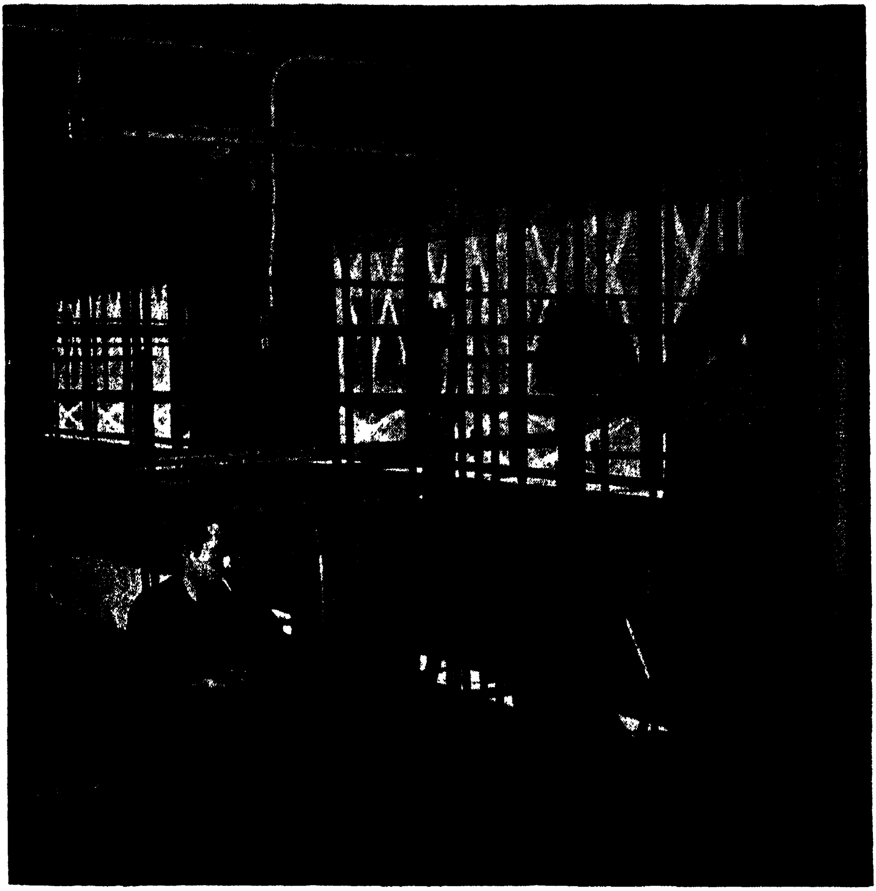


FIG. 9–10. Double Plaster Partitions for Complicated Wall Services. (*Courtesy George A. Fuller Co.*)

eliminate the necessity of plastering in the field and substitute prefabricated boards or sheets, which are clipped to the frames by some patented device. Some of these metal framed partition units are present in lightweight concrete and given a finish coat of plaster on the job.

CHAPTER 10

INTERIOR FINISH

FLOORS

10-1. Terrazzo

a. Terrazzo is the name applied to specially mixed and treated cement concrete floor finish. This finish is usually applied to rough concrete floor slabs, but has been used as the final wearing finish over wood-framed floors. The finish is used to give a more attractive and ornamental floor surface than that provided by the ordinary granolithic finish.

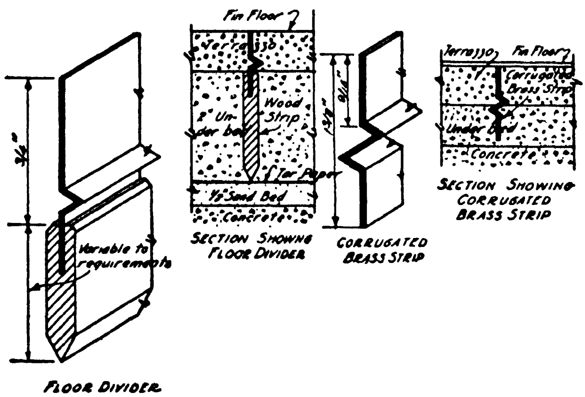


FIG. 10-1. Terrazzo Floor Divider.

b. The thickness allowed for terrazzo floors is usually about 2½″. Sometimes part of this thickness is used to provide a sand cushion from ½″ to 1″ thick. This is used to break the bond between the structural slab and the terrazzo slab. One of the criticisms of this type of finish is the formation of cracks due to shrinkage of the wet-mixed terrazzo and to the deflection of the structural slab. By releasing the finish from the structural slab some of this effect is removed, but the possibility of warping due to differential water content or heat effects is introduced. Reinforcement in the form of wire or sheet mesh is often introduced to prevent excess cracking. In many contemporary installations of terrazzo, direct bonding to the structural slab is used and brass strips are inserted to provide separation planes at frequent intervals. These strips are also used to provide ornamental patterns. Sections of the usual terrazzo installations are shown in Figure 10–1.

c. The usual method of building terrazzo floors is as follows:

(1) grouting structural slab,
(2) laying a 2″ slab of concrete,
(3) laying comparatively dry layer of a mixture of cement and sand and floating it into the wet slab previously cast,
(4) a mixture of vari-colored marble chips are patted into the wet surface,
(5) the surface is then rolled with a heavy concrete roller, excess water being worked out and run over the unfinished edges, and
(6) after the surface has set for about 3 days, the entire surface is ground with circular, power-driven machines and the excess grindings are washed off with "squeegees."

d. A careful review of the above steps will show why terrazzo floors are often troubled with unsightly cracks. In the first place it must be remembered that the finish floor is placed after the structural slab has had quite a long time to set and stabilize dimensionally. The coating of fresh concrete upon previously set concrete is more often fraught with failure than success. The use of rich cement grout aggravates the tendency to failure. It would be far more effective to scrub the structural slab with a wet mixture of cement and sand of the same proportions as the slab to be cast later. It will also be noted that the marble chips are laid on to the web slab and the surface is usually very wet with considerable excess water. The loss of water from this process after the completion of the finish is responsible for excessive shrinkage tendencies. This is resisted to a large extent by the mesh, but the total width of fine cracks is usually commensurate to the shrinkage coefficient for ordinary concrete, or about .0004″ per inch.

e. The objectionable cracking due to structural slab movements can be minimized by a careful placing of the brass strips. These should be located at all points of high tension in the top of the structural slab, or, in other words, at points of negative movement. Additional strips can, of course, be used but those mentioned above are important.

10–2. Tile and Flagstones

a. Tile. The tile used for floor surfaces are usually so-called "quarry tile" or ceramic tile. Quarry tile floors are usually bedded in mortar and shoved in place to establish intimate bond and push some of the mortar into the vertical joint. To establish a better bond with the structural slab, scrubbing in some of the mortar is recommended in the manner suggested for terrazzo. The mortar should contain a generous amount of lime hydrate and good results can be obtained with a mixture of 1 part of portland cement, ½ part of lime hydrate and not more than 3 parts of sand, by volume.

b. After the tile are properly bedded, aligned and leveled and the mortar has had a reasonable time to set—about a week or 10 days—the joints are filled and jointed. The jointing mortar is very often colored to produce an architectural effect. The mortar must also be proportioned so that raveling of the fine aggregate is retarded. This means a rich mixture of cement and sand, usually not in excess of 2 parts of sand to 1 part of cement. The coloring matter added should be a metallic oxide base and not in an amount greater than 5 pounds per sack of cement. Greater amounts are likely to impair the bond between the cement and sand.

c. In placing the pointing mortar it should preferably be placed in at least two stages. The joints should be pointed one half full in the first stage and the remainder placed, slightly in excess, immediately thereafter. The joints should be allowed to set until "thumb-print" hard and should then be firmly ironed with a flat or slightly oval jointer until smooth and hard.

*d. **Flagstones.*** Flagstones or flagging is the name applied to slabs of natural or synthetic stone which are laid to produce a finished architectural floor surface. Among the natural stones used most frequently are marble, slate and the finer grained sandstones. Granite slabs are also used and provide an excellent wearing surface. The synthetic stones are usually of cast stone concrete, many of which are made under pressure.

e. Stone floors are laid in a manner similar to that described for tile, except that in this case one is dealing with heavier units which require shimming or wedging. After the pattern has been carefully laid out, the individual stones are bedded in a rather stiff mortar and are wedged to bring them to level. The stones of key lines are laid first so as to form a sort of screed for the stones which later fill in the area. In leveling each stone a wooden mallet is used to pound the stone into line and level. As the stones are brittle, steel tools are usually not employed except perhaps the "pinch-bar" which is used to move the stone, but does not come into contact with the top surfaces or arrises of the stones. After the stones are all set and the bedding mortar has set, the vertical joints are treated in a manner similar to that used in setting tile. Care must be exercised in the choice of mortar so that staining will be prevented. Thus, portland cement should not be used with marble.

10–3. Floor Coverings

a. Floor coverings as distinguished from the more rigid surface discussed above include those materials, mostly synthetic in nature, which provide a surface with particular texture, cushioning, color and architectural shape effects. Among them we find linoleum, rubber, asphalt and wood.

b. Linoleum. This floor covering has a linseed oil base and contains powdered cork, wood flour, color pigments and special gums. It is usually backed with burlap into which the plastic mass is pressed. The sheets are cured and the linseed oil oxidizes and forms a stable, smooth and relatively hard surface. Variations of this product are called cork carpet and cork tile which have a variety of ingredients and manufacturing processes. The types, styles and patterns as well as the processes of manufacture can be found in the many catalogs and the literature of commercial companies.

c. In laying linoleum or any of its variations the most important first step is to make sure that one has a smooth floor free of pits, cracks and projections. Such imperfections will eventually show as defects on the surface of the floor covering. A lining felt is usually cemented down first and the linoleum is then cemented upon this base. When laid upon concrete floors one must be sure that the concrete is dry. In order to determine the suitability of a concrete floor for application of linoleum cement a simple test for the presence of moisture can be conducted. A small amount of anhydrous copper sulphate, which is a white powder in the anhydrous state, is sealed under a small watch glass which is cemented to the floor to prevent the entrance of air. If the floor surface is still too wet or damp for the safe laying of linoleum, or in fact for any of the organic sheets or tiles, the powder will turn blue. If the test shows, for an overnight period, that the powder remains white the floor will be proper for laying.

d. It is always a wise practice to lay the roughly cut sheets of linoleum for a short period in order to allow the linoleum to expand slightly so that future expansion due to ironing of the floor surface will be reduced as much as possible. After this has been done the process of cutting, matching and laying can be started. The cement is spread by a comb which distributes the cement quite uniformly and does away with excesses of cement which later cause turtle-backing. The principal thing to remember when using any adhesive is that the least amount capable of covering the surfaces is always desirable. Keep the joint material as thin as possible.

e. Rubber and Asphalt Tile. These materials are gaining wide acceptance because of their resilient, waterproof and durable characteristics. Of the two, the rubber flooring is made of vulcanized rubber with fibre and mineral fillers incorporated in some brands. The advance in the production of wider color ranges and patterns has given the use of rubber tile quite a market. The asphalt tile is, as the name implies, made of various low penetration asphalt mastics with or without fabric backing or fibre and mineral fillers. The color range is smaller with asphalt tile than with rubber tile or linoleum. Both of these materials are laid in a manner similar to that given for linoleum and the cements used are of quite a variety of composition. Manufacturers' literature will be a good source for this sort of information.

f. Wood Floors. The use of wood as the finished surface of floors in fireproof buildings which usually have a concrete slab upon which the floors must be laid, is still quite common. Under certain types of occupancies the wood floor is by far the most attractive floor. Several details have been used to secure the wood to the concrete. Generally these schemes involve either enchorage to screeds or sleepers or the floor is attached by means of asphalt or pitch adhesives.

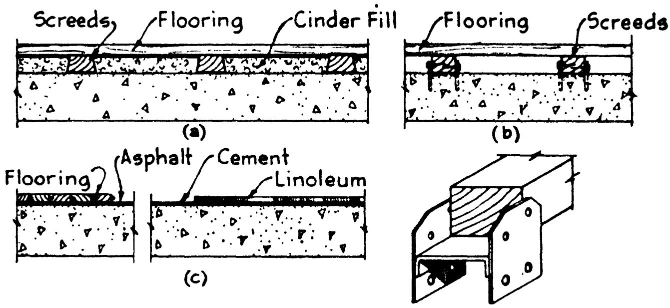


Fig. 10–2. Anchoring Screeds. (a) wood screeds and fill; (b) patented anchor; (c) direct attachment of finish with cement.

g. When screeds are used these are anchored to the concrete by means of metal anchors or are embedded in a cementitious or asphaltic floor fill as shown in Figure 10–2. It will be noted that the screeds are trapezoidal in section so they afford mechanical anchorage even though shrinkage may loosen the screed. The fill is usually dished as shown in order to allow a certain amount of freedom for deflection to provide resilliency and to allow breathing to prevent rot. A double floor may be used, a rough underfloor being nailed to the screeds, to allow greater freedom for nailing of the finish floor. When clips are used these must be set carefully to line and level in the fresh concrete so that they will provide proper line and level for the attachment of screeds.

h. When the finish floor is to be stuck to the concrete it is necessary to prepare the concrete slab to afford a smooth, level surface upon which the floor is to be secured. The usual practice is to apply a granolithic surface to the structural concrete, either integrally or as a two-course process. The best work laid hot in a good grade of lake asphalt has worn very well. The use of inferior asphalts or pitches should be guarded against as the stability of the floor depends wholly upon the retention of the bond of the adhesive.

