Erection and Inspection of Iron and Steel Constructions

WRITTEN FOR THE USE OF

ARCHITECTS, ENGINEERS AND BUILDERS AND FOR CIVIL SERVICE CANDIDATES FOR THE POSITION OF INSPECTOR OF IRON AND STEEL

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CHAPTER. V.

Riveting.

A Rivet is a pin of metal consisting of a "head" and a "shank" or cylindrical body which is driven through two or more pieces of metal, and then the point is bent or spread and beat down fast, to prevent its being drawn out.

Material. Rivets are usually made of soft steel or wrought iron. Copper rivets are sometimes used where iron would corrode too quickly. The steel used for rivets will generally have an ultimate tensile strength between 52,000 and 60,000 lbs. per sq. in. In such steel the carbon may run down to .06 per cent. with the sulphur between .02 and .03 per cent. and phosphorus even lower. Rivet steel must be ductile and tough and must stand well the effects of variations in temperature. Wrought iron rivets are less affected by temperature than steel rivets. In driving field rivets or in riveting done after the parts to be riveted are in place, the usual method is to heat the rivets in a portable forge resting upon a temporary platform made of planks, and then each rivet is thrown through the air to the riveters at the various points where riveting is being done. While the rivet is thrown through the air it partly cools off. Steel rivets may thus cool down to a point where good riveting can no longer be obtained, while if the steel rivet is heated in the forge to a slightly higher temperature and then thrown through the air, the rivet is often injured and the steel composing it is red short or liable to crack at a red heat. Wrought iron is less liable to injury from overheating and is less affected by the drop in temperature immediately after leaving the forge. For these reasons wrought iron rivets are preferable to steel rivets for field riveting.

Manufacture. Rivets are made either by hand or by machinery. They are indicated by means of their length and diameter. The length of a rivet is the length of its shank when cold, and does not include the head. The size most commonly used is ¾ in. diam. rivet. In order to allow the hot rivet to enter holes easily the holes are punched 13/16 in. diam. for a ¾ in. rivet and in general 1/16 in. larger than the diameter of the cold rivet.

The hot rivet should not drop into the hole. It should require slight pressure to put it in. The diameter of the rivet holes must not be less than the thickness of the plate, other-

