Some Practical Aspects of Column Base Selection

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The following three methods can be used effectively to prepare a landing site for the erection of a column:
1. Leveling plates (see Fig. 1)
2. Leveling nuts (see Fig. 2)
3. Preset base plates (see Figs. 3 and 4)

LEVELING PLATES

For small- to medium-sized base plates, say up to 22 in., the use of leveling plates is probably the most effective method to prepare for column erection. The leveling plates are usually ¼ in. thick and are sheared to the same size as the base plates. Sometimes the leveling plates are made about 1 in. larger in each direction than the base plate, but this is not necessary. It is not necessary to remove the edge burr left by the shear. Shearing may cause the plate to curl and if so the plate should be flattened to within standard plate flatness tolerances. The holes in the leveling plates are usually made $\frac{3}{16}$ in. larger than the anchor bolt diameter, but this is not a firm figure and may vary among fabricators. Leveling plates are sent to the field in advance of the main column and grouted in place, usually by the general contractor or foundation subcontractor. Since this work is done in advance it permits time for an accuracy check. Once set, plates are relatively tamper proof. If a leveling plate is found to be out of level or at the wrong elevation, it is easily removed, the grout broken up and cleaned away, and the leveling process repeated correctly.

When a column is first "stood-up" and the hook let go, there is a short period of time when it must stand alone before being tied in with beams or guy cables. During this interval the column may be subject to wind loads; jostled by other members being hoisted into place; or accidentally hooked by an errant choker or the eccentric loading of a float and the connecting erector. The column base, therefore, should offer some moment resistance. The leveling plate method provides a solid contact surface; safety is one of its prime attributes.

Leveling plates can be used with any number of anchor bolts and for square, rectangular, ell-shaped, or offset base plates.

Some designers express concern that the leveling plates may not be set flat; yet these same individuals do not hesitate to land a wall bearing beam on a preset bearing plate or to set a column on top of a beam whose flanges may be slightly out of parallel. Loss of contact between leveling plate and base plate may also be the result of inaccurate milling of the column shaft, curling of the column base plate caused by the heat of welding, or the column shaft being slightly out of plumb during the erection process. If the gap persists after plumbing, it should be treated the same as gaps at column splices.[1] Tests have proven that columns with initial gap at a splice have essentially the same load capacity as columns without splices.[2] There is no reason to believe this would not be true at column bases.

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LEVELING NUTS

Fortunately, when the size of the base plate becomes so large as to make the use of a leveling plate impractical, there is another method available for setting column base plates.

In this procedure, generally, four or more anchor bolts are utilized, each bolt having two nuts and two heavy

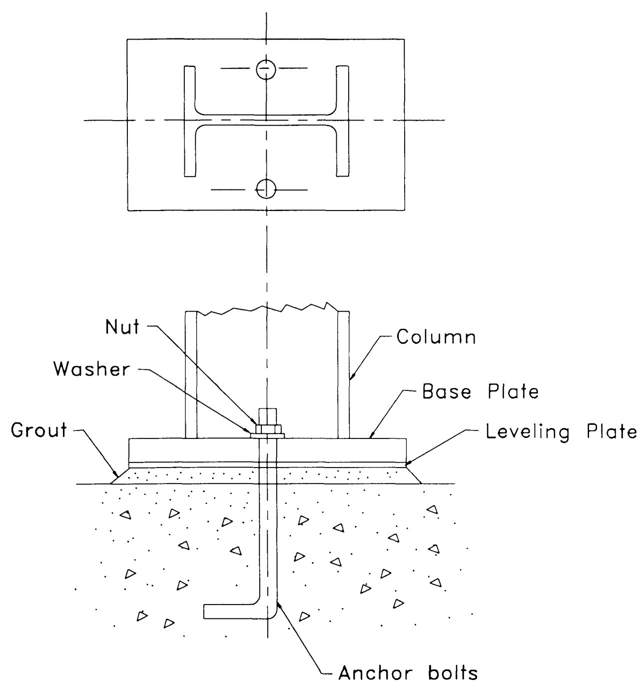

Figure 1. Column base w/ leveling plate

washers. The anchor bolts must be set far enough apart to be able to develop an effective resisting moment to overturning. The base plate is generally large enough so that the bolts can be located outside the perimeter of the column near the corners of the base plate. Avoid a closely spaced cluster of anchor bolts which will act as a fulcrum about which the column might rotate and topple. Also the leveling nut method is not recommended if the bolts must be closely spaced in one direction, as on a narrow wall. The bolts will not develop good restraint in that one direction. In this situation it would be better to use a leveling plate or to design the wall with a pilaster so as to utilize a more nearly square base plate.

When the leveling nut method is used, usually one of the lower nuts is brought to the proper elevation, allowing for the thickness of the heavy washer which must be placed on top of the nut and below the base plate. This bolt and nut is then spray painted to identify it as the nut with the proper elevation. The other nuts are brought to the same elevation. If someone bent on mischief attempts to change the elevation of the key nut, the broken paint will expose the misdeed and help to re-establish the proper elevation.

