Anchor Bolt Problems and Solutions

Baseplate and anchor bolt design are explained very thoroughly in AISC literature. The design involves numerous considerations and equations to calculate the necessary thickness, grade, and surface area of a baseplate as well as anchor bolt length, grade, and diameter. In most structural designs, the baseplate ends up just large enough to accommodate the column shaft, the anchor bolt hole, the washer diameter and weld size around the column shaft to the baseplate as seen in the illustration below.

Figure 1: Typical Gravity Baseplate
Columns that make up the brace frame part of the structure also tend to have just enough baseplate material to accommodate the weld at the column shaft, bolt hole, and plate washer. Thus, in both cases, the problems and solutions tend to be the same.

The typical designs work well if there are no problems brought about in the actual construction process. Unfortunately, problems with anchor bolts occur quite frequently. The most common problems with anchor bolt installations are as follows:

1. Insufficient anchor bolt projection above the baseplate.
2. Anchor bolt patterns rotated 90 degrees from plan design.
3. Individual bolts or entire bolt patterns out of tolerance in the x-y directions.
4. Bolts bent or damaged after the concrete is placed.

The first three items are listed in the order most likely to occur, in my experience. I examine each of the three most common issues in this article and review the least expensive solutions to resolve these problems. (For the purposes of this article, I am ignoring anchor bolts that are run over by equipment or damaged after concrete placement, as those must be assigned a repair by the EOR and are outside the scope of available pro-active options to the fabricator / erector).

Anchor bolts often end up with insufficient projection above the baseplate. This is a very common error that occurs on most projects at one or more locations. If only one anchor bolt has insufficient projection, it can probably be ignored on most gravity columns. The EOR would need to determine, through calculations, if this is permissible. If more than one anchor bolt or the entire group should have insufficient projection, there are multiple solutions. Only two of the solutions are common or practical. The first is to weld an extension on the anchor bolts. If the grade of the anchor bolt specified is 36 or 55, welding on an extension can be a solution to the problem. There must be at least enough projection for the welder to reach the end of the AB and still be able to see the weld puddle. The welder also needs enough clearance around the AB in order to see the weld puddle on all (or at least three) sides. A plate washer is added for filler material and then the nut is installed. If the design engineer has specified F1554 grade 105 anchor bolts, then welding is no longer an option due to the higher grade of material and the inability to make a compatible weld to grade 105 material.

If there is not enough projection to make a good weld, or the AB material grade is too high to weld, then the next best solution is a coupling nut. This typically involves using a torch to cut the AB holes in the baseplate even larger to accommodate the larger diameter of the coupling nut. Since most baseplates are sized with a minimum amount of edge distance from the bolt hole as design dictates, there is typically not enough extra material around the hole in the baseplate to allow for enlarging. This further complicates the use of coupler nuts. Once the decision is made to enlarge the hole and thus reduce the edge distance from the anchor bolt to the edge of the baseplate, then a series of fillers and plate washers must be added to compensate for the baseplate material cut away to make room for the coupling nut. (The plate washers will require welding to the baseplate.) These plate washers and fillers add considerably to the final projection of the anchor bolts and may interfere with interior finishes.
In both repair cases, welding or couplers, there is a cost and time that must be absorbed by someone on the project. Not surprisingly, no one wants to absorb this cost - and removing and replacing the concrete footing is almost never the preferred solution by anyone involved. Removing the baseplate and adding to the column shaft also rarely works due to the limitations of the grout thickness variance under the baseplate. Adding a larger plate and additional anchor bolts by drilling and epoxying new locations is also costly and may interfere with interior finishes.

There is a simple pro-active change that would add little to the overall cost of the project and yet prevent most AB projection problems. Simply specify a longer AB projection during detailing. Usually two to three inches of added projection is enough. If the Engineer of Record does not do this, the steel contractor should. Make sure that the extra projection does not interfere with interior finishes. Don’t forget to add additional thread length to the bolts in case they are installed at the correct elevation. This adds a very small cost to the overall project but prevents most field AB projection problems. As a project manager for a steel fabricator and erector, this became a common practice of mine on every project. I eliminated my most common anchor bolt problem with an easy solution at relatively little cost.

The second most common field problem with anchor bolts is pattern rotation. Invariably, someone will install the anchor bolts with the AB pattern rotated 90 degrees from design. In other words, the dimension in the x direction is longer than the dimension in the y direction when viewing the anchor bolt holes in plan view. Given that most anchor bolt patterns end up as a rectangular pattern due to WF shapes being slightly out-of-square, a rotation of 90 degrees presents a problem when attempting to set the column. A square anchor bolt pattern will eliminate this problem. By making the hole pattern square, the baseplate is made larger than design minimums require, and subsequently the baseplate thickness will increase. (For engineers, increasing the distance from the edge of the baseplate to the assumed bending line has a direct linear relationship with the thickness of the baseplate.) While the idea of a larger, and thicker, baseplate may seem to be an un-necessary expense for a potential field problem, that may not occur, the problem is not that uncommon, and I would have opted for a square pattern and larger base-plate every time if given the choice as a steel fabrication and erection project manager. This increase in size would make the average gravity column baseplate about 50% heavier or about 10 to 20 dollars more per baseplate. Further, the larger baseplate also helps with the problems due to anchor bolts lacking projection. Some material may be removed to accommodate the coupling nut without adding plate washers and additional weld. For frame columns with many anchor bolts, a better solution is discussed at the end of this section.

