

A Guide to Concrete Anchors

To pick the right fastener—look at cost, performance, and ease of installation



A worker fastens a duct hanger to concrete using concrete screws, which are inexpensive and fairly strong fasteners.

Contractors face a wide array of choices when they need to structurally fasten to concrete. Their main problem is how to get good solid information and make sense of manufacturers' claims about fastener performance. I will try to shed some light on this by reviewing the different features of the fasteners most commonly used with poured concrete, concrete or masonry block, and structural steel.

The "design load" is the recommended load you can put on an installed fastener, and all design-load comparisons in this article—except for the powder-actuated fastener (PAFs) and concrete screws—will be for anchors installed in a 3/8 inch hole. Though heavy sleeve and wedge anchors take different size studs in 3/8-inch holes, this will give us a fairly accurate comparison of load capabilities and price relationship for the different types of anchors.

When considering fastener load capabilities, make sure you obtain design loads and not ultimate loads. Design loads should be 10 percent of the ultimate loads. Get these listings from the manufacturer or from a regulatory agency. Both the International Congress of Building Officials (ICBO) and Southern Building Code Congress International (SBCCI) issue reports on manufacturer's design loads. Design loads are conservatively rated by taking the low end of the bond or steel strength.

All the design values listed here are taken for ITW Ramset/Red Head products. Other manufacturers' listings are similar, but check the published design value for the specific anchor you plan to use.

Powder Actuated Fasteners (PAFs)

Before we look at the fasteners, here's a safety tip about the tools that drive them. The most important element in the use of power-actuated tools is ensuring that all your operators are adequately trained. Every U.S. manufacturer will provide this training at no cost to you, and every state requires it, but the contractor should make sure that the trainer is an authorized, licensed instructor.

Several companies manufacture powder-actuated fasteners (PAFs) including ITW Ramset/Red Head, Hilti, Desa, and Speed. Of all concrete fasteners, PAFs are the fastest to install, so they probably have the lowest in-place cost of all fasteners. The most common fasteners in this category are drive pins (specially made nails) and threaded studs. Shank diameters for drive pins and threaded studs generally range from 1/8 to 1/4 inch, and

lengths range from 1/2 inch (commonly used in steel) up to 3 inches (usually used to attach sill plates to pour concrete). These fasteners are driven with a powder-actuated tool by blank cartridges called "loads."

I am only covering the most common, low-velocity fastener tools (there are two other types). These are available in either the less expensive single-shot version, or faster, but more expensive, semi-automatic version.

Design load capacities for PAFs vary and depend on three factors: (1) the base material—they can only be used in structural steel or poured concrete, (2) the "embedment" or depth the anchor is embedded in the material, and (3) the shank diameter or the thickness of the anchor embedded in the base material. Tension design loads for the low-velocity fasteners can be as high as 550 pounds, and shear design loads as high as 1,950 pounds. But PAFs can't withstand severe vibration or shock.

The fasteners are heat-treated for

hardness, but this process makes the fastener unable to stand normal weathering corrosion when exposed to the elements. Any protective coating you might apply would be damaged when the fasteners are driven into the base material.

PAFs are good for installation of dry-wall track, conduit clips, and other electrical wiring fixtures. They are also

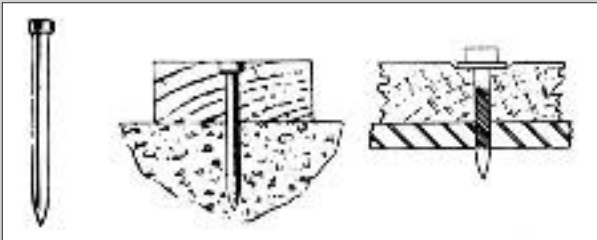
good for attaching sill plates to concrete, and steel deck and siding to structural steel of joists. They shouldn't be used for piping that will carry fluids since it is subject to "water hammer" or severe shock and vibration. They should not be used for any structural support or overhead structural installations.

Summary: PAFs

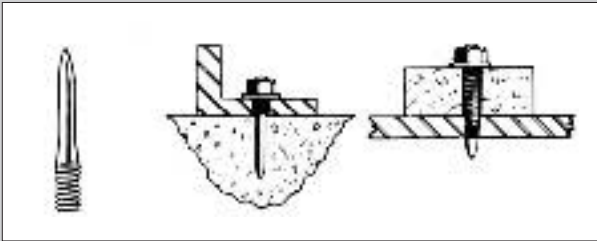
Powdered Actuated Fasteners (PAFs) can be quickly installed, but have poor resistance to vibration and corrosion. PAFs have a fair load capacity. They can only be used in poured concrete or structural steel, and the law requires operators to be licensed. They are inexpensive.