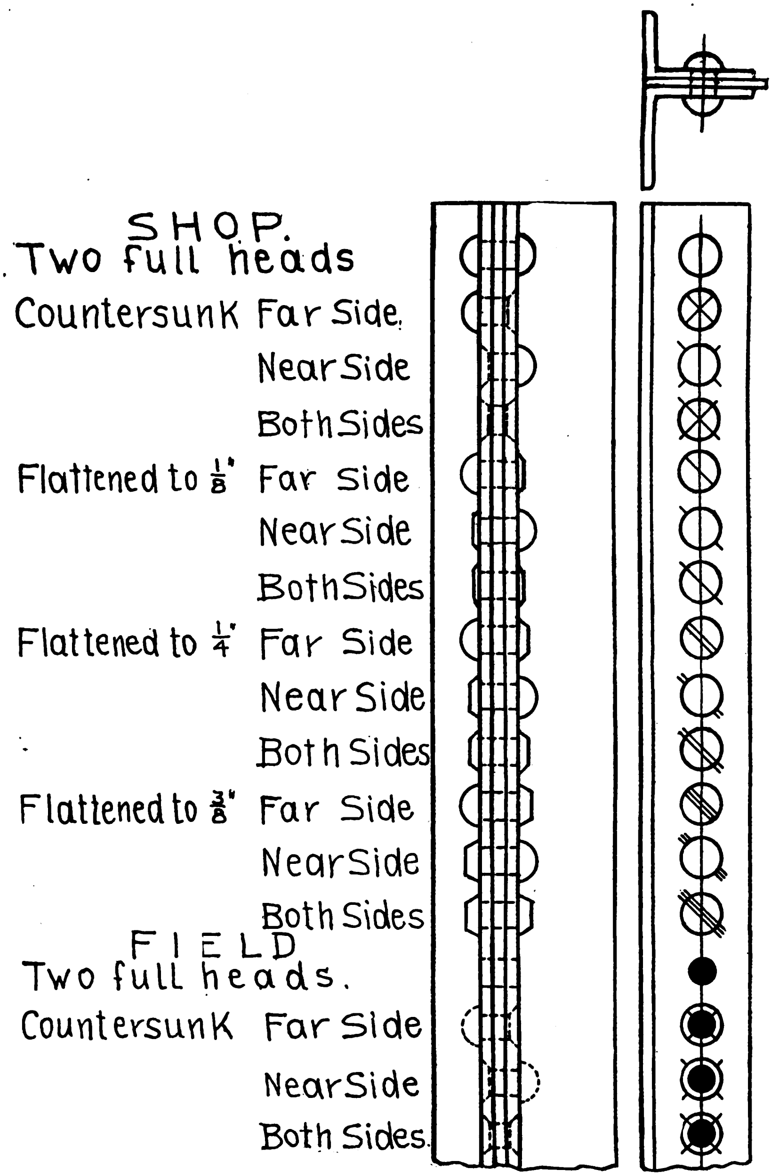

Fig 10—Rivet Signs.

wise the punch in the shop is liable to crush. For plates less than 5/8 in. 3/4 in. rivets are commonly used; for plates 5/8 in. and over, either 3/4 in. or 7/8 in. rivets are used.

The length of the rivet depends on the grip or total thickness of the parts joined by the rivet, and on the number of pieces to be joined by the same rivets. A hot rivet has a tendency to fill up any slight openings between the plates through which it passes. Hence to find the length of the cold rivet add to the grip about 1/32 in. for each opening between plates; then add about 1 5/8 times the diameter of the rivet for the new head and about 8% for filling up the hole which is slightly larger than the rivet. For instance, to join two 3/4 in. plates with 3/4 in. rivets we need for:

	Inches.
Grip	1 1/2
Opening between plates	1/32
New rivet head, 1 5/8x3/4	1 7/32
	2 3/4

to this add about 8% or 7/32 in. and this gives in all about 3 in. as the required length of shank for the cold rivet. The same value could be obtained from a table at the end of the volume which gives the length of rivet shanks to the nearest 1/8 of an inch. For countersunk rivets add only one half the diameter of the rivet for the new head. No rivets should be used which are too short; such rivets do not leave sufficient material for the new head and the usual result is loose rivets. Rivets that are too long require additional hammering and are hard to make tight.

Form of Rivets. There are in use several forms of rivets. These forms are generally indicated on drawings by the conventional signs shown in Fig. 10.

The diameter of a head of a rivet, when such head is finished with a tool called a "snap," should be about one and a half to twice the diameter of the shank.

The height of the head of a snap finished rivet should be about three-fifths the diameter of the shank.

Fitting Connections. Before riveting the two or more parts which are joined by this process have to be brought close together and in such a relative position that the corresponding rivet holes should match as nearly perfect as possible. In connections taking in a large number of rivets, like column splices or large gusset plates, the various pieces are made to match by hammering the buckled or bent parts with a sledge hammer and then by placing temporary bolts through about thirty per cent. of the rivet holes. When these bolts are made tight, all the holes in the connection will match, if the shop punching was carefully done. With careless punching some of the holes may not fall fair anywhere from 1/32 in. to ¼ in. and more. In such cases the holes are made fair by reaming, using either hand reaming or machine reaming. Where the rivet grip is to be two or more inches machine reaming is essential.

It is a common practice in building work where holes do not match by 1/16 in. or a little more, to drive a drift pin through the holes and make them match.