WALLS

10–4. Tile and Stone Slabs

a. Tile. Tile may be used for wall surfaces either providing the final finish as the finish of the structural tile or by applying ceramic tile to the usual structural material of the walls or partitions. The glazed tile are made in a variety of sizes and finishes. They may be glazed on both faces, may be used as "soaps" which are thinner units glazed only on one face, a veneer on masonry walls, or may be glazed on one face and rough on the other for plastering.

b. When using glazed structural tile it is important that the sizes of the tile be coordinated with room dimensions, door and window locations, ceiling heights, door heads, window sills and heads, as well as the position of pipes, ducts, registers, beam soffits and the like. Good planning, cognizant of practical factors, would lay out the coursing so that heads of windows and doors, beam soffits and other lines affecting horizontal coursing, will coincide so as to avoid cutting which is expensive and often mars the appearance of the walls. Wherever pipes, registers or other mechanical appurtenances pass through the finished walls, it is highly desirable that they intersect the horizontal and vertical joints wherever possible. (Figure 10–3.)

c. Ceramic Tile. When ceramic tile are used for wall surfaces the same general procedure is used as was given under floor tile in Article 10–2. The tile are either floated on a mortar plaster coat or are buttered and set as individual units if they are of any appreciable size. When small patterned ceramic tile are used they are most commonly floated on to the wall. When the tile are set they are grouted as for floor tile and rubbed off with burlap and cleaned in the process to avoid set cement stains. In coursing these tile the same precautions and planning should be used as suggested for glazed tile. Clipped tile, which are necessitated by improper study of coursing, are likely to leave sharp arrises which are objectionable from the standpoint of safety and appearance. Good detailing would suggest careful study of coursing. Sanitary base core details are shown in Figure 10–4.

d. Stone Slabs. Slabs of stones have been used for many years as the finished surface of walls. The most common stones used are marble and slate. Recently, thin slabs of limestone and sandstone have been used also. Of course, it is always possible to set finish interior stone surfaces by the same methods used for exterior stonework. This discussion will be confined to the use of thin stone veneers.

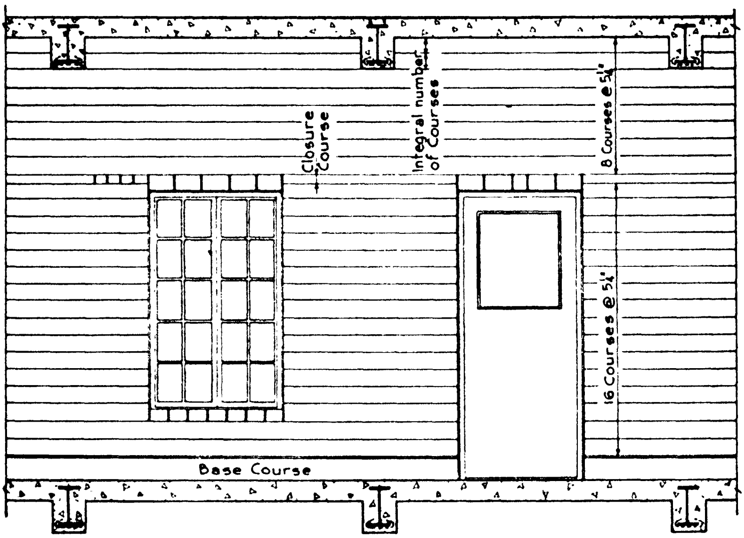


Fig. 10–3. Compensating Tile Covering.

e. These slabs are always anchored to the backup masonry by means of metal anchors. Brass rods are customarily used and are bent into the required shape to afford a mechanical fixation, the rods being bedded in plaster of Paris to form a cushion and to cement the rods into place. When the backup masonry is brick or some other solid masonry, the anchors are bedded into anchor holes as shown in Figure 10–5. When the backup is hollow tile or masonry units of some type the rods are hooked over holes drilled into the walls of the hollow tile and cushioned with plaster of Paris. To fix the anchors into the stone facing, holes are drilled into the edges of the slabs or are embedded into inclined holes drilled into the back of the slabs and then bedded in plaster of Paris which is forced into a prearranged hole in the backup and forms a cushion against the backup as the slab is plumbed into position, as shown. When marble is used the joint mortar and cushion mortar pads must be of non-

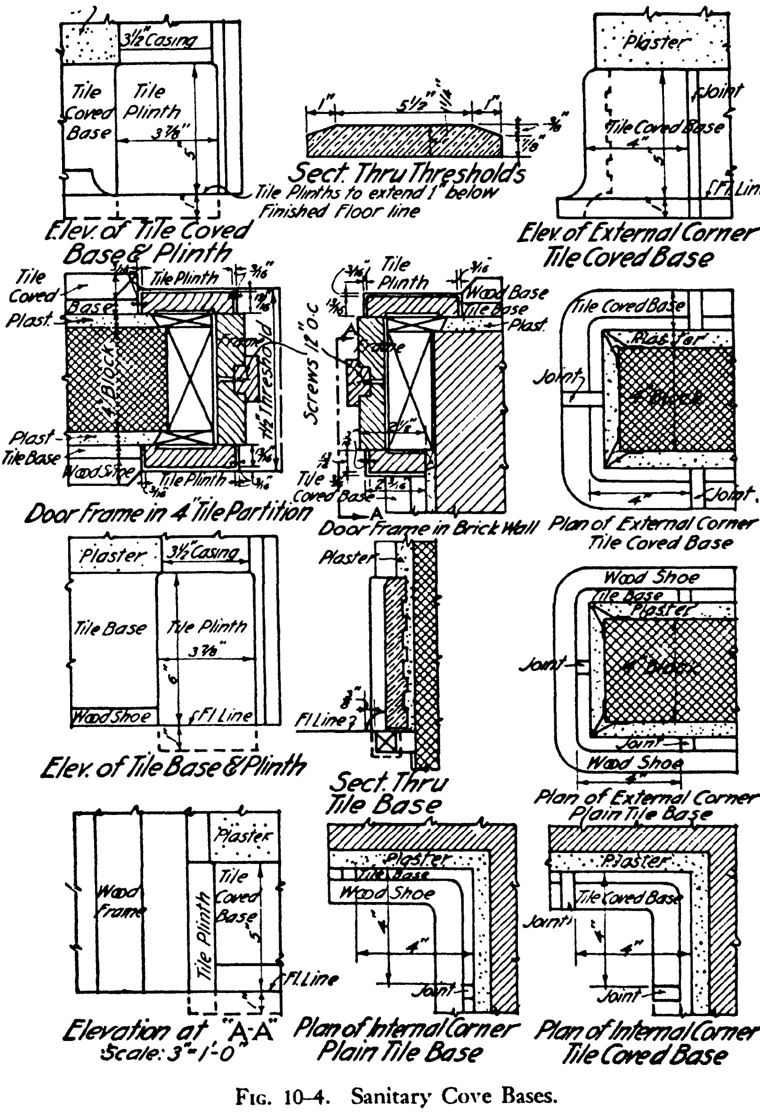


FIG. 10–4. Sanitary Cove Bases.

staining mortar. Plaster is the usual and most commonly accepted material. In some of the more modern adaptations of stone facing non-ferrous metals or stainless steel mouldings are used to frame the pieces, the plaster serving as cushioning material only. The metal border strips are anchored into the backup.

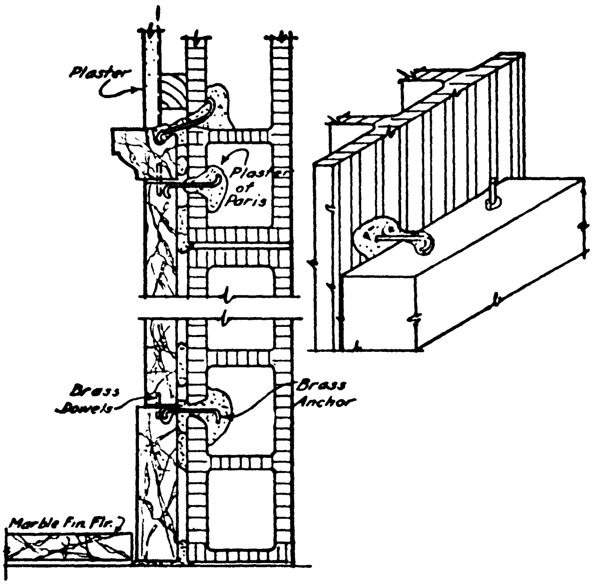


FIG. 10–5. Anchorage of Wall Marble.

10–5. Wall Coverings

a. Linoleum. The substitution of fabricated sheet materials for the usual plaster has become quite common, because of the more readily maintained surface and the opportunity for color, pattern and design at a more economic price. The former plaster surfaces were of Keene's cement which gave a hard surface but which were subject to cracking and required occasional painting to keep the surface clean and intact. Among the earliest and most commonly used is linoleum. It is applied in the same manner as formerly described for floors, with the exception that it must be protected against sagging and bubbling or "turtlebacking" by being secured by dado caps, joint strips and core base details. The adhesive must also be applied in a thin and tacky coat to insure quicker drying and more intimate contact. Quite often the base is also covered with linoleum as a continuation of the floor linoleum. The base for the application of linoleum should always be a smooth surface free of any joints and depressions and is usually a plaster coat, smoothly troweled.

b. Flexible Fabric. There are quite a number of flexible fabrics of various thicknesses and compositions which are used as substitutes for linoleum. These may be made of woven fabrics, or papers, and may have a linseed oil, asphalt or plastic base. These fabrics can be obtained in greater lengths than linoleum and so eliminate vertical jointing on long stretches of wall, which is often necessary when linoleum is used. These materials are cemented to smooth wall surfaces in a manner similar to that given for linoleum except that the adhesive must be compatible with the fabric used.

c. Sheet Materials. These materials are distinguishable from the above by their characteristic property of stiffness and their merchandizing in prefabricated sheets of standard dimensions. The most commonly used materials of this type are made of pressed paper pulp, of cement asbestos or of plastic laminates. Many of these materials are made in a variety of patterns and finishes. The finishes may be developed in the manufacturing process or they may be produced by a variety of paints and enamels.

d. These sheet materials are attached to the masonry walls by a combination of mouldings and screws and clips, many of which are patented and fitted to the particular material to be used.

10–6. Wood Paneling

a. In many fireproof buildings the occupancy requires wood paneling for certain walls. Wood paneling is usually attached to masonry walls by providing nailing strips which are brought to line and plumb by means of wedging and plaster pads. These strips are fastened to the walls by means of toggle bolts when hollow tile is used or to sleeves of some type if solid masonry is used. Several typical fastenings are shown in Figure 10–6. It is important to locate these screeds in such a manner as to afford critical nailing for the finished woodwork. The woodwork may be attached by nailing or screwing which may be blind as shown.

10–7. Blackboards and Bulletin Boards

a. These finishes are applied in a manner similar to wood paneling. Blackboards are usually of natural slate, black glass or surfaced composition boards. Bulletin boards are usually made of some sheet substance which will take thumb tacks or stapling devices. Such materials are usually made of artificial cork or of a fibred material such as "Celotex" or like trade materials. The more rigid materials such as slate and glass are usually stabilized by means of plaster pads and held in place by firmly affixed frames of wood or metal. Several details of these appurtenances are shown in Figure 10–7.

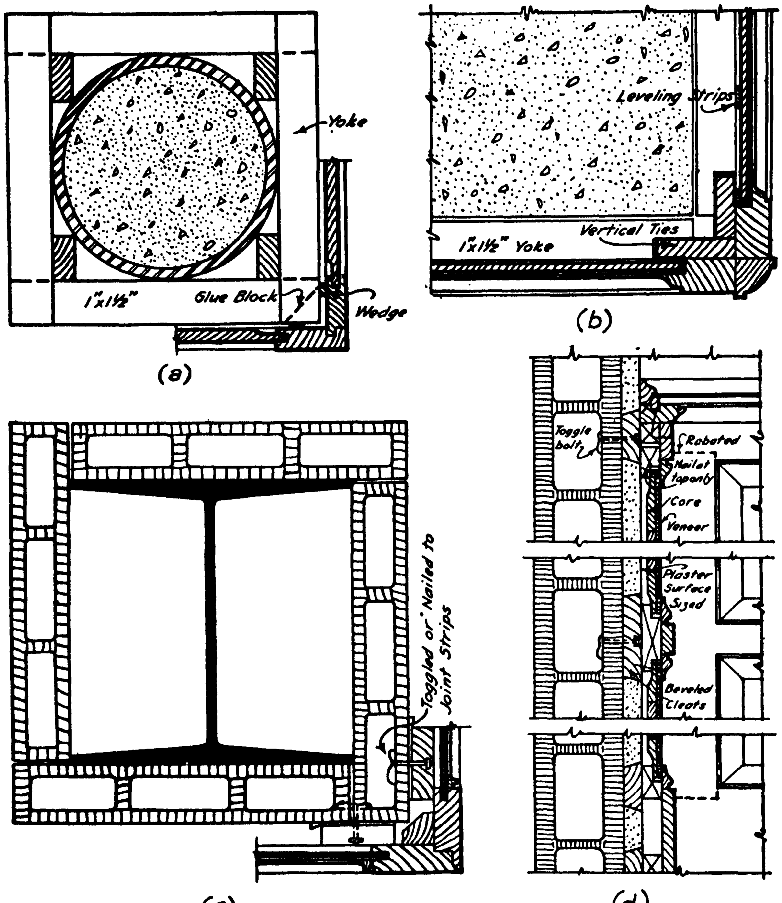


Fig. 10–6. Wood Paneling at Walls and Columns. (a) furring around cement-filled pipe column; (b) furring around concrete column; (c) furring around fireproof steel; (d) furring for dado.