When it comes time to erect the column, it can be dropped into place very quickly and efficiently and the upper washers and nuts installed. One of the major advantages of the leveling nut method is that it can accommodate a base plate slightly out of level or a base plate curled by the heat of welding. Leveling nuts are best used for base plates ranging up to about 36 in. in size. Beyond this size, bending of the base plate may become a problem, and shipping the base plate separately should be considered.

PRESET BASE PLATES

Large-sized base plates (36 in. and larger) are often shipped to the job site and set in advance of the start of erection. This is done because these large plates are often so heavy and cumbersome that they make shipping and handling of the column very difficult if not impossible.

These large base plates are usually furnished with some kind of leveling devices in the form of bolts or threaded rods. Shims and wedges can safely be used in this situation because there is not an attached column shaft waving around in the sky. A three-point support (like a milking stool) is satisfactory. If leveling bolts are provided, small steel plates must be placed under the points of the bolts so they won't dig into the concrete.

When colossal-sized (say over four tons in weight) base plates are required, an angle frame is often supplied in advance. This angle frame is carefully leveled and filled with concrete which is screeded off accurately and results in a

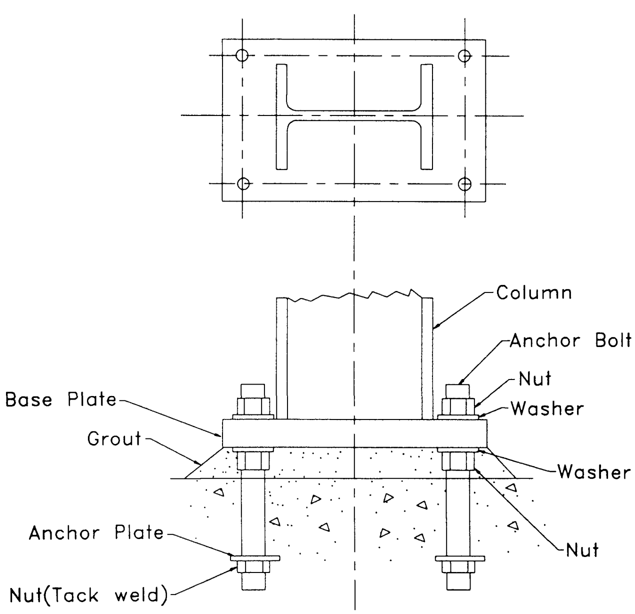

Figure 2. Column base w/ leveling nuts

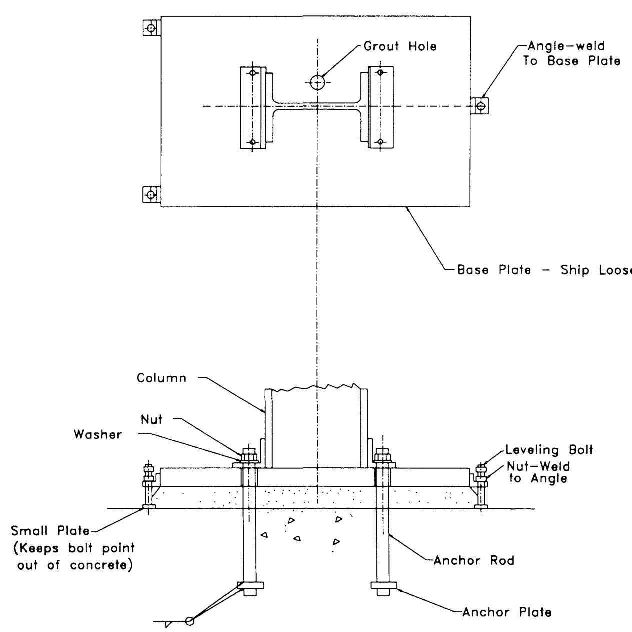

Figure 3. Heavy column base

level concrete pad of proper elevation on which the column base plate is directly placed (see Fig. 4).

ANCHOR BOLTS

The selection of the column base type is determined primarily by the geometry of the foundation and the nature of the loads which influence the base. The geometry consists of the shape and location of the foundation—whether it is a square or rectangular footing, pile cap, a narrow wall, a pier or a pilaster, isolated or part of a wall, or at a corner of a wall. The loads may consist of vertical gravity loads, uplift, shear, moment, or combinations of any of these. Erection loads, for example, may be a combination of gravity load and moment (see Fig. 14).

Columns subject to gravity loading alone, theoretically, would not need any base anchorage. During the erecting of a column, however, there is a brief period of time, before the column is stabilized with beams or guys, when a column must stand on its own. For example, a 14 in. wideflange freestanding column 31 ft long, being scaled by an erector on a breezy day, will require a resisting base moment of approximately 5 ft kips. Some kind of anchorage is required to hold the base plate to the foundation—usually anchor bolts or rods. Anchor bolt and anchor rod mean the same thing in this text, and the terms are used interchangeably as they are in the trade. Anchor bolts are primarily a tension device. To prevent the anchors from pulling out of the concrete—should the bond stresses be exceeded—hooks, plates, or other shapes are added to the embedded portion of the anchors (see Fig. 10).