A drift pin is a round piece of steel made slightly tapering, and should be used only for easily bringing pieces together preparatory to riveting. The drift pin may also be used in correcting burrs and in smoothing out holes. It should not be used, however, to enlarge a hole. Forcing a drift pin through a hole injures the metal, causing a hardening of the material around the hole, with a corresponding increase in the elastic limit and a decrease in ductility. This is considered injurious, and good specifications prohibit the use of drift pins for enlarging holes. Instead of this, reaming should be used whenever possible. For this purpose compressed air reamers are employed on many good structures. The action of these reamers is similar to that of a drill of large diameter, and the holes are made perfectly smooth. In some cases it will be found that one or more holes have been omitted by mistake in some of the parts to be riveted. This can be remedied only by drilling through the blind hole. It also may happen that the men in the shop have punched more holes than required. In good work any hole which is not to be filled in by a rivet or bolt is plugged up with lead. This prevents corrosion to a certain extent; it also fills up the cross section, which is desirable in compression members.

Riveters. The work of fitting up connections is partly done by "fitters" and partly by the riveting gang. A riveting gang consists usually of four men, i. e., heater, passer, holder up, and riveter. Such a gang will drive about 250 rivets in a day of eight hours. Each man gets about five dollars a day, and adding to this the cost of supervision and of the materials, together with the depreciation of tools, etc., the cost of field rivets will not be far from ten cents apiece. Where two or more riveting gangs are employed there is usually a boss riveter and fitter, at about six dollars a day, who is responsible to his superintendent for the work done by the riveting gangs and fitters.

Tools and Instruments Used in Riveting. Following are the essential parts of a riveting outfit:

The forge for heating rivets.

A dolly bar for backing up the old rivet head while the new one is being formed. The dolly is a round iron bar, with one end hollowed out, or cup-shaped, in such a manner as to fit the rivet head. A dolly bar weighs from 15 to 25 pounds.

The snap is a hollowed out or cup-shaped hammer used for forging the heads.

The forging hammer is used in hand riveting for upsetting the shank or the red hot rivet and for roughly shaping a new head. Forging hammers usually weigh about five pounds each.

In hand riveting, after the new head has been shaped roughly with the hammer, one of the men, usually the rivet "passer," holds a snap against the rough rivet head while the riveter strikes a few good blows on this snap. This gives the rivet head a spherical form.

A portable air compressor, popularly known as a "gun," is used for riveting in work where machine riveting is required. The shape of the driving hammer is similar to that of the snap. Hence no extra snap is used in machine riveting, the rivet head being formed and made spherical in one operation.

The buster is a blunt-faced hammer having a cutting edge used in shearing off the heads of rivets.

After the head of a defective rivet has been cut off, the balance of the rivet is driven out from the hole by means of a special hammer having a tapering head. This hammer is known as the backing-out punch.

Drift pin is a round piece of steel, slightly tapered, and used for the purpose of drawing pieces together so as to make the holes match preparatory to riveting. Each riveting gang is provided with several drift pins.

A ten-pound sledge hammer is used in straightening out all lugs and splice plates which have been buckled or distorted during shipping or during erection.

The sledge hammer is further used in connection with backing out punches, busters, etc. It is also used with snaps to form cup-shaped rivet heads, and for this reason it is sometimes referred to as the cupping hammer.

The ratchet is a portable hand drill used for making holes on the job where same have been omitted.

The steamboat ratchet is a turn-buckle device to which cables are attached. It is used for bringing up or pulling columns into a plumb position.

We may add to this list bolts, rivets, washers, fillers, and other minor parts. Each gang is further provided with several planks for a temporary scaffold and with ropes or chains for fastening their scaffold to the steel work.

Heating Rivets. Good riveting depends to a considerable extent upon the care used in heating. Rivets carelessly heated may burn; this greatly reduces the strength of the rivet. In addition, after the rivet is driven there is no way of telling whether the rivet was burnt or not, as the head may look good while the shank is weak and brittle.

Steel rivets should be heated uniformly to a dull red; the orange color must not be passed. The rivets should be put in place as soon as they reach this temperature and should be worked as quickly as possible. No steel rivet should be worked at a blue heat.