CEILINGS

10–8. Ornamental Plaster

a. Inasmuch as "fireproof" or "first-class" buildings are used for our more important commercial and civic structures, we find that the architectural requirements include ornamentation and surface finishes which have been accomplished for many years by the use of plaster finishes in some way or another. The more nearly the design follows the usual type pattern the more use is made of run mouldings, plaques and other forms

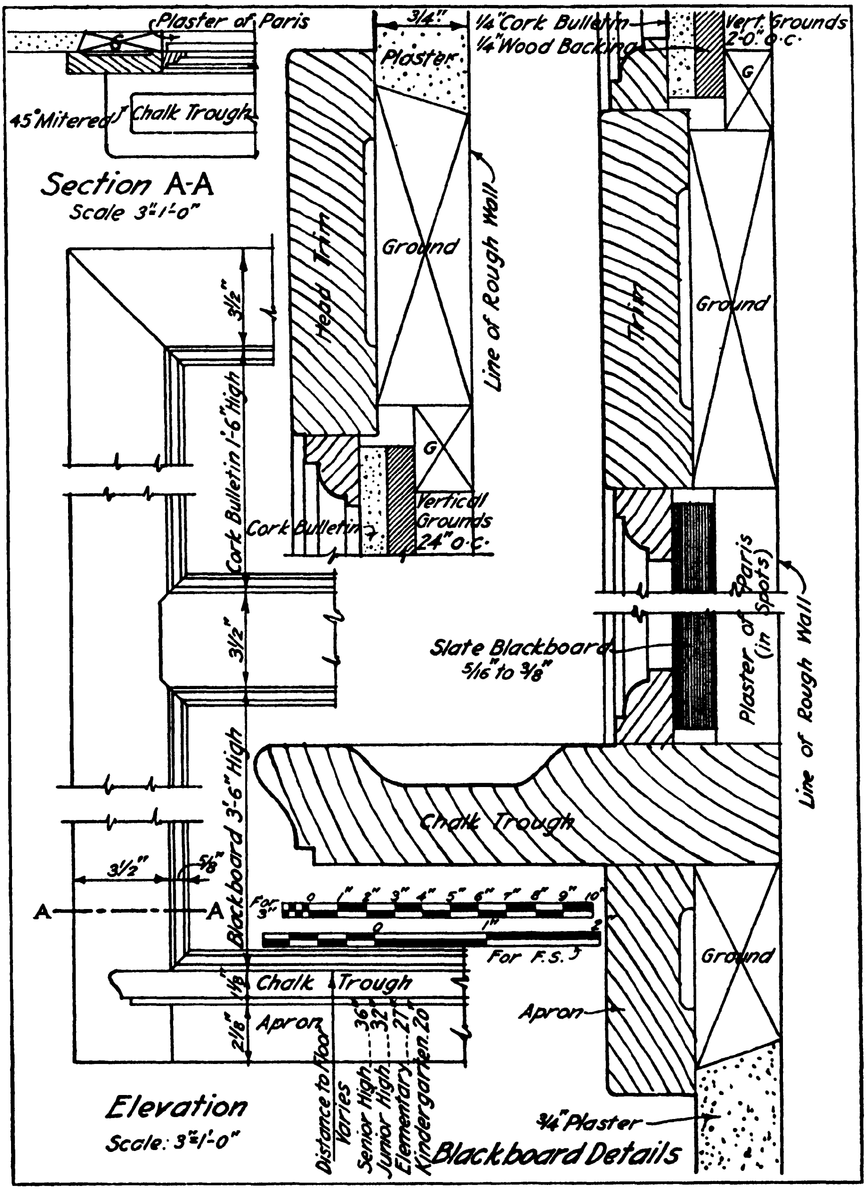


Fig. 10–7. Blackboards and Bulletin Boards.

of ornamentation. In nearly all of such work the plaster work is suspended from the structural slab and frame by means of metal furring and lath.

*b. **Run Mouldings.*** Where the ceilings are designed with moulded cornices and other paneled designs involving mouldings, these mouldings, if straight runs or circular arcs, are formed by the process of "running," so called. In this process the bulk of the section is built up with white-coat plaster, usually a mixture of plaster of Paris and lime putty, and then shaped by running a metal profile knife over the plaster, the knife being guided by pre-set screeds. Small panels or unit ornaments are precast integrally or are applied to the surface. Figure 10–8 shows a detail of the furring and profile of a specimen cornice moulding. The scratch coat and brown coat are applied as usual but with sufficient clearance for the plaster as indicated. The sheet metal template or knife is cut to the reverse profile of the mould and attached to the running frame. Guide screeds are attached to the ceiling and wall, and the running frame slides upon these. After the moulding is built up and smoothly run, corners and other inaccessible places where it is impossible to run the template must be moulded by hand. The finish coat of plaster work on the walls and ceilings is not applied until all such mouldings are run, in order to remove the screeds before applying the wall and ceiling finish.

c. All ornaments, if heavy, must be made hollow, as plaster of Paris checks when used neat in thick sections. This coring method is also used where the mouldings are intricate. The plasterer must exercise great care in aligning and fitting to make sure that all lines are true and all joints obscured by the finished work.

d. In placing a bracket, such as shown in Figure 10–8, the run moulding is cut back at this point when still soft and the bracket is subsequently affixed, with liquid plaster of Paris. The details of the abutting moulds are then patched against this bracket with a small trowel, at the point (a).

e. Cartouches and other ornaments of bold relief are usually made of fibrous plaster or carton-pierre. The latter is a mixture of whiting, glue and paper, rags or hemp pulp. This mixture is forced into gelatine moulds and allowed to harden. It produces a resultant material lighter and tougher than plaster of Paris and is extensively used for special panels and ornaments so placed as to be liable to damage. Fibrous plaster is a thin coating of plaster of Paris upon a stretched canvas backing introduced as a means of reinforcement after thorough soaking. The plaster of Paris is run into a mould and the canvas is then pressed into it and embedded by a further coating of the plaster.

f. The degree of complication in the installation of furring, to receive the lathing and plastering, will depend upon the intricacy of the design of the actual finished plaster surface. This may vary from the simple and unbroken level ceiling, at one extreme, to the surfaces of penetrated vaults

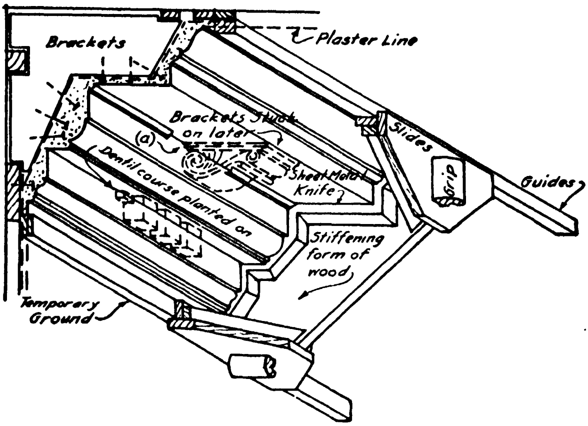


FIG. 10–8. Running Plaster Mouldings.

or caissoned domes at the other. Any of these surface skeletons may be produced, however, by various combinations in the assembly of the three simple metal elements:

(1) hangers,
(2) runners, and
(3) ribs.

These are shown in Figure 10–9. The furring bars which are attached to the concrete joist reinforcing bars furnish the ribs for the furred ceilings. Sometimes the metal lath is placed directly upon the forms before casting the ribs and is embedded without the use of the hanger, rib and runner construction. This affords an air space for plastering across the bottom of the joist.

g. Vaulted ceilings and domes in plaster are usually formed by bent runners or ribs and require care in the location of the hangers. Several details of this type of furring are shown. Metal lath lends itself admirably to all sorts of surfaces and to furring for ornamental cores, cornices, beams and the like.

10–9. Acoustical Treatment

a. Walls and ceilings may be treated acoustically by means of applied plastic material as plaster or by applying prefabricated blocks or sheets by the use of mechanical fastenings or adhesives. The plastic materials are quite variant but fall into two general groups, one of which uses the commonly used mineral adhesives such as cements and plasters, while the other uses the organic or resinous binders for the various fillers or aggregates. The prefabricated sheets or blocks are made of metal and siliceous fibres, wood derivatives with various binders and some are truly cementitious synthetic materials which are provided with large void characteristics to allow sound absorption and destruction.

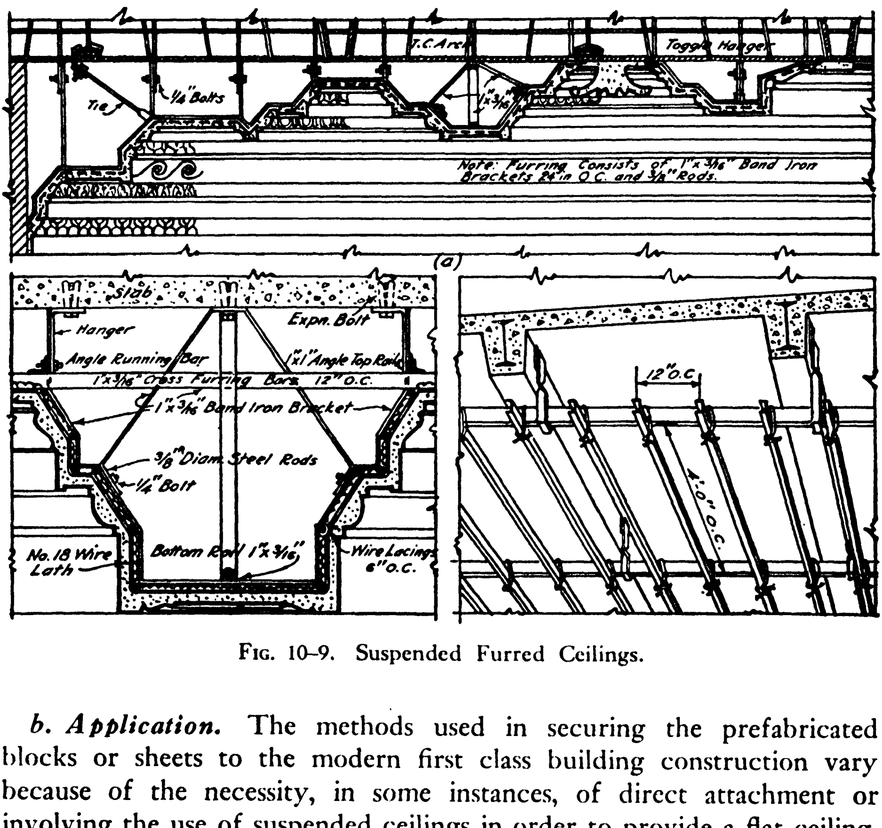


FIG. 10–9. Suspended Furred Ceilings.

b. Application. The methods used in securing the prefabricated blocks or sheets to the modern first class building construction vary because of the necessity, in some instances, of direct attachment or involving the use of suspended ceilings in order to provide a flat ceiling. Several illustrations of the many methods employed in this work are shown in Figure 10–10. The detail shown at (a) is one which has been used with success on several installations. Here nailing strips are embedded in the bottom of the slabs. These also serve as spacers for the reinforcement. The strips are either dovetailed to secure them mechanically or effect attachment by the embedment of nail heads in the concrete. The cross furring is nailed to the nailing strips at a spacing which allows direct attachment of the acoustical blocks. The blocks are then nailed to the furring with a vapor barrier inserted between the strips and the blocks.