Anchor bolts vary in size from approximately $\frac{3}{4}$ in. diameter to $2\frac{1}{2}$ in. diameter with $\frac{3}{4}$ in., $\frac{7}{8}$ in., 1 in., $1\frac{1}{4}$ in., and $1\frac{1}{2}$ in. being the most common diameters. Avoid specifying bolt diameters in sixteenths and eighths (except $\frac{7}{8}$ in. and $1\frac{1}{8}$ in.) as these sizes may not be readily available. Anchor bolts less than $\frac{3}{4}$ in. diameter may lose section due to corrosion and result in less than anticipated service life. Anchor bolts greater than $2\frac{1}{2}$ in. diameter may be difficult to find nuts for and wrenches to fit.

Anchor bolts, subject to corrosive conditions, may be galvanized. When ordering galvanized bolts, specify that the threads be "chased" so the nuts will work freely. If anchor bolts must be galvanized, it is best to specify A307 and A36 material to avoid the embrittlement sometimes resulting when high-strength steels are galvanized. Weathering steels may also be used where anchor bolts are exposed to corrosive atmospheres, but with the understanding that they will rust and stain the foundation concrete if so exposed.

Most anchor bolts are made from A36 material. Other materials used are A307, A325, A572, and A588. When

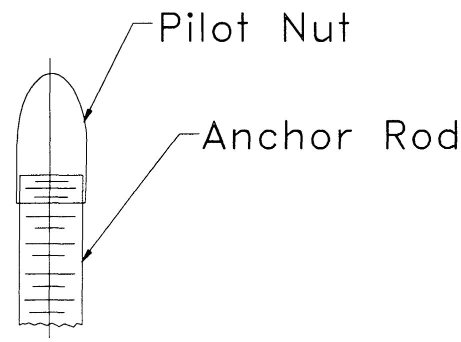

Figure 5

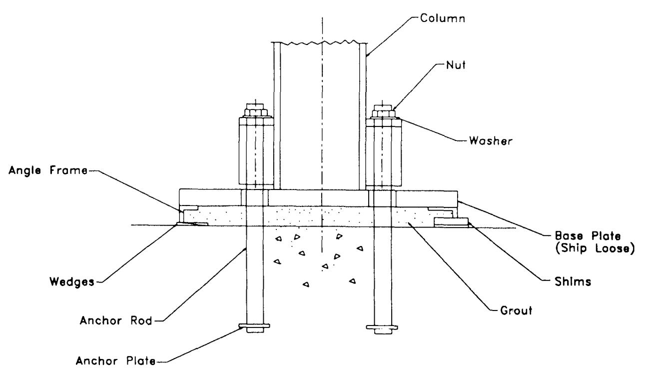

Figure 4

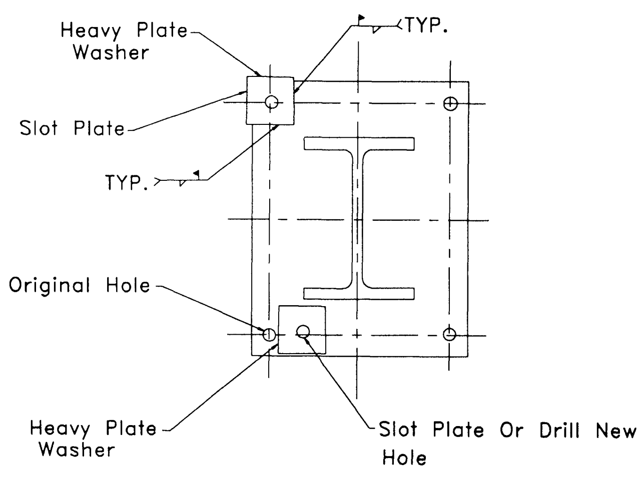

Figure 6

higher strength is required, 4140 steel is sometimes used. If it is necessary to identify the exact type of steel used, certified mill test reports should be requested from the supplier. Normally this is not required unless the anchors are subject to significant tension. See Table 1C, page 4-4, AISC *Manual of Steel Construction,* 8th ed.[1] for other rod steels.

Most anchor bolts come with hex nuts. Occasionally a supplier may furnish square nuts. This is of little consequence. In tight situations where bolt projection is critical a half nut may be utilized. In rare cases, where the anchor bolt is not allowed to project above the top of the base plate, the plate can be counterbored so the nut will set into the depression. This is expensive and should not be used unless absolutely necessary. Of course, the plate must be thick enough to permit the required depth of counterboring. Generally, because most base plates will be provided with oversized holes, it is necessary to provide thick erection washers under the nuts. These are usually $\frac{5}{16}$ to $\frac{1}{2}$ in. thick and must be accounted for when the bolt projection is established. The use of lock washers on anchor bolts is seldom justified. Split-ring type lock washers have a relatively small outside diameter and have been known to suck down into the oversized holes resulting in an ineffective anchor bolt. It is better to spike the threads or use double nuts than to use lock washers.