With machine driven rivets the point of the rivet is often heated more than the head. This facilitates the upsetting and flowing of the rivet metal into the hole. When the riveting is done by hand the pressure made to bear upon the rivet through successive blows is considerably smaller. Hence the rivet should be heated uniformly, or the head should be even hotter than the point, otherwise the blows which will upset the rivet and make it fill the hole near the point will have little effect at the other end, and the rivet may not quite fill the hole near the original head.

Iron rivets can be heated without serious injury even to a "wash" or "waste" heat, which is reached when the slag in the metal begins to soak out. Like steel rivets, iron rivets should not be worked at a blue heat.

The following additional rules if followed will contribute towards good riveting:

1. The forge used for heating the rivets should be placed as near to the point of use as practicable.

2. Only a few rivets should be placed in the fire at a time, otherwise some are liable to be left in too long and be burnt.

3. When the rivets are too long it sometimes happens that the heater will burn the points on purpose, just to shorten the shank. This is bad practice and should never be allowed.

4. Re-driving cold rivets injures the heads and should be prohibited.

5. Caulking of rivet heads may injure both the rivet and the plate, and has no excuse in structural work. It is used to make loose rivets appear tight, and should not be permitted. All caulked rivets should be cut out and replaced.

6. Rivets should not be heated several times, nor should they be allowed to remain too long in the forge. In both cases a chemical action of decarbonization and oxidation takes place, and this may injure the rivet when prolonged.

Riveting may be defined as the process of passing a hot rivet through holes in pieces to be united and of forging another head from the projecting shank. It is generally performed by means of air, steam or water power machines, or by hand.

Hand Riveting. In this kind of work the red hot rivet is passed through the hole; it is then held up in place by means of the iron bar called "dolly." This bar is hollowed out at one end in the form of a cup that fits on the rivet head. The dolly is pressed against the rivet head by one of the men, the "holder up," and in the same time the shank is upset by the riveter, who uses a forging hammer with a flat face. The end of the rivet is roughly hammered to a convex point. It is then finished or rounded up, just as the rivet loses its red heat, by placing a "snap," or hollowed steel tool, against the rivet head, and by striking a few blows with a heavy sledge hammer.

Machine riveting is performed by pneumatic, steam or hydraulic riveting machines. It is better and generally cheaper than hand riveting. The practically steady pressure brought by the machine upon the rivet enlarges the shank and squeezes it into the hole, thus thoroughly filling up all the irregularities of the hole, in addition to forming the new head.

Machine driven rivets can be easily distinguished from hand driven rivets. In the first case the rivet head is smooth and more regular, with exception of a slight burr which is often found on the new head and which is due to the die having caught the rivet a little off the centre. Furthermore, machine driven rivets will generally fill up all the irregularities of the hole; when such rivets have to be cut out, after chipping off one head, the balance of the rivet can be pushed out only by means of a pin and hammer, and with great difficulty, while in some instances the rivet will have to be drilled out.

In hand riveting when one head is cut off the shank can be driven out easily, or it will actually drop out. This shows how little hand riveting fills up the irregularities of the hole as compared to machine work. Hand driven rivets also have their heads covered with marks made by the hammer and by the shifting of the snap during forging.

In comparing machine with hand riveting, we may note the following points to the advantage of machine work:

1. In machine riveting the holes are better filled.

2. The rivet is more quickly headed, due to a larger pressure, hence there are, as a rule, less loose rivets than with hand riveting.

3. The work is more uniform and more reliable.

4. Machine riveting is generally cheaper.

Shop and Field Rivets. Hand riveting done in the shop is generally stronger and better than field riveting done in the same manner. With machine riveting and good supervision there is little difference if any between shop and field work. Some specifications require ten per cent. more field rivets than shop rivets for the same connection, when driven by machine in the field, and twenty-five per cent. more when driven by hand. Machine rivets are more uniform in strength than hand driven rivets.