Blocks which are set over pull-boxes or other mechanical devices which must be reachable can be screwed up so that they may be removed and replaced. The detail shown at (b) is the common practice of attaching the blocks with adhesives. Here it is essential that the soffits of slabs must be level and relatively smooth so that the thickness of the adhesive pads need not be excessive, which would accentuate shrinkage and ultimate rupture of bond. Unless this work is done carefully with excellent

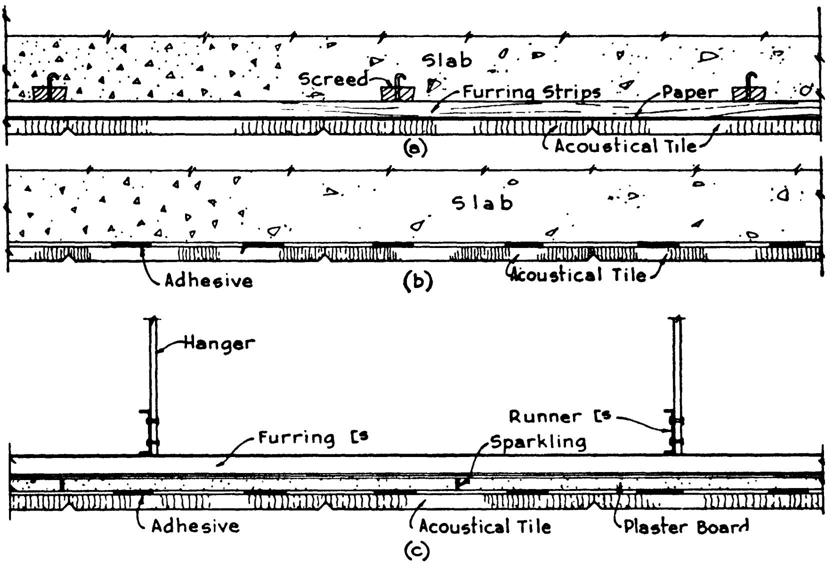


FIG. 10–10. Attaching Acoustic Tile. (a) wood furring and direct nailing; (b) direct attachment with cement; (c) suspended ceiling using plaster board.

adhesives blocks may warp and loosen. The heavier the blocks the more likely that individual blocks may become loose. The details show several methods of attaching acoustic units to suspended ceilings. In some cases the usual plastered ceiling is installed, eliminating the finish coat. The blocks are then applied with adhesives. A variation attaching plaster board to wood strapping and then fastening the blocks by the use of adhesives is also used. Where direct nailing to strapping is used a vapor barrier paper should be used to prevent condensation in the void above the ceiling. In other words, direct breathing into the furred space void should be reduced to an absolute minimum. It will be noted that the use of plaster board allows one to carry the board over close to the structural wall to seal the intersection between walls and ceilings. There are also several available perforated metal sheets with insulation above the perforations to absorb sound. These types of acoustical panels allow direct breathing and may encourage corrosion and the accumulation of dust and bacteria. They thus are not too satisfactory in areas where humidities may be high or where moisture is excessive.

c. ***Plaster Coats.*** The attachment of white coat plaster or acoustic plaster to concrete slabs has been a problem for many years. One of the solutions proposed by the industry involves the use of a so-called "bond-coat." This is usually a specially prepared gypsum plaster which is supposed to provide intimate bond with the concrete and then to provide a surface to which other gypsum plaster materials will bond. In this method chemical bond is of prime importance, and for this reason is subject to the failure induced by the action of moisture and heat on this bond.

d. It is far better to provide mechanical bond for ceiling plasters. This can be accomplished by one of two very simple procedures. The first of these employs lightweight metal lath which is laid on the forms so that one surface of it provides a mechanical bond for the browning coat. Another scheme is to line the forms with open-mesh burlap which is ripped out when the forms are removed and leaves a cross-scored surface which provides mechanical bond for the browning coat.

e. One of the problems involved in the use of acoustical ceilings is posed by the necessity for occasional cleaning or painting to provide brightness or cleanliness. Blocks which depend upon the pore structure for sound absorption are likely to be plugged gradually by the application of paint. Blocks which are provided with perforations which cannot be plugged by painting are far superior from the standpoint of maintenance.

WALL OPENINGS

10–10. Door Trim

a. The use of bucks, in some form, in masonry partitions is quite necessary where openings occur. (See Art. 9–5.) When steel bucks are used it is advisable to keep the finish separate from the bucks, except in certain grades of work, as the finished surfaces may be marred during the process of installing tile partitions and plaster. Steel jambs are either carried up to the frame of the floor above and the steel heads form the lintel, or a circumferential frame is set. The wood frame is fastened to this steel buck by means of machine screws or toggles concealed behind the stop bead. When metal trim is to be used, the buck may be set as shown in Figure 9–8 for rolled sections and when the pressed metal buck is used. It is seen that the buck may be set flush with the plaster and forms the finish while it is possible to use moulded pressed steel trim which is later attached to the rough pressed steel buck. Bucks are usually made to detail, thus allowing considerable latitude. For more economical construction the architect can select the flush buck in standard door sizes which are used quite extensively and thus are obtainable at a reduced cost.

b. Steel bucks are used with marble trim. In these cases the detail must be altered to afford means of securing door trim and plinth made of cut stone. In one case the trim laps the stone while in the second case the trim is attached by means of bond rods.

10–11. Metal Sash

a. Metal sash in modern first-class buildings may vary in type and in material. They may be casement, double-hung or projected, and may be of steel, aluminum or bronze. The most important properties which any sash must possess are:

(1) weathertightness,
(2) ease of operation,
(3) durability, and
(4) ease of maintenance.

b. Weathertightness in a metal sash is linked with proper alignment, intimacy and number of points of contact, and weathertightness of assembly points. Sash are usually prefabricated in sash plants and must be shipped to the job. At the job they are usually stacked before use. The shipping and storage, unless carefully done, may result in distortion which may throw carefully aligned contacts out of line. It is also possible that the manufacturer may be careless in manufacture and finishing, thus impairing the intimacy of contact. When sash are set first and bricked in the masons may distort the sash. Careful inspection all down the line is required to insure weathertightness. The jamb, sill and head construction for weathertightness is also quite important. Figure 10–11 shows several standard details for the factory sash manufactured by the Detroit Steel Products Co., while Figure 10–12 shows the special details for bronze sash.

c. Whether a metal sash operates easily or not is not only dependent upon the treatment the sash receives in packing, transit and erection but is influenced by the detail of attachment at head, sill and jambs. Unless a sash has means of expansion without excessive restraint the sash will buckle or the movable portions will bind. This release can be provided by means of slotted slip joints, flexible diaphragms, rebated frames or framing in a compressible sub-frame such as wood. The author favors the use of wood sub-frame because it does provide expansibility, prevents direct contact of metal and cementitious mortars and masonry. In addition it is possible to build the sub-frame into the masonry without exposing the sash to the wear and tear during the erection of the masonry work. Figure 10–13 shows the standard metal fin jamb plate. Other details

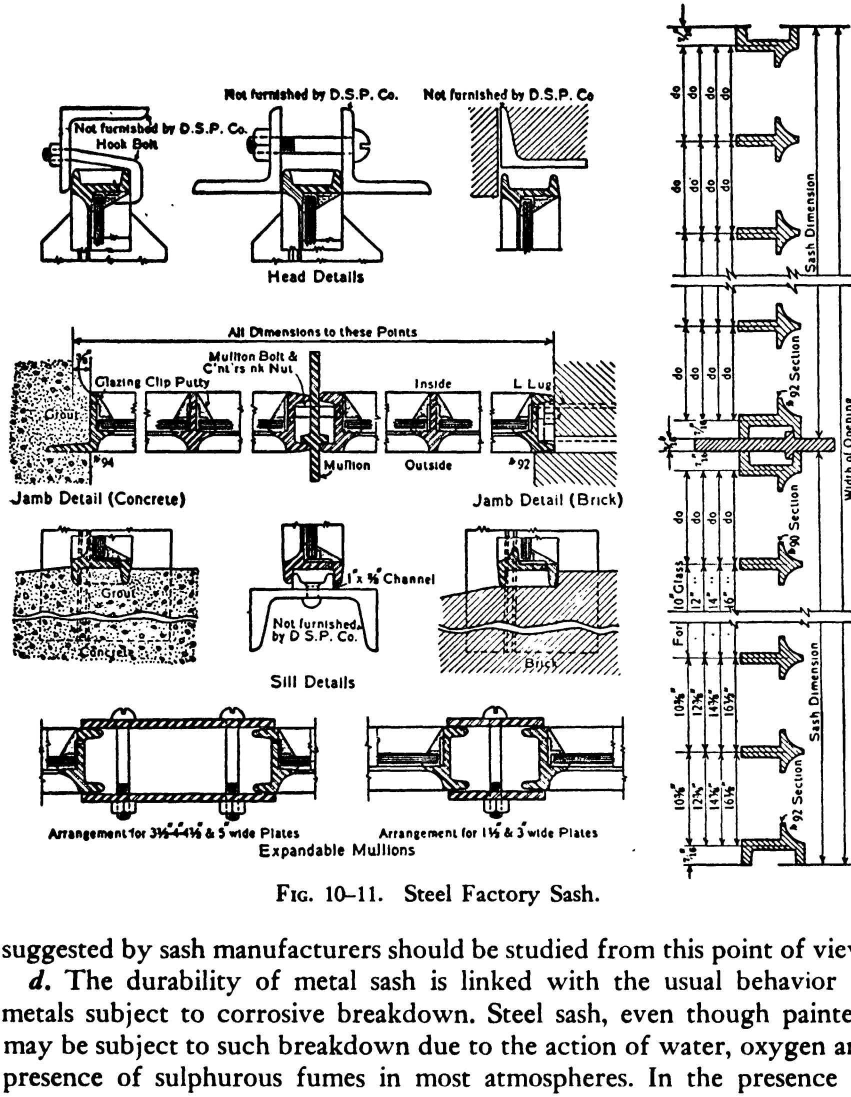


Fig. 10–11. Steel Factory Sash.

suggested by sash manufacturers should be studied from this point of view.

d. The durability of metal sash is linked with the usual behavior of metals subject to corrosive breakdown. Steel sash, even though painted, may be subject to such breakdown due to the action of water, oxygen and presence of sulphurous fumes in most atmospheres. In the presence of alkaline waters coming from the masonry this action is greatly accelerated in the sill sections and the lower ends of the jamb sections. Care should therefore be exercised in inspecting steel sash after delivery to see that scoring of the finish is a minimum and is repaired promptly and that the finish specified has a good record for durability. Aluminum sash, when not exposed to atmospheres known to cause pitting of aluminum, give a good account of themselves. It is important that aluminum does not come into direct contact with cementitious materials as these attack aluminum actively in the presence of water.

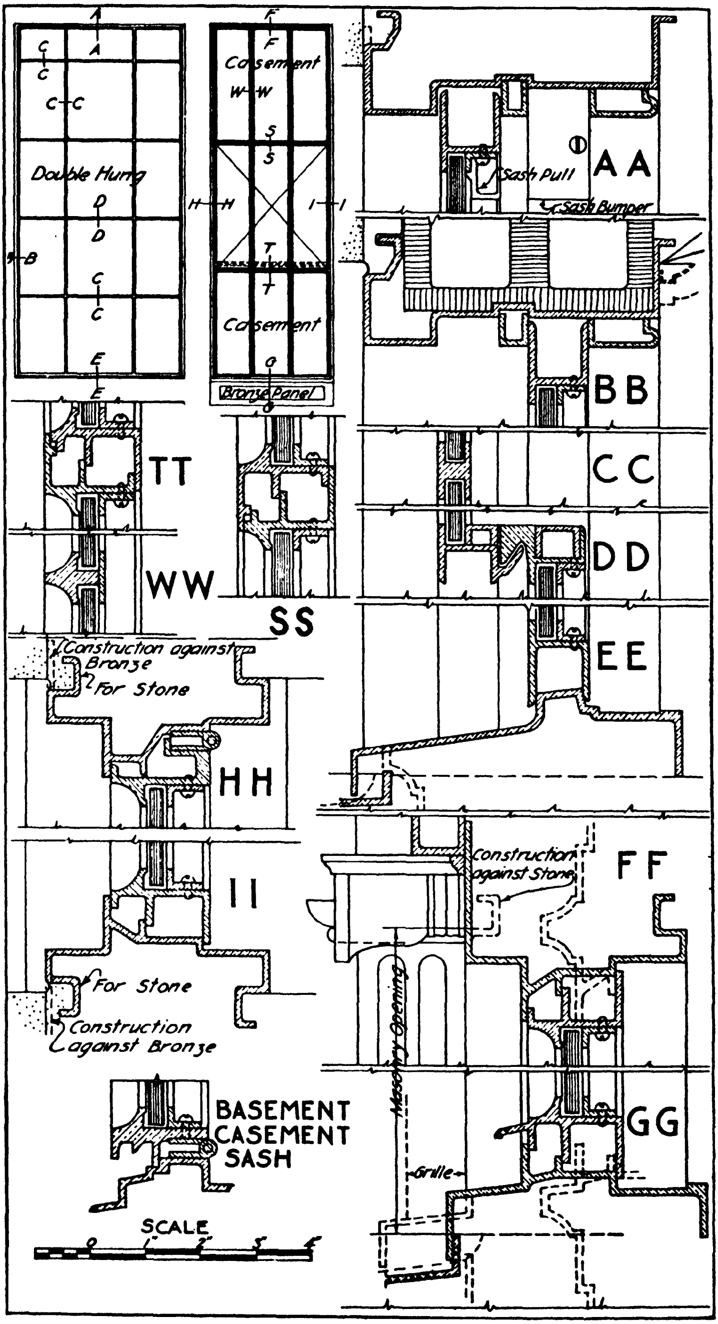


FIG. 10-12. Special Bronze Sash. (*Courtesy Jackson Company.*)