Anchor bolt projection is shown in one of two ways, depending on the custom of the fabricator–erector. The top end of the anchor bolt may be dimensioned either down to the underside of the base plate, as in Fig. 11A, or down to the top of the concrete, as in Fig. 11B. During the concreting operation, it is very difficult to get the concrete to the exact elevation. This must be recognized by those who choose to dimension to the theoretical top of concrete. (Theoretical and as-built usually differ.) However, both methods are used extensively and both seem to work.

Provide plenty of extra threads on anchor bolts. It is very frustrating for an erector to have a nut "shank out" (run out of threads). In such an event the nut must be backed off and extra washers added. Stacked washers are not a problem on anchor bolts and special restrictions should not be imposed.

When anchorage is required in concrete which is already poured, a hole is core drilled in the concrete and a straight anchor bolt with a swaged shank may be grouted in place. The swaging consists of dents pounded randomly in the shank. A similar result can be obtained by depositing little blobs of weld metal on the shank (see Fig. 12). Concrete reinforcing rods with threaded ends have been successfully used for this application. In any event such bolts should be used with caution. If the dents or blobs are a bit sparse or the concrete is not properly cured, then the anchors may pull out of the concrete. Anchor bolts of any type should have proper concrete embedment.

Avoid anchor bolts with upset threads unless absolutely necessary. The source of these rods are scarce and delivery times are long. Avoid specifying unusual threading requirements such as NF threads or left-hand threads.

Anchor bolts, when used with the *leveling nut* method of setting column bases, should have a nut and heavy erection washer both above and below the base plate. The washers are used to prevent the nuts from attempting to push through the oversized holes. Extra thread should be supplied for lower nut adjustment (see Fig. 2).

Rods with full length threading and nuts on each end can be used for anchor bolts. The lower nut must be welded to the rod to prevent it unwinding when the top nut is tightened (see Fig. 10C).

Because of long-term relaxation of concrete, prestressing of anchor bolts is unreliable and hardly ever justified.

Anchor bolts are the link between foundation and column. When a column base is subject to uplift, the uplift

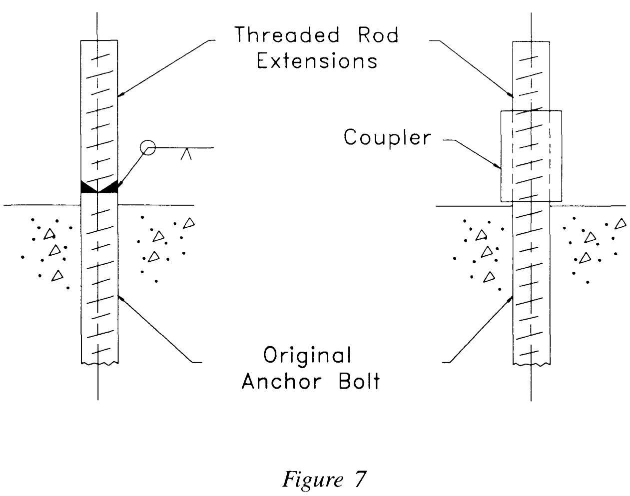

Figure 7

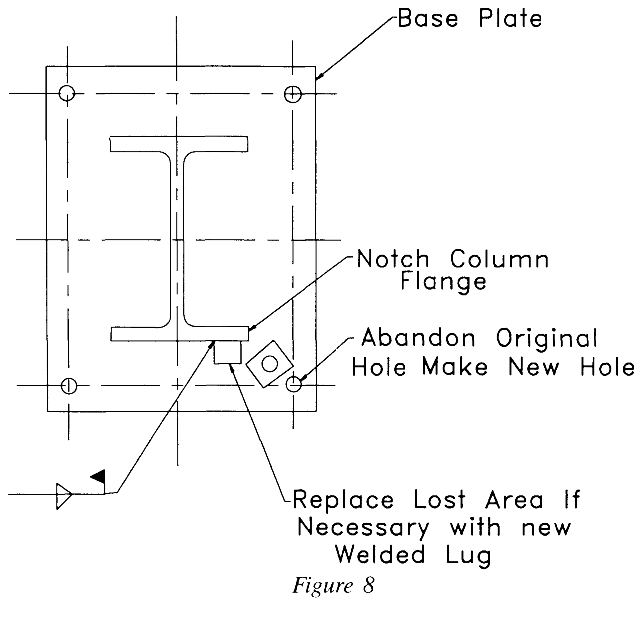

Figure 8

force must be resisted by a weight greater than the uplift force or the column base must be connected to the basic rock. Anchor bolts transmit this tension force. Several characteristics in anchor bolt design can be varied to suit the load requirements: the quantity of bolts, the diameter, the length, and type of material.

Anchor bolts should not be used to resist shear forces in a column base. Shear forces can be resisted by some device attached to the underside of the base plate and inserted into a groove or keyway in the concrete foundation (see Fig. 9). The shear forces can also be resisted by the encasement of concrete around a column base. More commonly, the shear resistance is developed by the friction developed between the bottom of the base plate and the top of the concrete foundation. (If the leveling plate method of setting column bases is used, the coefficient of friction used should be that of steel-to-steel.)