There are several causes which tend to make shop riveting better than field work:

1. Parts to be riveted together can be handled more conveniently in the shop.

2. The heating of the rivets is done under more favorable conditions and close to the riveting machine.

3. Powerful stationary riveting machines are sometimes used. These are definite in their action and results and will generally turn out better work than the portable field riveting machines.

4. The conditions of inspecting the work in the shop are more favorable. This results in better inspection.

5. The stock of rivets kept in the shop is, as a rule, considerably larger than that kept on the job. This avoids the use of short rivets when the rivets of proper length do not arrive on time, as it sometimes happens in field work.

The New York Building Code allows for steel rivets in shear a unit stress of 10,000 pounds per square inch for shop rivets, and only 8,000 pounds per square inch for field rivets. This gives for a ¾-inch shop rivet 4418 pounds shearing resistance, while the corresponding value for field work would only be 3534 pounds. With good field riveting, however, 4000 pounds per ¾-inch rivet in shear may be safely assumed.

Rivets vs. Bolts. Good riveting is better than bolting for the following reasons:

1. The rivet is forced into the hole and fills it completely. This adds strength in the case of compression members.

2. Riveting furnishes a more rigid connection than bolting. For this consideration riveting is generally used in column splices.

3. The rivet heads upon cooling draw the riveted parts more firmly together.

4. Each rivet filling its hole, moisture cannot work its way into the joint; thus deterioration through rust around a rivet is prevented or delayed.

5. Stresses are likely to be more evenly distributed among a number of rivets than among the same number of bolts. To illustrate this, consider a hanger A (Fig. 11) connected to the web of a channel B by means of two ¾-inch

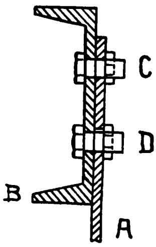

Fig. 11—Bolted Hanger.

bolts. The bolt C was first put in. The second bolt hole in the plate was punched 1/16 of an inch too high. The lower hole was elongated and the bolt D was put in, but as shown in the diagram this bolt takes no load in shear and hence the upper bolt may be overloaded. The only use of bolt D is to slightly prevent the downward motion of the hanger through the friction caused by making this bolt tight. By using rivets, although the lower holes do not match, the upset shanks will completely fill the hole spaces, and both rivets will share more evenly in resisting the shear due to the load supported by the hanger.

It often happens that splices in columns along the walls cannot be conveniently riveted on account of lack of room. In such cases the adjoining wall may sometimes be broken off for one or two feet next to the column splice, thus making riveting possible. Where the adjoining walls are weak, and where breaking into them may render such walls unsafe, as many of the holes as are not accessible for riveting are either provided with ¾-inch bolts or else such holes are "plugged up" by driving through them red hot rivets and then upsetting the shank by means of a small hand hammer, or by using one end of a dolly bar. Where bolts are used they should be made tight, and then the thread of each bolt should be checked or distorted in order to prevent the loosening of the bolt. From what was stated before, it is obvious that rivets in plugged up holes, although not good looking and with a non-snapped head, are often preferable to ¾-inch bolts in 13/16-inch holes.

Specifications. Riveting is more expensive than bolting, but riveted joints lend to a steel structure the rigidity which is essential to the safety and durability of the finished building. Where rigidity is lacking, the ceilings may crack, the walls may open, and the whole structure may become unsafe and useless in a comparatively short time. The attention paid to rigidity depends mainly upon the purpose and the proportions of the structure. A very narrow and tall building will have to have strong, rigid joints to resist the effect of wind pressure. A structure used for manufacturing purposes where heavy machinery is employed requires rigid connections to resist the effect of accumulated vibrations due to repeated pounding of such machinery.

For buildings used for printing presses or similar heavy machinery the specifications usually require all connections to be riveted.