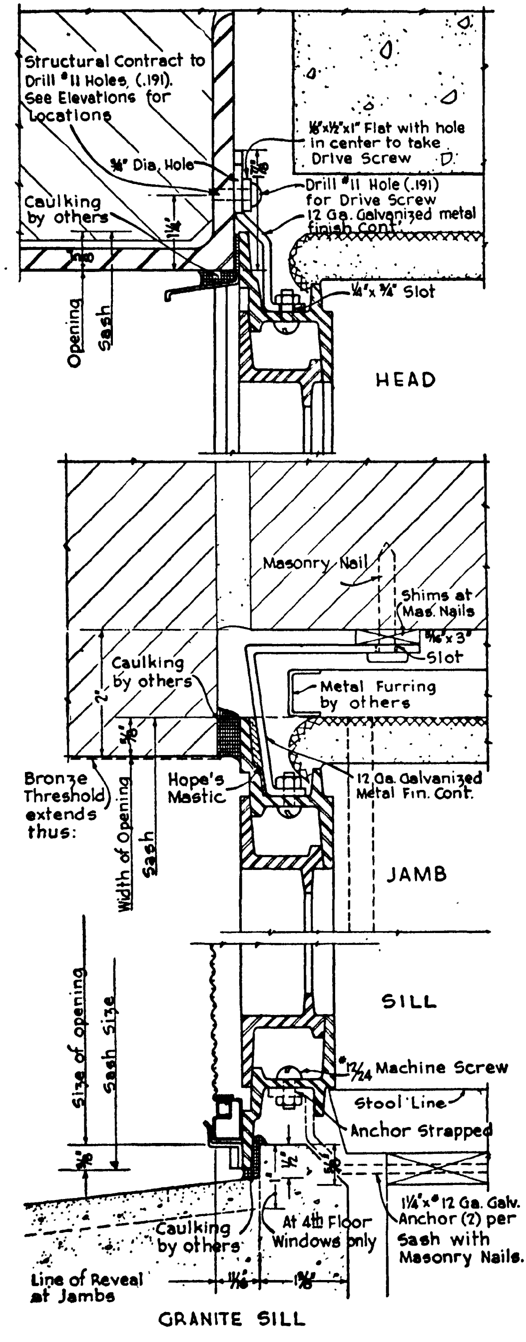


Fig. 10–13. Details for Fastening Steel Sash in Masonry Walls.

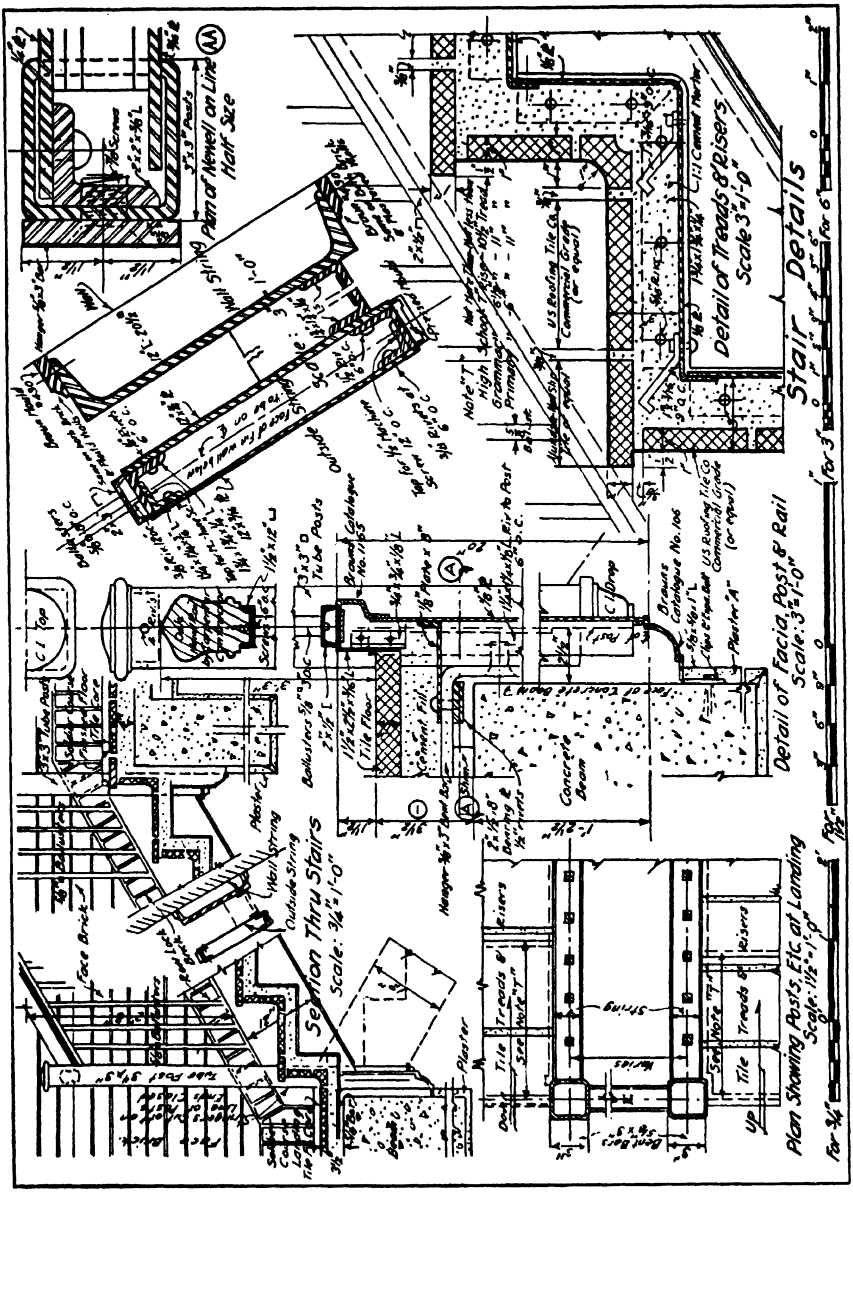


FIG. 10-14. Fireproof Stairs.

e. Maintenance of metal sash is definitely related to the conditions discussed above. Sash which are carefully made, shipped, erected and glazed will give very little trouble in service and if to this is added a material which resists corrosive action the life of the sash will be greatly extended with very small expense for maintenance.

10–12. Glass and Glazing

a. The glazing of metal sash is similar to that for wood sash in most respects with the exception of the accessories used to fix the glass mechanically. (Figure 10–13.) Nearly all metal sash rails, stiles and muntins are provided with perforations to engage a variety of spring steel clips so that the sash is fixed. It is more important in setting glass in metal sash to provide carefully for bedding and sprigging in putty. The details show this quite clearly. The glass may be protected by putty or may be bedded in metal beads which are secured by screws.

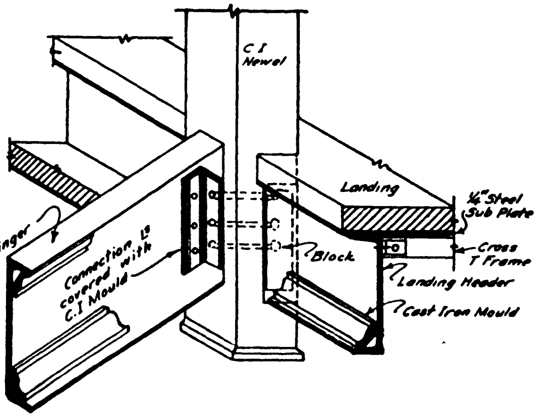


Fig. 10–15. Fireproof Stairs.

STAIRS

10–13. Fireproof Stairs

a. The general details of steel stairs and the attachment of the strings and risers to the structural frame are shown in Figure 10–14. Treads may be exposed checkered steel commonly used in service stairs, a concrete- or mastic-filled steel sub-tread, or steel sub-tread upon which marble, slate or non-skid tile is laid. The general frame involves either rolled or pressed steel strings and wrought iron, cast iron or bronze posts and rails. Where large cast iron newels are used, they are blocked around the strings and headers. Details of finish other than the rolled steel shape are provided by attaching a cast iron or pressed steel mould into the flange projection. (Figure 10–15.)

b. The pressed steel stairs are rapidly supplanting the old channel riser and plate sub-tread. The tread in any of these may be of slate, marble,

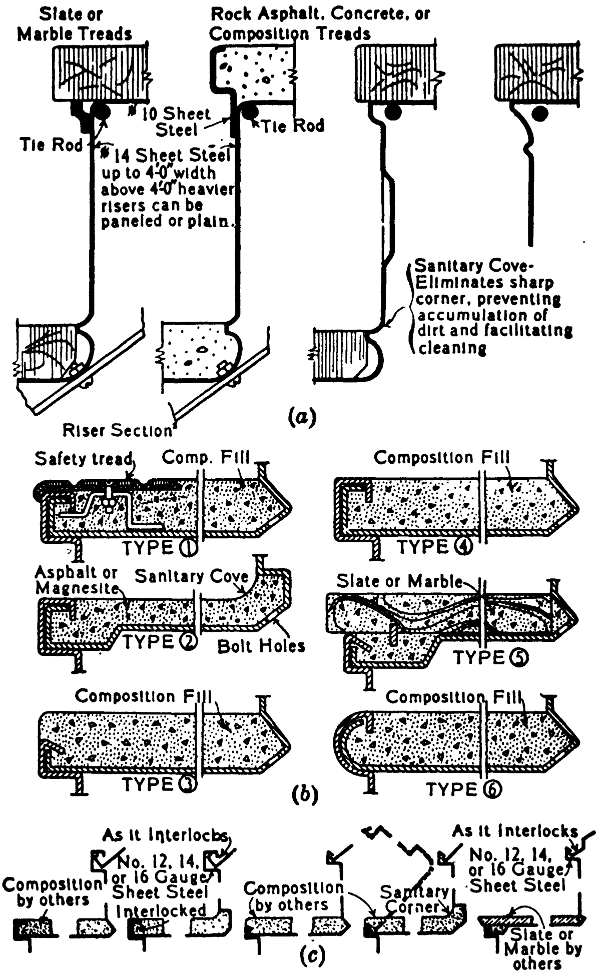


FIG. 10–16. Pressed Steel Stair Types.

concrete, composition or asphalt if desired. The stringers are usually built up of plate channels and the treads and risers are clipped to them in one piece or in two, depending upon the manufacturer. When slate and marble are used the nosing is formed by the stones and the treads are set upon the sub-plate with plaster of Paris. When concrete, composition or asphalt are used the tread sub-plate is turned up to form a pan to receive the mixture used. Figure 10–16 shows several typical pressed steel tread and riser sections.

ARCHITECTURAL PARTITIONS

10–14. Ornamental Metal

a. Metal partitions, equipped so that they may be readily changed or readjusted, are in common use in schools, office buildings and other

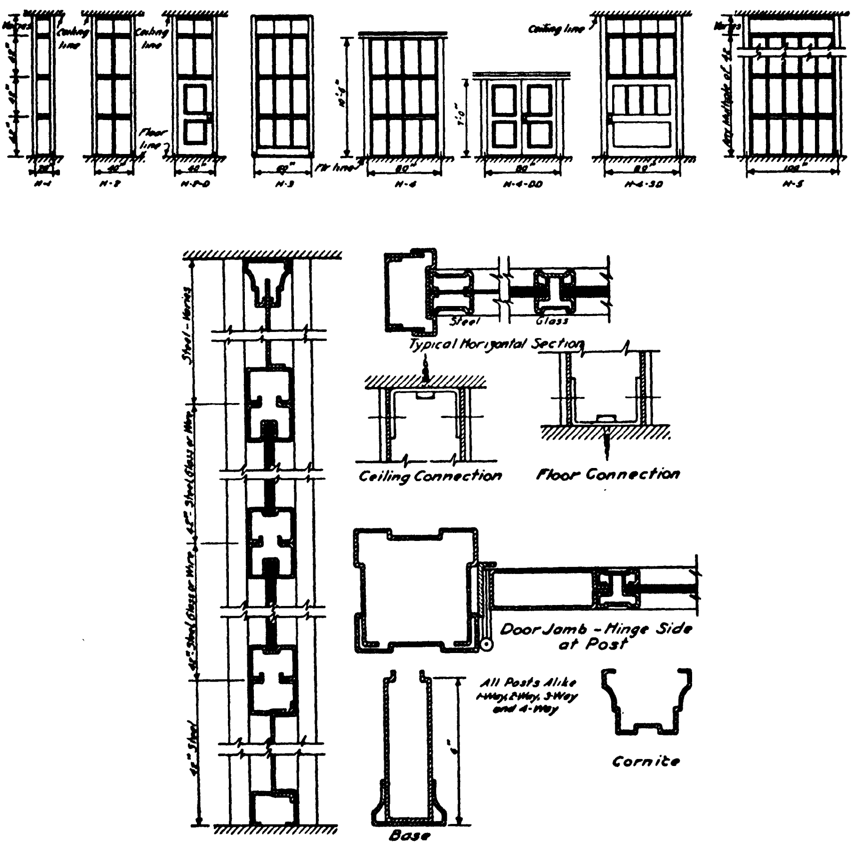


FIG. 10–17. Typical Metal Partitions.

places where economical and easily removable subdivisions are desired. They are built of pressed steel sections sometimes reinforced with small rolled channels, and are fitted as occasion demands with solid panels, glazing, or woven wire panels. They are always built so as to be lightweight and all materials used in their construction are chosen to this end. The details vary with different manufacturers and Figure 10–17 shows several typical details. In all cases the contractor will be required to submit shop details to the architect for approval.

b. Special partitions may be made of bronze, aluminum or stainless steel and such are usually especially detailed. It is important that the builder check the shop drawings of such expensive partitions with the other work to make sure that the metal work will fit perfectly.