The main reason anchor bolts should not be used to resist shear forces is that they have a relatively low bending resistance. If a base plate were to ease sideways into bearing against an anchor bolt, the load (discounting the grout) would be delivered an inch or so above the concrete top. The anchor bolt would act like a vertical cantilivered member. A ¾ in. diameter A36 anchor bolt resists less than a 5 kip lateral load delivered 2 in. above the top of concrete. Also the random location of anchor bolts as they are located in the oversized base plate holes results in a situation where seldom does more than one bolt of a multi-bolt group go into bearing at any one time.

Large uplift forces are resisted primarily by the anchor bolts going into tension. Significant uplift forces must be resisted by a greater weight anchored to the lower end of the anchor bolts or by drilling direct into basic rock. For large uplift forces, it may not be adequate to rely merely on the attachment of the base plate to the bottom of the column shaft or to hope that the base plate will not bend. For

New Suggested Sizes for Oversized Holes in Base Plates

Bolt Diameter	Hole Diameter	Bolt Diameter	Hole Diameter
¾	1⁵⁄₁₆	1½	2⁵⁄₁₆
⅞	1⁹⁄₁₆	1¾	2¾
1	1¹³⁄₁₆	2	3¼
1¼	2¹⁄₁₆	2½	3¾

these conditions, it may be required to extend the anchor bolt up the side of the column flange to provide a shear connection to the face of the flange, thus bypassing the base plate altogether (see Fig. 4).

Pure moment forces are rare in column bases. They are usually accompanied by gravity loads and also shear. The moment couple consists of a downward force near one edge of the base plate and an opposite force upward at the anchor bolts on the far side of the plate. Naturally, the further apart these forces are, the greater the moment resistance. Modest moment can be developed by means of a base plate welded to the bottom of column. However, significant base moments may require an arrangement such as shown in Figs. 4 or 13. This relieves the base plate of bending and the base plate weld of over stressing and may allow a thinner base plate to be used.

Pilot nuts are sometimes used on top of the anchor rods to facilitate the entry of the rods into the base plate holes. This is an option of the erector (see Fig. 5). The base plate holes must be made large enough to accommodate the pilot nuts. After the column is set, the pilot nuts are removed and replaced by the desired washer and nut.

The design of the actual base plate itself is well covered elsewhere. (See John T. DeWolf, Ref. 3.) Base plates are square more often than not. However, some foundation geometry may dictate that the plate be rectangular, such as a plate on a narrow wall. Sometimes the shape of the base

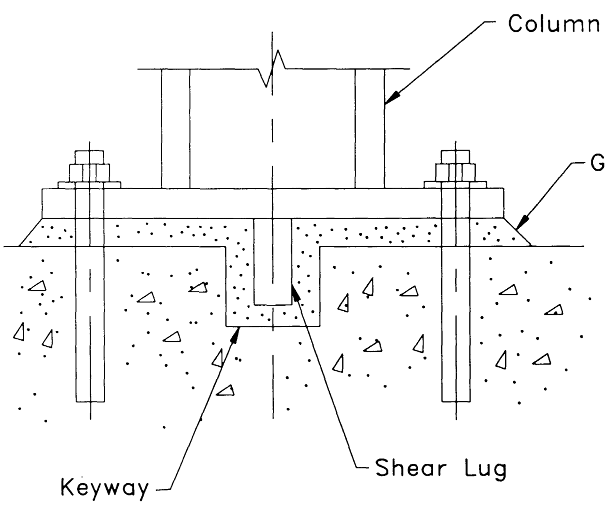

Figure 9

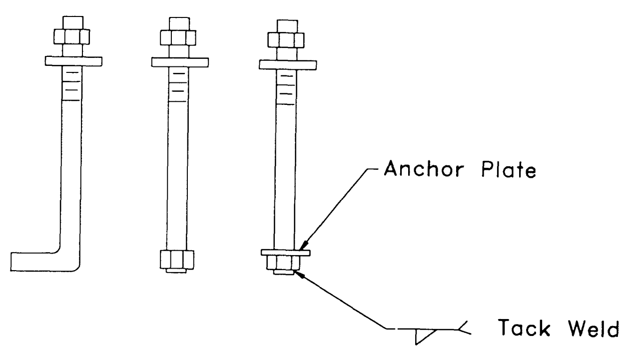

Figure 10

plate is dictated by where the anchor bolts are located and the number of bolts required. A pair of bolts may be located close into the column web, as in Fig. 14A, or there may be four bolts located near the outer corners of the plate or any of a member of similar patterns (see Fig. 14).

Anchor bolts exert relatively small lateral load on base plates, and the edge distance rules listed in AISC Table 1.16.5.1[1] do not apply since "tear-out" is not a problem. The only edge requirement is: enough steel is left between the edge of the plate and the closest edge of the hole so that the drill or punch will not drift as the hole is made. One-quarter in. is usually enough for this. (See the discussion on misplaced anchor bolts.)