A larger baseplate also helps in solving the third most common AB problem, which is anchor bolts out of tolerance in the x or y direction. This problem is solved typically by using a torch to cut the AB hole in the baseplate larger in one direction. Thus, the hole(s) in the baseplate ends up not having enough edge distance material to meet design requirements, or the column flange interferes with the nut or washer. Again, after material is cut away, a series of plate washers and filler plates must be used to build up this section of the baseplate to meet minimum design requirements. This complicates the solution as there is typically not enough normal anchor bolt
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projection to accommodate the added fillers and plate washers. Oftentimes, if the entire pattern is out of tolerance in the x – y direction, it is simply left alone, and the steel erector starts that column out at an angle and attempts to slowly pull the columns above back into plumb tolerance.

Therefore, by adding enough material to make the AB hole pattern square with at least ½” of extra material at each corner, and adding 2” of AB projection, the most common field AB problems will be eliminated or easily solved on your projects. This will eliminate a lot of back-and-forth between the steel erector and EOR. This added material may add a couple of thousand dollars to a multi-million-dollar steel project up front, but the savings in time and cost later will more than offset the initial investment. Further, avoiding the use of high grade non-weldable steel anchor bolts will make any errors much easier to correct. Often, the cost between a 1” grade 105 bolt and 1-1/2” grade 55 bolt is negligible or minor, even when considering the slightly larger baseplate needed to accommodate the larger diameter bolt. Given the opportunity, such as a design-assist project, opt for including square baseplates and longer anchor bolts in the design documents. Also, if F1554 grade 105 bolts can be avoided, it is advisable to do so.

On projects where baseplates have been sized without any extra material, or on projects where longer anchor bolt projections are not an option, I would recommend using one or both of the following two suggestions.

First, the anchor bolts should be fitted in a steel fabricated frame before placement in the concrete formwork. With small bolts, the frames can be nailed into position within the footing formwork. These AB frames may be as simple as a 16-gage piece of sheet metal with holes cut out for the anchor bolts and double nuts against the plate to hold each anchor bolt to the correct spacing and projection. For larger bolts or brace-frame bolt patterns, the fabricated AB frame may need to be assembled from angles welded together to carry the weight of the larger anchor bolts. These larger frames may need to be coordinated with the GC and concrete subcontractor in order to accommodate the considerable weight of each frame. On very large brace-frame bolt patterns, a rat slab may be needed to allow for AB support during construction. These frames should be marked “North” on the appropriate side in the fabrication shop to further reduce the chance of error in field placement.

Second, send out a surveyor to the project and survey the anchor bolts after they are placed, and before concrete is poured. The surveyor should check at each grid point for proper AB patterns, projection length, and rotation of the pattern. This will be slightly more expensive than the extra baseplate material and added AB projection, but it is the next best alternative. At many companies, it is standard practice to survey the anchor bolts before concrete placement. Also, most large GCs will add this to the contract as an erector duty to survey before concrete is placed, especially if the GC is self-performing the concrete work.

Most engineer and General Contractor employees consider anchor bolt issues to be of minor concern. This is unfortunate, because AB problems cost everyone on the project both time and money. As mentioned above, entire anchor bolt patterns that are not centered correctly on the grid are generally ignored. The entire AB pattern may be ¾” to the West or South for example. While this may not seem like much, and is typically ignored, it starts that column off by being
¾” out of plumb. This make the work of physically connecting the beams and braces around that column much more difficult. It also affects the next several levels of steel, because the next column above also starts out slightly off grid center. It has been my experience, that a few bad AB patterns off the correct grid locations can slow erection speed by 10 to 20% on the first two tiers of steel. In other words, the raising gang, which is the pace setter for the entire steel erection crew, is now working at a much slower pace. This has a very detrimental effect on their productivity and the company’s profitability, as the overall progress of the structure is slower.

As an Engineer, Structural Steel Project Manager, or General Contractor Supervisor, I would encourage you to consider anchor bolts much more seriously in terms of potential impact to your overall project. I would also encourage you to give serious thought to the suggestions above. Unless you are part of the team on a design assist project, it is often not realistic to change the baseplates to a square pattern or make them larger than originally designed, but the other suggestions are easy to implement and very cost effective. I believe they will provide great benefit which exceeds their minimal cost.