10–15. Glass Block

a. Glass block are being used quite extensively for interior architectural partitions. The general details for the various portions of such work are similar to other masonry units. The details at the ceiling, floor and walls are quite variable, but the basic approach is the same. Details around

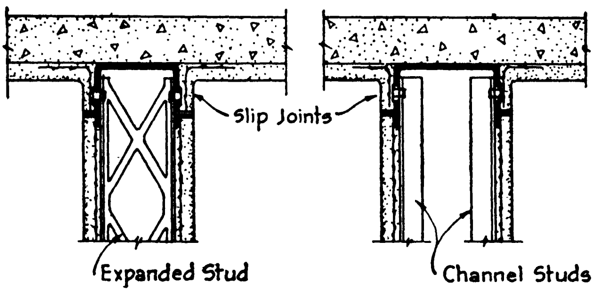


FIG. 10–18. Providing Movement for Steel Stud, Lath and Plaster Partitions at Ceiling Line.

doors, window frames for clear vision and grilles are also interesting. When combined with aluminum, stainless steel and various finishes of steel, glass block produce very interesting partitions.

b. The most important factor to be considered in connection with glass block partitions is the provision for the expansion which takes place. The blocks should be cushioned against any rigidly confining framing elements. This cushioning may be accomplished by means of felt, cork or some form of non-staining mastic. The joint at the ceiling line is particularly important. Slabs and beams deflect under load and in reinforced concrete frames the gradual consolidation of the structure increases the danger of ultimate binding at the ceiling. This precaution is true of all partitions. Figure 10–18 shows a simple solution of this detail, for metal lath and plaster partitions.

PAINTING

10–16. Painting Plaster

a. New plaster work always presents two characteristics which may cause trouble. These are "lime action" and "unevaporated moisture." The strongly alkaline reaction of the surface must be neutralized and a strong alum and soap size may be used to offset the burning action of the lime. The walls should be sponged with fresh water after sizing. Walls must be thoroughly dry before painting. To check the moisture content a very simple test may be used. By applying a small amount of phenolphthalein to the surface one is able to detect small traces of surface moisture. If the liquid turns pink or red, moisture to excess is still present. If no red color appears the wall surface is dry enough to paint. One must be careful to keep moisture away from the applicator of the phenolphthalein.

b. The nature and application of the paint will follow the directions of the manufacturer. Various manufacturers use their own special materials and have prepared specifications to insure good results. The use of these specifications is advised when the products of a manufacturer of long standing are used.

10–17. Painting Metal

a. The surfaces of metal to be painted must be free from oil, grease, scale or rust. Rust and scale must be removed by wire brushing, scraping or sandblasting; grease or oil may be removed by the use of gasoline or benzine. The priming coat, very often of red lead and oil, must be brushed into the surface vigorously and, if possible, as soon after cleaning as possible. At times inhibitors, such as chromates, are mixed with the primers to allay early oxidation. Painting should not be done at temperatures below 50 degrees or in damp or rainy weather.

b. Where baked enamel metal trim is used painting is unnecessary. Unless care is exercised in the handling and setting of such metal work, the problem of repairs is a difficult one. Where the work is badly scored it should not be set, and if already set should be removed and replaced with satisfactory work. Small mars can be patched by a competent painter. The patches will not be baked but there are excellent varnishes and enamels which can be used, rubbed down and blended. It is needless to note that repairs of this kind are costly.

CHAPTER 11

ROOFING AND SHEET METAL

11-1. General Considerations

a. In considering the subject of roofing and sheet metal for fireproof buildings only those details which apply particularly to such buildings will be considered here. All sheet metal which is normally related to the subcontracts for "heating and ventilating," "miscellaneous iron," metal covered doors and the like is excluded. As this type of building involves reinforced concrete slabs or other forms of masonry roof surface structures the application of roofing to such material involves several alternatives to the usual wood roof construction.

11-2. Flashing

a. Flashings are commonly used at gutter eaves, parapets, at floor levels, and at the intersection of roofs and walls. Metals or fabric may be used. The details vary with the materials used for the roof and walls. The metals may be copper or lead and occasionally lead-coated copper.

b. Wall Flashing. The full, skeleton-framed building, in which the exterior walls are panel or closure walls which are carried at each floor level, involves the possibility of horizontal cracks in the joints at the various floor levels. To provide a dam at these points through wall flashings are employed. The use of metal in these instances is often claimed to produce such a positive break in the walls that metal should not be used. Various fabrics with better surface characteristics for bond with the mortar and with or without embedded metal or mesh are used as an alternate. These fabrics provide greater flexibility for the movement which unquestionably occurs at these points. The metal or mesh provides enough forming rigidity to enable the roofer or waterproofing contractor to preshape the strips on the job.

c. The typical details for flashing at the floor lines or spandrels of multi-story buildings are shown in Figure 11-1. The principal function of these flashings is to provide flexibility for movement and to insure the shedding of impenetrating water toward the exterior of the building. To make sure that these conditions are met the detailer must ask himself whether his proposed scheme allows movement of the wall and floor to a limited extent without disengaging the parts of the flashing dam and whether the dam crosses the path of the movement of any water which may be drawn into the wall by absorption or driven in by wind and rain.

d. The best metal to use for such flashings, if through metal flashing is desired, is copper. Generally this is the 16 ounce weight. The exposed edges of the flashing should be turned down over the joint as shown in order to prevent capillary entrance of water under the flashing. As copper may stain stonework the exposed edges are tinned to protect the copper

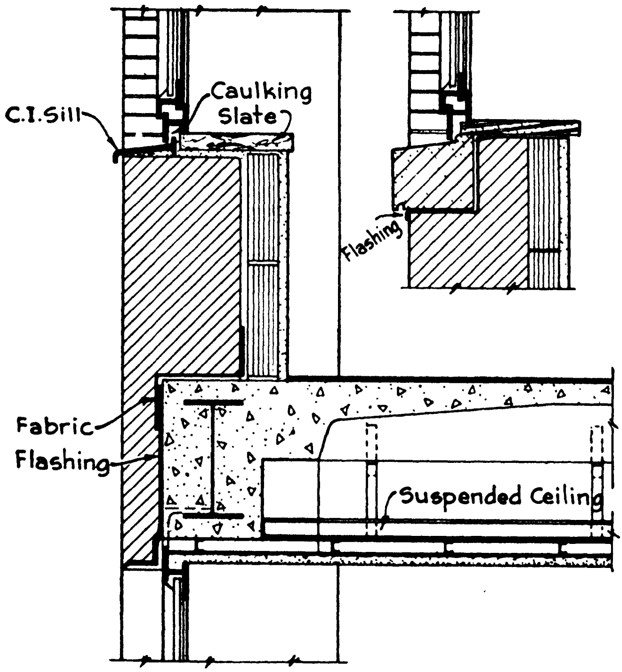


Fig. 11-1. Wall Flashings at Spandrel and Sill.

from dissolution or from forming a patina. This is often accomplished by using a lead-coated copper strip at the extreme end of the flashing. The flashings should always be turned up on the interior of the wall to form a protective trough. It is easily seen that details for this work must vary for the many conditions met in different locations in any building. Thus what happens over windows, doors, louvres and other openings must be carefully studied. The sills of windows, occurring as they do at elevations above the usual floor level, must also be protected so that the sill will not shed accumulated water into the wall.

e. When fabric flashings are used, the problem of the breakdown of the pitch or asphalt filling when exposed to vapor pressures, light and air must be solved. Thus it is advised that such flashings should always be completely enclosed by intimate contact with masonry materials. In order to do this it becomes impossible to provide the lip over the masonry suggested in (*d*) above, by using the fabric itself. To enable one to use

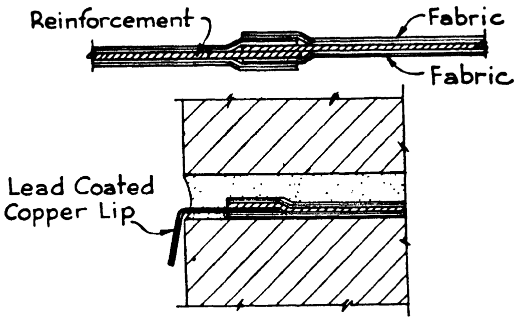


FIG. 11-2. Lapping Reinforced Fabric Flashings.

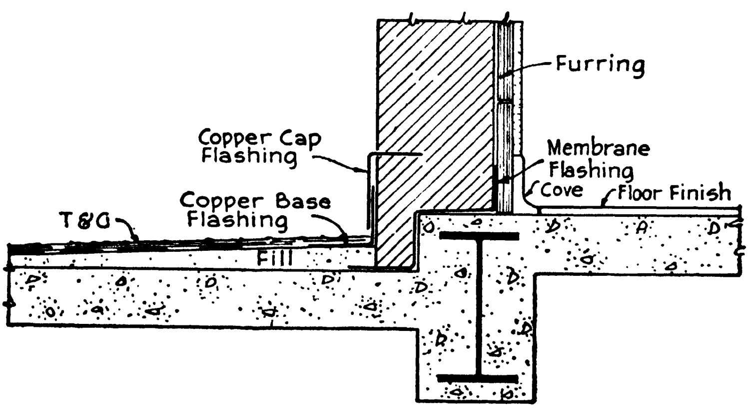


FIG. 11-3. Flashing at Intersection of Roof and Wall.

fabric, because of its particular advantages, and still effect the exterior detail which is required, the detail shown in Figure 11-2 is often used effectively. It will be noted from this detail that the fabric must be a compound sheet which may be two layers of fabric, two layers of full seal fabric with a mesh embedment, or two layers of fabric with thin sheet copper as the embedment. These fabrics can be exfoliated to insert the lead-coated copper edging satisfactorily.

f. Where roofs intersect setback walls as shown in Figure 11-3, the detail changes somewhat, but the general fundamentals are still appropriate. The difference here is the insertion of the fabric into built-up roof construction. If, however, the detail involves a floor level in the setback portion of the structure at, or near, the roof level, the question of exposed flashing surfaces enters.

g. Parapets. Parapets are a source of great trouble. Through flashings are not weighted heavily enough and the flexural movements induced by roof load and expansion are not resisted and aggravate breakage in joints. Unless a dam is provided at the roof line similar to that at the floor lines, the danger of entering water is greatly enhanced. Most architects provide an additional flashing under the coping stones, or the entire parapet is provided with a copper, usually lead-coated, cap. Here again, fabric when totally enclosed is desirable. Figures 8–9 and 11–4 show some of these details.

h. Contemporary architecture has introduced methods which do away with parapet walls. These schemes carry the roof slabs over the exterior walls and employ gravel stop construction to hold back the roofing gravel and water which is pitched back to interior roof drains. Figure 11–5 shows one of such details. It will be noted that the edge of the projecting slab is covered by a copper fascia which is provided with a crimp near the bottom edge to prevent buckling due to expansion. Crimps may thus be used to serve a structural purpose as well as become an architectural feature.

11–3. Gutters and Conductors

a. Gutters may be "hung" or "built-in." The hung gutters are not frequently used in fireproof building. If used, they are attached in the same general way as for wooden and semi-fireproof buildings. Figure 8–7 gives a detail for a built-in gutter which illustrates the usual construction for masonry buildings. Where hung gutters are used the conductors or "downspouts" are also externally attached.

b. Where built-in gutters are used the conductors may be attached externally to the building and become an architectural detail or they may lead into cast iron conductors which are carried down in chases in the external masonry walls.

c. The section of the built-in gutter, the gauge of the copper and the location of conductors, or points of fixation are rather closely related. A recent study of these related characteristics has resulted in rather interesting data given in Table 11–1. It will be noted that the breadth of base, the angles which the wings make with the base, and the gauge of the metal have a distinct relation to the spacing of conductors and expansion joints. The expansion joint must be so constructed that it will protect

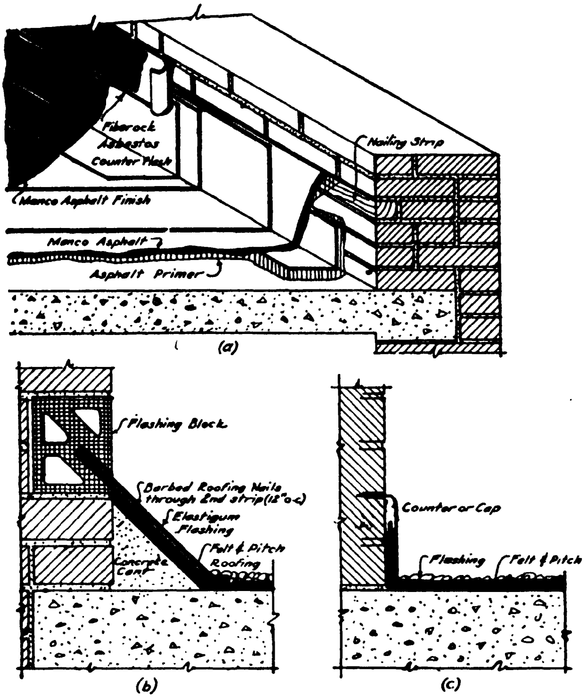


FIG. 11-4. Flashing Parapets. (a) felt with wood nailer; (b) concrete cant; (c) standard cap.