Burning of base plate holes is an accepted procedure, especially when applied to field repair situations. Most base plates over 1 in. thick are cut to size by the burning process. The slight hardening exhibited at the burned edge is not important since bearing of the anchor bolt against the side of the hole is not a factor; it makes little difference how the hole is made.[4]

When sizing the area of a base plate, the loss of area at the anchor bolt holes (and grout holes) is generally ignored.

AISC *Manual of Steel Construction,* 8th ed., pp. 4–125, lists suggestions for oversizing holes for anchor bolts. Based on the trend toward foundation inaccuracy, these allowances are very often not enough. It is suggested that an additional quarter inch over the hole diameter listed be used. A heavy plate washer should be used over the holes (5/16 to 1/2 in. thick).

The finishing requirements of column base plates given in AISC Spec. 1.21.3[1] were adopted many years ago when plate rolling and temperature control were not as sophisticated as they are today. Consequently, much costly and unnecessary plate milling is paid for each year by unsuspecting clients. Many base plates are received from the mill flatter than after they are welded to the column. Welding, especially large groove welding, tends to curl the plates upon cooling. It is frustrating for a fabricator to mill an already flat plate and then watch it curl up after welding. A sensible approach used by some engineers is to *not* require milling unless the out-of-flatness exceeds allowable tolerances, *regardless of the thickness.*

To prevent the curling mentioned above, it is suggested that base plate welds be kept as small in size and quantity as the strength requirements and good practice allow, and that fillet welds be given preference over full and partial penetration welds. However, the minimum fillet weld sizes listed in the AISC Table 1.17.2A[1] must be observed.

Base plates in contact with other steel members, such as leveling plates or steel beams, should have any spatter left from the burning process removed to ensure good surface contact. Burrs resulting from shearing are of little consequence and need not be removed. Bearing plate surfaces in direct contact with concrete need not be ground smooth.

It is not necessary that base plate material match the column shaft material. It is, however, most important that the material be weldable if welding is used. Some commercial grades of steel have the necessary strength but contain too much carbon to permit reliable welds. Most base plates can be ASTM-A36 steel.

Base plates near the edges of walls, piers, foundations, etc., should be held back an inch or so from the edge, if possible, to prevent spalling at the free edge of the concrete.

GROUTING

The grouting of base or leveling plates is governed primarily by common sense. When leveling plates are used, the grout is plopped in place off the end of a shovel or trowel and the plate is laid on top of the grout pile and tapped to the proper elevation and made horizontal. The grout does not have to flow except toward the free edges of the plate, and hence the theoretical grout thickness can be established at any figure that will accommodate comfortable construction tolerances. Three-fourths to 1½ in. are common grout thicknesses, the lesser figure being common for smaller plates while the higher figure favors larger leveling plates.

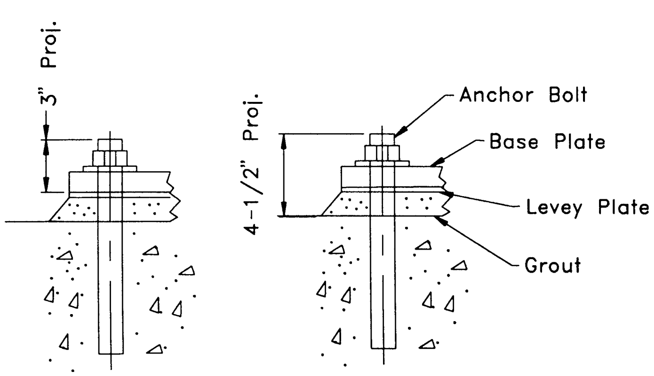

Figure 11

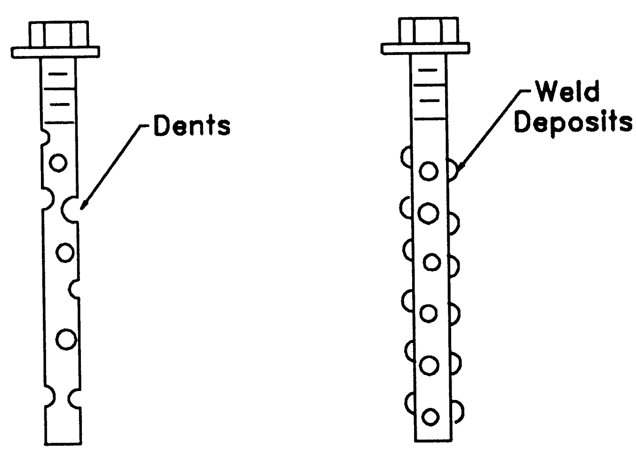

Figure 12

When the leveling nut system is used or when large base plates are shipped loose to the job and preset on leveling devices, the grout must be worked under the plate so that there are no resulting air pockets or other non-bearing areas. For small to medium-sized base plates (say, to 36 in. square) a common method to ensure total bearing is to start the grout in one side of the plate, continuing the process until it comes out the far side. For the grout to flow laterally for any distance, there must be ample space between the bottom of the steel plate and the top of the concrete. An inch and a half would be a minimum space. Also, it is suggested that the concrete foundation be dampened prior to grouting—dampened but not puddled. This helps reduce the absorption of water from the grout by the otherwise dry concrete. However, check the directions on the grout bag prior to use.