In loft and office buildings it is customary to have all column splices and all connections of beams to columns or beams to beams within 3′-0″ from a column, riveted; all other connections bolted. There is nothing in the New York Building Code that requires riveted field connections in structural work, with the exception of a minor restriction shown in the difference between the allowable working stresses for field rivets and field bolts. The Building Code allows, i. e., in shear:

For field rivets, 8000 pounds per square inch, which amounts to 3534 pounds for a ¾-inch rivet.

For field bolts, 7000 pounds per square inch, which amounts to 3372 pounds for a ¾-inch bolt.

The rivets and bolts being steel.

This shows that about 14 per cent. more field bolts than field rivets are required in a connection to comply with the law. In the case of a twelve-story loft building where this condition was fulfilled with regard to column splices, and where the iron erector was given the choice between bolting and riveting at the same price, he chose bolting. Bolting column splices in anything like a twelve-story loft is considered poor practice and should not be encouraged.

Faking Riveting Work. Poor field riveting may naturally be expected from men who just start into this kind of work and who have little experience in overcoming difficulties and new conditions which constantly arise before them. Most of the defective work, however, is due to carelessness, lack of active supervision and unreasonable speed, caused by a desire of some gang to turn out more work than other gangs in the same time, or by the compelling action of some foremen or superintendents, who will discharge a gang doing first rate work when the number of rivets driven in a given time falls below their expectation. Poor work is sometimes due to defective tools, to holes not matching correctly, to driving rivets through such holes without reaming, and to using rivets of improper lengths. Defective work may also be caused through careless heating, slow and careless driving, improper backing up and so on.

Most of these faults are manifested in the finished rivets, either through unsatisfactory size and shape of the new rivet head or through the loose condition of the rivet.

Faking generally consists in making a loose rivet appear tight under a hammer test. Here are some of the common ways:

1. By going around the head of the rivet with a caulking tool. This will make the rivet sound all right, and the mark due to caulking will generally not be noticed unless carefully looked for.

2. By driving over the cold rivet heads, using a smaller snap.

3. By hammering or in any way deforming the original heads of the cold rivets. There is absolutely no reason for such action, and any such rivets should be regarded with suspicion.

4. By placing the snap sideways upon the rivet and striking it a few good blows with a sledge hammer. The snap is usually applied below the head, where it cuts a ridge in the plate and makes the rivet appear tight by forcing part of the plate metal under the head.

A similar action takes place in machine riveting when, after driving all rivets in a given splice, the riveter goes over loose rivets with his riveting machine and re-drives the cold rivet heads. This usually results into forming a groove or circle all around the rivet head. In few cases such a groove or a snap mark as above described may be formed in driving a perfectly tight rivet, and due judgment is necessary in condemning defective rivets.

It is a good policy to dismiss any gang of riveters which persistently continues to do poor work.

Testing Rivets. Complete rivet testing involves a test of the rivet metal for tensile strength, bending and ductility. In addition, the riveting inspector must observe the following points:

1. The rivet holes must match correctly.

2. All rivets must be heated properly.

3. Each rivet must be of sufficient length to fill the hole completely.

4. The edges of the rivet heads must be free from caulking marks.

5. The plate metal around the head should be free from any ridge or impress.

6. Both rivet heads should fit tight against the plates.

7. The rivet heads should be free from cracks.

8. The rivet heads should be concentric.

9. The rivet heads should be of full size.

Loose rivets are easily detected by means of one or two blows struck with a one-pound hammer upon the rivet head. In case of rivets driven horizontally in a column splice, for instance, strike one blow downward against the head of the rivet at an angle of about 60 degrees to the length of the rivet; then strike a symmetrical blow upward. If the rivet is loose a jar or rattle will be produced. By holding one finger against one head while the other head is struck with the hammer even the slightest jar can be easily detected. In absence of a hammer, any piece of iron, even a cold rivet, may be used to perform this test.

Rivets are easier to examine before being painted; for this reason it is customary in good work not to paint any column splices until all rivets have been approved by the inspector.