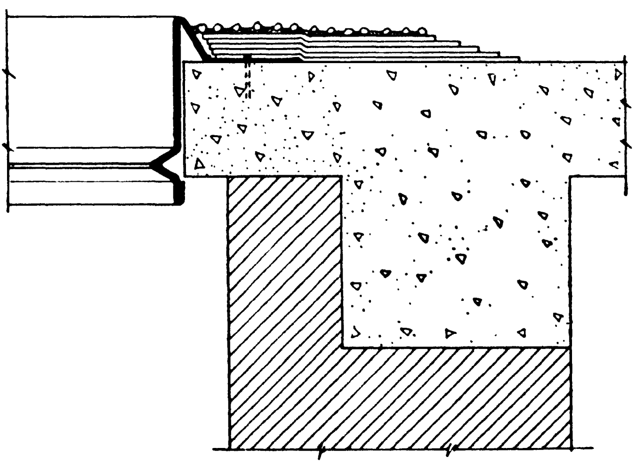


FIG. 11-5. Typical Gravel Stop.

against leakage but afford sufficient freedom of movement. This will be accomplished when the joint shown in Figure 11–6 is used.

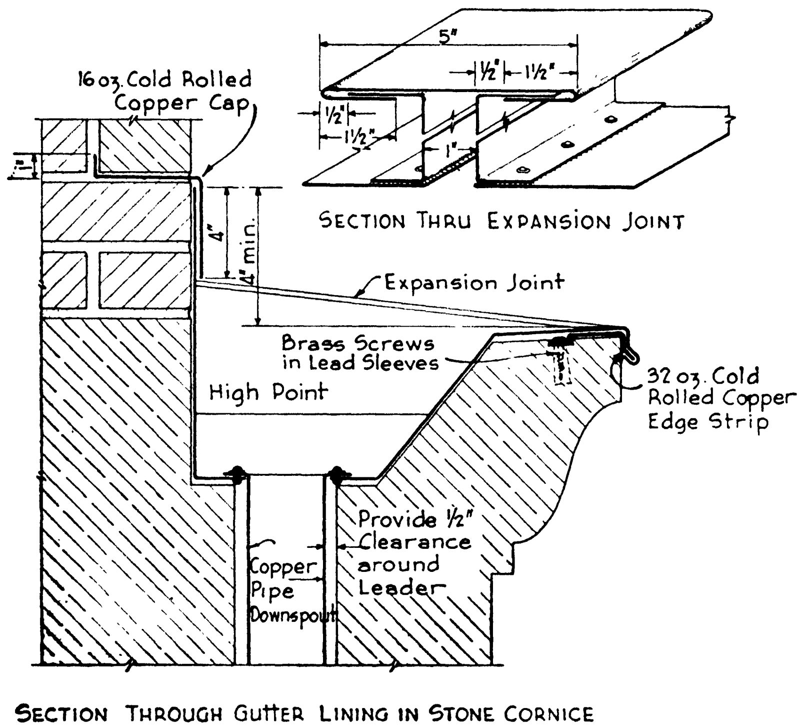


FIG. 11–6. Expansion Joint for Built-In Gutter. (*Courtesy Revere Copper and Brass, Inc.*)

11–4. Built-Up Roofing

a. Built-up roofs are used in most multi-story, fireproof buildings and are generally called "tar and gravel" roofs. They are generally combined with some form of insulation and are often combined with promenade surfaces. The felt used in these roofs may be so-called felt paper or may be asbestos paper, both treated with tar or asphalt pitch. Each of these should be laid in tar or asphalt depending upon the material used for impregnation of the felt or paper.

b. Specification Clauses—(Barrett Roof)

1. *Coat the concrete uniformly with Barrett specification pitch.*

2. *Over the entire surface lay 4 plies of Barrett specification, tarred felt, lapping each sheet 24½" over preceding one, mopping with Barrett specification pitch the full 24½" on each sheet, so that in no place shall felt touch felt.*

TABLE 11-1
DETERMINATION OF MAXIMUM DISTANCE BETWEEN EXPANSION JOINT AND DOWNSPOUT IN FEET

Weight in Ounces	Width of Base in Inches	Max. Angle / Min. Angle	90° / 25°	90° / 35°	90° / 45°	90° / 60°	90° / 90°	60° / 25°	60° / 35°	60° / 45°	60° / 60°	45° / 25°	45° / 35°	45° / 45°
16	4		22′-0″	24′-0″	25′-0″	26′-6″	29′-6″	19′-0″	20′-6″	22′-0″	24′-0″	17′-6″	19′-0″	20′-6″
	8		14′-0″	15′-0″	16′-0″	17′-6″	19′-6″	12′-0″	13′-0″	14′-0″	15′-0″	10′-6″	12′-0″	13′-0″
	12		10′-6″	11′-6″	12′-0″	13′-6″	16′-0″	9′-0″	10′-0″	10′-6″	11′-6″	8′-0″	9′-0″	10′-0″
	16		8′-6″	9′-0″	10′-0″	11′-0″	12′-0″	7′-0″	7′-6″	8′-6″	9′-0″	6′-0″	7′-0″	7′-6″
	20		7′-0″	8′-0″	8′-6″	9′-0″	10′-6″	5′-6″	6′-6″	7′-0″	8′-0″	5′-0″	5′-6″	6′-6″
	24		6′-0″	6′-6″	7′-0″	8′-0″	9′-0″	4′-6″	5′-6″	6′-0″	6′-6″	4′-0″	4′-6″	5′-6″
20	8		18′-0″	19′-6″	20′-6″	22′-0″	24′-6″	15′-6″	17′-0″	18′-0″	19′-6″	14′-0″	15′-6″	17′-0″
	12		14′-0″	15′-6″	16′-6″	17′-6″	19′-6″	12′-0″	13′-6″	14′-0″	15′-6″	11′-0″	12′-0″	13′-6″
	16		11′-6″	12′-6″	13′-6″	14′-6″	16′-0″	10′-0″	11′-0″	11′-6″	12′-6″	9′-0″	10′ 0″	11′-0″
	20		10′-0″	11′-0″	11′-6″	12′-6″	14′-0″	8′-6″	9′-0″	10′-0″	11′-0″	7′-6″	8′-6″	9′-0″
	24		9′-0″	9′-6″	10′-0″	11′-0″	12′-6″	7′-6″	8′-0″	8′-6″	9′-6″	6′-6″	7′-6″	8′-0″
	28		8′-0″	8′-6″	9′-0″	10′-0″	11′-0″	6′-6″	7′-0″	8′-0″	8′-6″	6′-0″	6′-6″	7′-0″
24	8		23′-0″	25′-0″	26′-0″	28′-0″	31′-0″	20′-0″	22′-0″	23′-0″	25′-0″	18′-6″	20′-0″	22′-0″
	12		18′-6″	20′ 0″	21′-0″	22′-6″	24′-6″	16′-0″	17′-6″	18′-6″	20′-0″	14′-6″	16′-0″	17′-6″
	16		15′-6″	17′-0″	17′-6″	19′-0″	21′-0″	13′-6″	14′-6″	15′-6″	17′-0″	12′-6″	13′-6″	14′-6″
	20		13′-6″	14′-6″	15′-6″	16′-6″	18′-6″	11′-6″	13′-0″	13′-6″	14′-6″	10′-6″	11′ 6″	13′-0″
	24		12′-0″	13′-0″	14′-0″	15′-0″	16′-6″	10′-6″	11′-6″	12′-0″	13′-0″	9′-6″	10′-6″	11′-6″
	28		11′-0″	12′-0″	12′-6″	13′-6″	15′-0″	9′-6″	10′-0″	11′-0″	12′-0″	8′-6″	9′-6″	10′-0″
32	8		41′-0″	44′-0″	46′-0″	49′-0″	53′-6″	36′-6″	39′-0″	41′-0″	44′-0″	33′-6″	36′-6″	39′-0″
	12		33′-6″	35′-6″	37′-6″	39′-6″	43′-0″	29′-6″	31′-6″	33′-6″	35′-6″	27′-0″	29′-6″	31′-6″
	16		28′-6″	30′-6″	32′-0″	34′-0″	37′-0″	25′-0″	27′-0″	28′-6″	30′-6″	23′-0″	25′-0″	27′-0″
	20		25′-6″	27′-0″	28′-0″	30′-0″	33′-0″	22′-0″	24′-0″	25′-6″	27′-0″	20′ 6″	22′-0″	24′-0″
	24		23′-0″	24′-6″	25′-6″	27′-6″	30′-0″	20′-0″	21′-6″	23′-0″	24′-6″	18′-6″	20′-0″	21′-6″
	28		21′-0″	22′-6″	23′-6″	25′-0″	27′-6″	18′-6″	20′-0″	21′-0″	22′-6″	17′-0″	18′-6″	20′-0″

3. *Over the entire surface pour from a dipper, a uniform coating of Barrett specification pitch, into which while hot embed not less than 400 pounds of gravel or over 300 pounds of slag, for each 100 square feet. The gravel or slag shall be from ¼" to ⅝" in size, dry and free from dirt.*

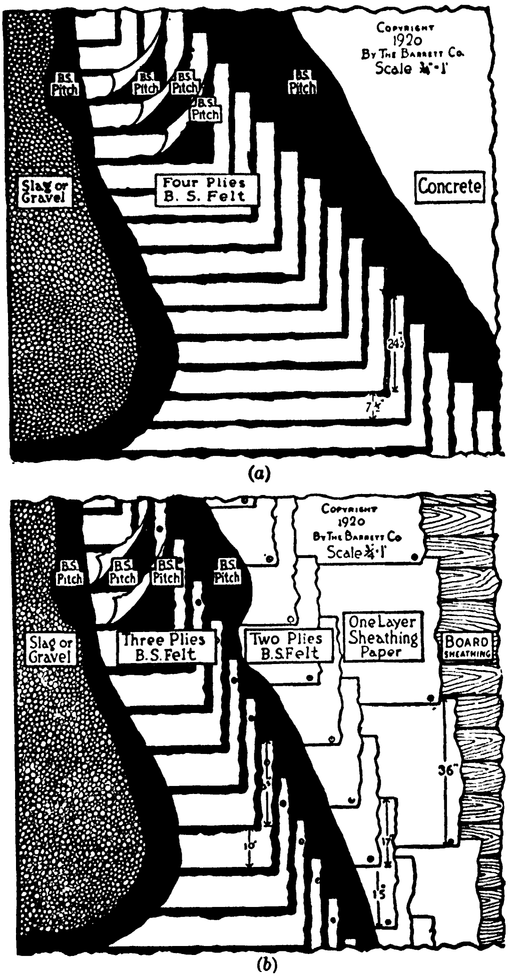


Fig. 11–7. Tar and Gravel Roofs. (a) concrete base; (b) wood base. (*Courtesy Barrett Mfg. Co.*)

4. *The felt shall be laid without wrinkles or buckles. Not less than 200 pounds of Barrett specification pitch shall be used for constructing each 100 square feet of completed roof, and the pitch shall not be heated above 400°F. Each ply of felt shall be turned up at least 5" at all walls and mopped with tar, same as specified above for roofing and shall be left ready for flashing.*

There are variations of this specification when asphalts are used and each manufacturer furnishes such specifications which if followed should give good results. Figure 11–7 shows the steps in the installation of a built-up roof.

c. Roof Drains. When flat roofs are drained the water is pitched to so-called roof drains. The detail of making these perforations of the roof slab and maintaining a tight roof has been studied for a long time. One of the types of drains very frequently used is shown in Figure 11–8. This drain is known as the Holt roof drain.

d. Insulation. The losses of heat through roofs are now being minimized by the use of various schemes for insulating them. The most usual of these places the insulation upon the top of the structural slab. The insulation very commonly specified is cork or some form of fibre board and either may be of the required thickness, from 1″ to 4″ thick. Another form of insulation coming into favor is cast upon the concrete just as concrete is, and possesses the characteristics necessary to afford insulation. Such materials are "Porete," "Mascrete," or "Aerocrete." All of these materials are made with portland cement treated in various ways, "Porete" and "Aerocrete" using neat cement, while Mascrete utilizes vermiculite, a mineral which is flaky and light in weight. None of these materials are quite as effective as cork, but they do possess the characteristics of greater compressive strength without excessive deformation and greater resistance to deterioration. The general detail of such construction is shown in Figure 11–9.

e. While insulation of the roof is commonly limited to the upper surface it is quite as important to insulate the edges of slab against the transfer of cold to the inside of the building. This is particularly important where roof voids occur and if suspended ceilings are used. If the rooms directly under the roof are air conditioned or have high humidities the chilling of the air above the ceiling by the cold transferred by the roof slab or the masonry enclosing the roof void will cause condensation in the roof void and start corrosion or rot of materials there used. It is therefore quite advisable to guard not only against cold transfer but also against the transfer of moist air through the ceiling. The suggested construction is detailed in Figure 11–9.