Regardless of the grout space allowed, grout will flow only so far laterally, even though it is prodded with a blunt board. For large base plates (say, over 36 in.) it may be necessary to drill a hole in the base plate near the center but not so as to foul the column section. The grout is fed through this hole and urged with the handy blunt board to fill the void beneath the base plate. This grout hole should be approximately 3 in. diameter. For very large plates or long rectangular plates, two grout holes may be required.

The more space left between the bottom of the base plate and the top of the concrete, the easier will be the lateral flow of grout. Spaces 3 to 4 inches are not uncommon for large plates.

Large base plate size is not the only determining factor for grout holes. If a column base plate must be set in a depression in a concrete foundation, with no side access for poking the grout along using the ubiquitous blunt board, a grout hole near the center of the base plate will allow the grout to enter and flow outward toward the plate edges. Grout is usually trimmed neatly at the edges of the base plates—either squared off or at an approximate 45 degree angle. There are many good grouts on the market today of varying strengths. They should be of the nonshrink variety.

When column bases are subject to shear and when the base is designed to resist the shear by means of a shear lug fitted into a concrete keyway, access must be provided to ensure that grout is distributed throughout the cavity to provide the proper bearing area (see Fig. 9).

General contractors should be aware that grouting must be performed before too much load is applied to the column bases which could collapse the anchor bolts or bend the base plates.

In summary, the grout thickness for the *leveling plate* method should be in the ¾ to 1½ in. range. For the *leveling nut* method, allow between 1½ and 3 in. of grout, depending on anchor bolt diameter and the corresponding nut height. Extra-large base plates require more grout thickness in general. In establishing the grout thickness, the anticipated degree of accuracy of the elevation of the concrete pour should be considered. More grout space should be allowed for a foundation contractor known for inaccurate work.

In certain rare circumstances, the concrete foundation may be finished to such a precise level and elevation that

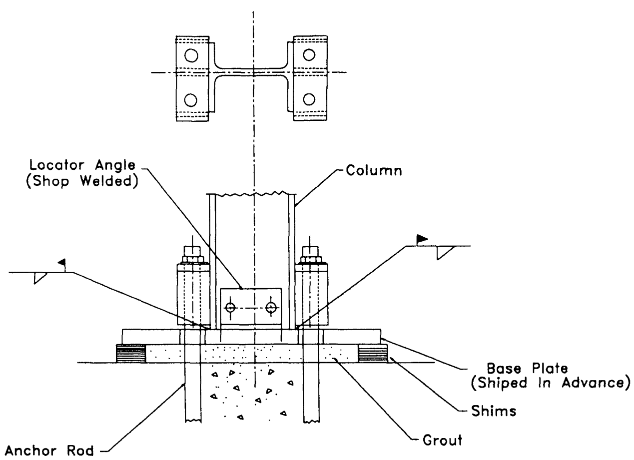

Figure 13. Moment base or base subject to uplift

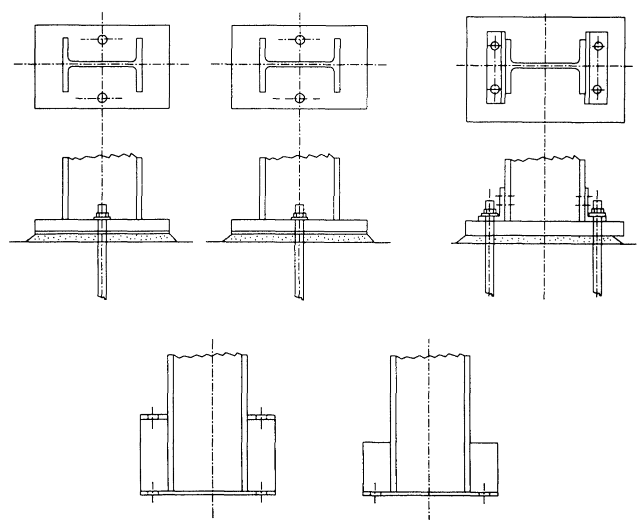

Figure 14

the column base plate is placed directly upon it without grout. Such precision usually requires the use of mechanical finishing devices, and these are difficult to operate in the presence of anchor bolts protruding from the concrete. This method is more often associated with the setting of heavy machinery bases and is rarely used in building construction.

FOUNDATION INACCURACIES

The concrete chemists who do such an admirable job of transforming sand, stone, water, and cement into concrete foundations do not always understand the full significance of the little lines between the inch marks on their measuring tapes. Often the result is mislocated anchor bolts. In addition to being out of place, the bolts may be tilted, have too much or too little projection above the top of the concrete, or be at the wrong elevation. The entire bolt group may be rotated 90 degrees from its proper orientation, or the wrong diameter bolts may be used. Sometimes only one bolt of a four-bolt cluster will be misplaced. It seems at times as if anchor bolts are set with about as much finesse as a brain surgeon operating with a garden hoe and with callous disregard for the other trades which must build upon the foundation.

Thanks to alignment tolerances (see Ref. 1, Code of Standard Practice, par. 7.5 regarding the accurate setting of anchor bolts and bearing devices) and the fact that most column base plates are furnished with oversized holes, small mislocations of anchor bolts can usually be tolerated. Bolts that are tilted (not vertical) can sometimes be straightened

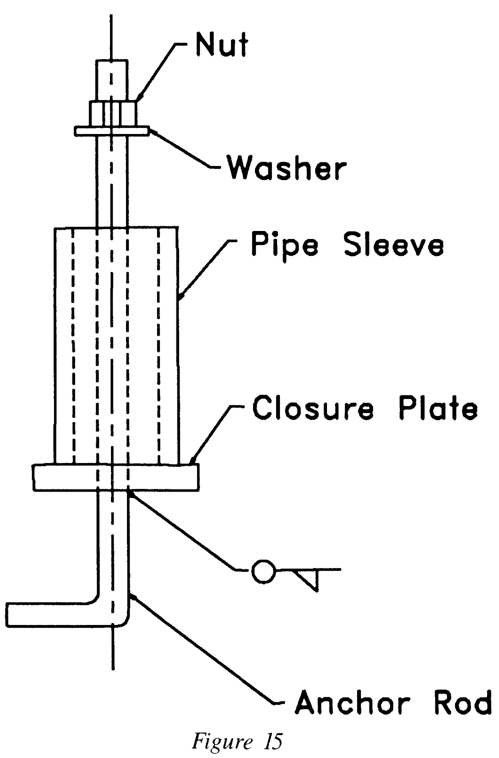

Figure 15

with a rod bending device called a "hickey." For anchor bolts mislocated up to about ¾ in., the concrete may be chipped away to a depth of a few inches and the "hickey" used to bend the bolt into the proper position.

Anchor bolts mislocated by over ¾ in. usually require that the base plate be slotted. Severe error may locate the bolt outside or near the edge of the base plate. Edge distance is usually not a problem even if the base plate hole needs to be slotted clear through and out to the edge of the plate as long as the plate is not weakened. Heavy plate washers with offset holes are used to cover the slots. These are welded to the top of the base plate in the field (see Fig. 6). Anchor bolts may also be mislocated toward the interior of the base plate. Large errors may result in the bolts fouling the web or flanges of the column. There are several remedies to this situation, all costly. The errant bolt can be burned off at the surface of the concrete and a new expansion bolt drilled into the proper location if room permits. Swaged bolts set into core drilled holes with epoxy grout can also be used for this purpose. Such drilling, however, is often complicated by the presence of reinforcing rods, and it must be determined by the engineer-of-record if it is permissible to sacrifice the reinforcing should one or more rods be encountered.

If an entire bolt group is misplaced but the individual bolts otherwise are in proper relationship with one another, it may be possible to offset the column base plate from its intended location. There are benefits to having the anchor bolt survey performed *before* fabrication. Likewise, if a bolt group is set in place 90 degrees to what it should be, very often the base plate can be turned on the column with no ill effects.

Anchor bolts which are accurately located but do not project far enough above the top of the concrete to allow a washer and nut to be installed are a real problem. Threaded rod extensions can be welded to the top of the bolt. A sleeve coupling can be used with a short threaded rod extension, but the hole in the base plate must be enlarged to ensure that it clears the coupling (see Fig. 7).

Sometimes a bolt group is so poorly placed, out of alignment and with the individual bolts tilted and off line, that a new base plate must be fabricated with holes drilled to suit the errant locations.

Bolts that are mislocated too near the edge of the column flange may require the flange to be notched somewhat to allow the nut to turn. This slight loss of column bearing area is usually not a problem but should be investigated. If the area loss should prove to be a problem, the deleted area can usually be added nearby in the form of a bearing stiffener with only a small ripple of inconvenience (see Fig. 8).

Anchor bolts set with too much projection are less troublesome. If the threads are insufficient to allow tightening of the nut, then washers must be stacked under the nut. This is not detrimental to performance but is an advertisement of sloppy work on the part of the foundation contractor. If the bolts are so long that they would extend above the floor line, they must be cut off. This can usually be done after the column is tied into the structure with beams. The anchor bolts, one by one, can be denutted and the shank welded directly to the base plate or to a heavy washer which is in turn welded to the base plate. The offending rod is then burned off somewhere below the floor line. Field alterations of this nature may affect the tension capacity of the anchor bolts, and this should be checked by the engineer. Any contemplated column base alteration should be brought to the attention of the engineer so that he may pass judgment as to its effectiveness. This is especially true of bases subject to uplift, moment, and/or shear forces.

Anchor bolts with sleeves provide a greater latitude of adjustment (see Fig. 15). Oddly enough, this device is declining in popularity at a time when the incidence of anchor bolt error appears to be on the rise.

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