11–5. Promenade Roofs

a. Under the prevailing practice of providing setbacks in multi-story buildings, some of these roofs are used for passage or occupancy. In these cases the wearing surfaces are some form of granolithic, terrazzo or quarry tile. These roofs have caused a great deal of trouble and still do. There is no sure detail which will insure satisfactory results in all cases. There are

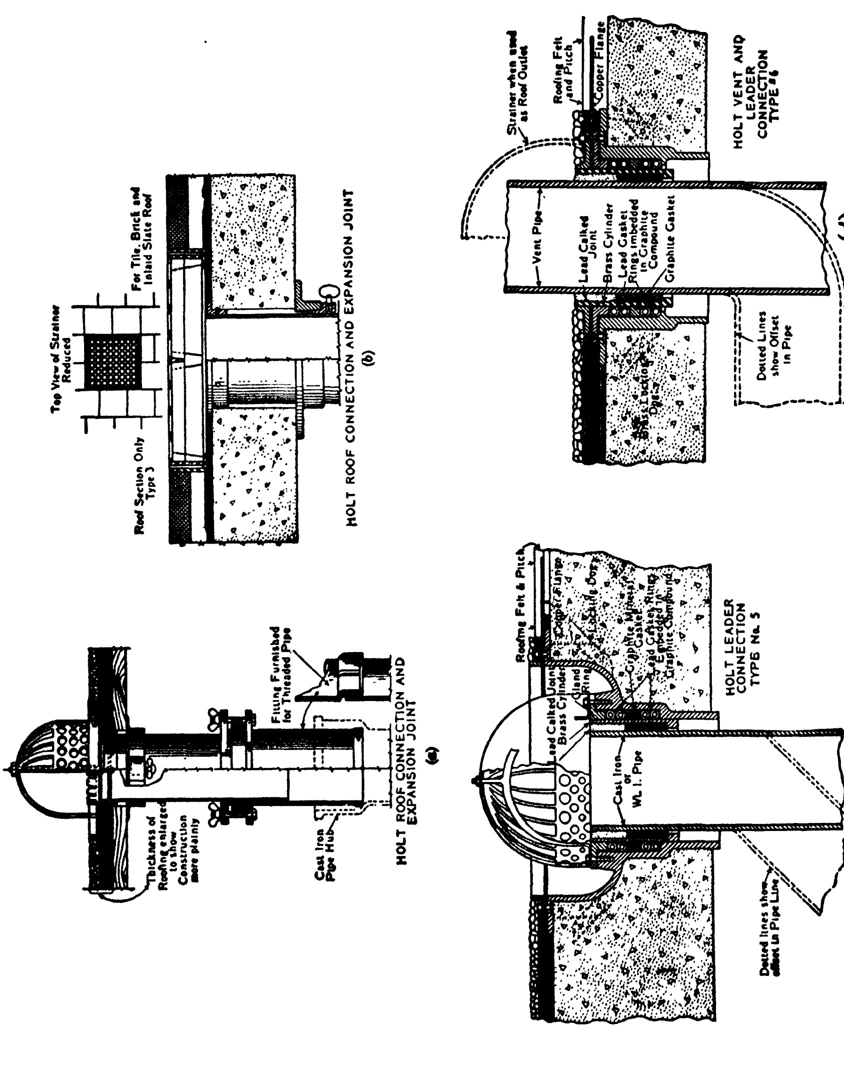


FIG. 11-8. Holt Roof Drains.

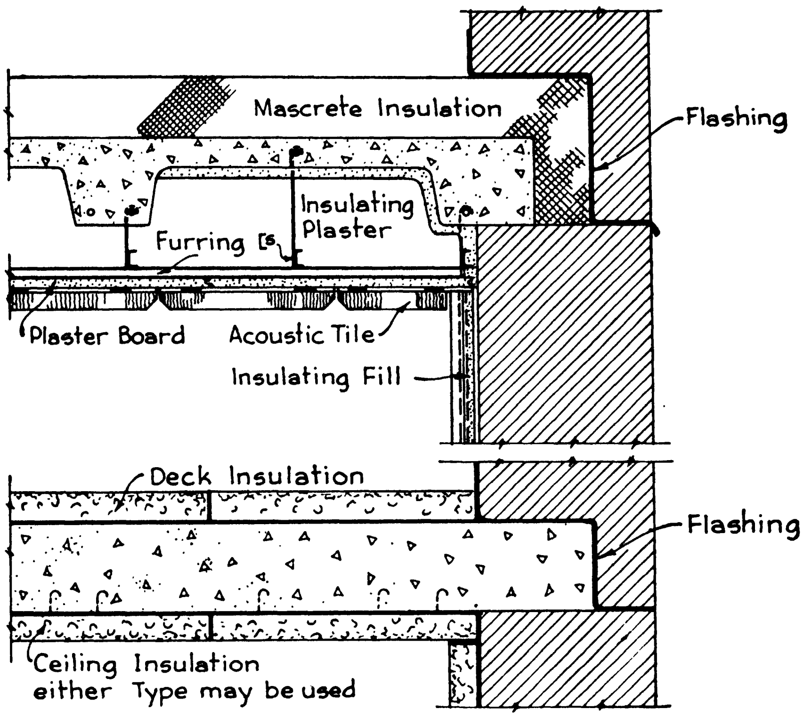


FIG. 11–9. Insulating Concrete Roofs.

several basic requirements that are involved in this work. Such roofs must be watertight, the tile must remain bonded to the roof structure, and the thermal expansion of the roof surfacing must be provided for. It is not simple to provide all of these requirements in one installation. Watertightness can only be effected by a watertight membrane attached to the roof slab. Any perforation of this membrane would lead to leaks, but it is necessary to provide mechanical attachment for the mortar in which the tile are laid or for the mesh used in the granolithic or terrazzo finish. Careful consideration of the thermal characteristics of the material used for the roof surface will aid in determining the location of expansion joints. It is therefore important to take into consideration the time of year the roof is laid and the thermal exposure which will ultimately ensue. Thus a roof laid in the low temperatures of late fall, winter or early spring will expand materially when heated by July temperatures. This will cause the maximum of movement and compression. The reverse will be true if the time of year is during the hot summer. The ideal time to lay such roofs is at a medium time such as late spring. The expansion joints will therefore need continuous attention.

11-6. Metal Roofing

a. Flat Seam. Copper, tin, lead and zinc sheets have been used for years where roof slopes are quite flat and where the roof has an unusual contour. Where flat seam roofing is used over concrete slabs or some types of gypsum plank, the details vary somewhat from the details used

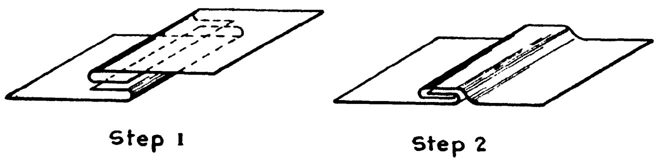


FIG. 11-10. Flat Seam Roofing. (*Courtesy Revere Copper and Brass, Inc.*)

for plank or wood roofs. Flat seam roofs are occasionally laid with a single lock but the modern procedure is to use the double lock in all cases. The roofing should be laid with 10 x 14 or 12 x 20 sheets applied the narrow way. The sheets should be tinned for 1½″ all around and on

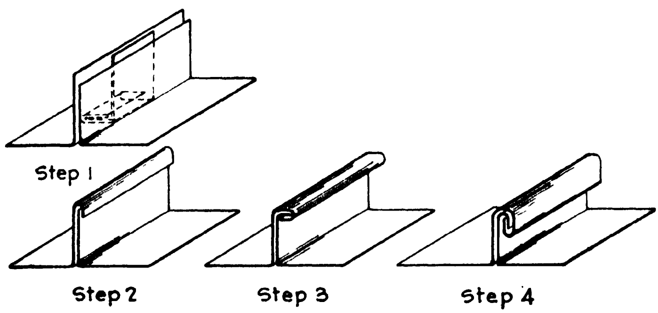


FIG. 11-11. Standing Seam Roofing. (*Courtesy Revere Copper and Brass, Inc.*)

both sides. The edge of the sheets should be turned up ½″ and should be properly notched. The sheets are secured to the roof by copper cleats locked into the seams and each cleat should be secured by two copper nails about ⅞″ long, using three cleats to each sheet. The cleats are usually cut long enough to provide for a turnback over the nails. After the sheets are locked, they are flattened out with a wooden mallet. By this method no nails are driven through the roof. The seams are then sweat with solder, the long seam being soldered first and then the short ones. The solder used is composed of one-half pig lead and one-half block tin with rosin as a flux. Figure 11–10 shows the laying of a flat seam copper roof, where the steps are:

(1) first sheet laid and cleats inserted,
(2) cleat turned back over nails,
(3) second sheet laid in place, and
(4) finished seam, sheet flattened.

b. Standing Seam. Standing seam roofs are commonly laid with 20 x 96 sheets and with 1″ upstanding finished seams. In this case only the cross seams are tinned 1½″ on one edge and 1½″ on the other to provide a ¼″ turnover for the seam. The standing seams are not soldered.

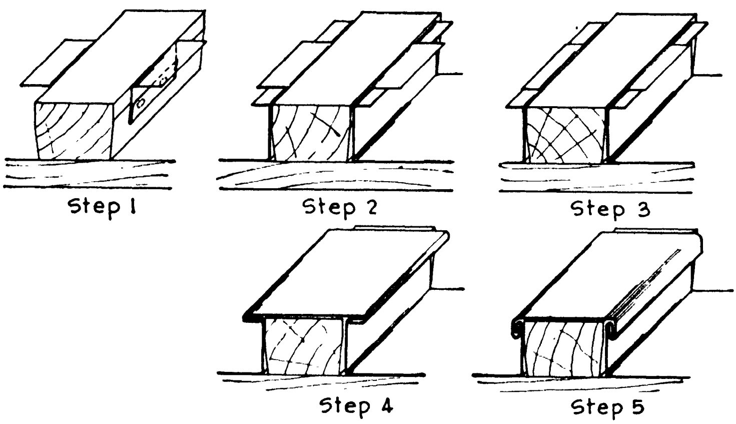


FIG. 11–12. Ribbed Seam Roofing. (*Courtesy Revere Copper and Brass, Inc.*)

Figure 11–11 shows the method of laying standing seam roofing in which the steps are:

(1) cleat and sheet laid,
(2) cleat turned over sheet,
(3) cleat turned over nails,
(4) second sheet laid,
(5) second sheet turned over cleats,
(6) seam partly locked, and
(7) standing seam complete.

c. Ribbed Seam. In order to produce the same effect as the standing beam but to give greater flexural strength the ribbed seam is used. The steps in laying this roof are shown in Figure 11–12 and are divided as follows:

(1) sheet laid and turned up against battens,
(2) cleats nailed to ribs and locked to sheets,
(3) cap cut and hooked over sheets, and
(4) ribbed seam completed.

CHAPTER 12

BUILDING SERVICES

12-1. General Considerations

a. The services in buildings are commonly considered to be the heating, ventilating, air conditioning, electrical light and power, and sanitary and water supplies. The plans for these services are usually prepared by engineers specially trained in their respective fields in cooperation with the architects and coordinated with the architectural and structural plans. These plans are referred to as "mechanical plans." Discussions of the design and details connected with these plans are not considered here and reference should be made to treatises on such matters. A survey of any of these documents in connection with a particular building will disclose the complexity involved. As these services are basic to the successful functioning of the building, no matter what its design, time must be allowed the engineers to do a complete job and the architects should stand ready to make such changes in design or structural detail to effect economical distribution of the services. Furthermore the architectural, structural and all mechanical plans must be integrated to make sure that they are all properly coordinated.

12-2. Mechanical Plans

a. Heating. Inasmuch as the radiators, registers, heating pipes, ducts and generating plants, ventilation and appurtenances and air-conditioning equipment and layout are included in the "heating plans," the mechanical engineer must prepare general floor plans showing distributing mains and returns, riser diagrams, branch or runout details, and defining details for any important areas or equipment. All of these will, of course, be combined with specifications describing the scope of the work, the materials used and the type and make of machines and fixtures.

b. Electrical. In a manner similar to that described above for heating, the electrical engineer prepares his main power distribution lines, floor plans showing the distribution of conduit lines, riser diagrams for the electrical shafts for vertical distribution, fixture location plans, plans for transformer areas, if required, and for panel boards and switchgears, and the specifications for all of these items, including number and gauge of wires, type and details of equipment and fixture types and schedules.

c. ***Plumbing.*** The plans prepared to show the location of the various drains, risers, runouts and vents for the plumbing fixtures will also be prepared separately and will show their exact location and sizes, as well as plans for the location and arrangement of pumps, tanks and the like. These plans, with the specifications which define the quality and type of all fixtures and corollary materials, provide the documents for the successful installation of the necessary equipment.

d. The general contractor should delegate one of his competent engineers to study the mechanical plans in connection with the architectural plans and provide proper clearances for all mains, ducts and other lines, as well as make sure that proper headroom is provided everywhere.

INDEX