The commonly used, low-velocity fastening tools come in single shot (above) and semi-automatic versions.



Drive pins (above) can be quickly installed, so they have a low in-place cost. Threaded studs (below) are good for attaching sills to concrete.



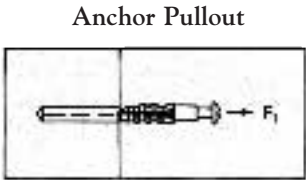
Diagnosing Anchor Failures

Anchor failures may be caused by incorrect installation methods or by using the wrong anchor type or size. Here's how to identify and correct the cause of failure.

Anchor Pullout

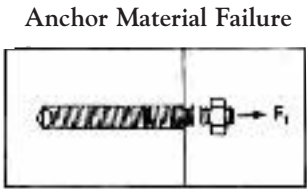
This failure is typical for low-strength, lightweight, or early-age concretes. The resisting friction force produced by the expansion mechanism or by the adhesion of the chemical bond is less than the applied load. To solve the problem:

- Increase anchor expansion force
- Increase concrete strength
- Increase anchor embedment



Anchor Material Failure

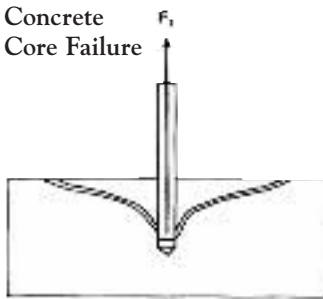
The applied load exceeds the ultimate strength of the anchor material. Deeply embedded anchors or anchors with a small cross-sectional area may fail in this manner. To solve this problem, choose a high-strength anchor.



Concrete Cone Failure

The applied load is greater than the concrete can resist in tension over the cone failure surface. This failure mode is typical for anchors of shallow embedment. To solve this problem:

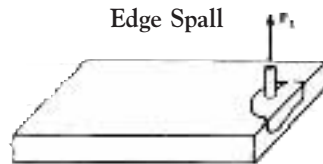
- Increase concrete strength
- Increase anchor embedment



Concrete Edge Spall

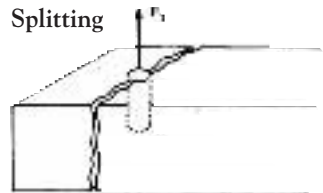
An anchor loaded near a free edge causes concrete to spall. Anchors exerting large expansion pressures on the edge or anchors subjected to shear force towards the edge exhibit this type of failure. To solve this problem:

- Increase distance between anchors or from edge
- Increase concrete strength or provide reinforcement
- Use anchor system (chemical or undercut) that does not exert expansion force



Concrete Splitting

An anchor loaded in a thin or narrow slab may cause the base material to split. Insufficient concrete strength also may contribute to this failure mode. You can solve this problem using the same solutions listed above for edge spall.



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Concrete Screws

The largest manufacturers of these products are ITW/Buildex (Tapcon), Construction Fasteners (Confas) and Yamashima (Con-Lok).

When concrete screws are installed, the screw anchor is "threaded" into a pilot hole, using a screw driver or power tool. As the screw turns, the threads tap into the masonry material, and this provides the holding strength.

In general, the most effective embedment in the masonry material is 1 to 1 1/2 inches. You calculate the length of the concrete screw needed by adding this embedment depth to the thickness of the material being attached and then add on the height of the nut and

washer. Based on OCBO reports, accepted design loads range up to 590 pounds at 1 1/2 inch embedment in 4,500 psi concrete. In lightweight concrete or masonry block, the tension value is only 310 pounds. Shear design values are generally in the 200-pound range.

These anchors resist vibration better than PAFs. Their tension values are about the same; shear strength is lower. They are better suited for lower-strength base materials like brick and concrete block. Concrete screws are ideal for attaching thick material like 2x4s or insulation to concrete, unreinforced masonry walls, and brick or concrete block.

Expansion Anchors

Expansion anchors are used widely in the U.S. There are four types: self-drill, drop-in, sleeve, and wedge. They are all "friction anchors," and the friction is provided in various ways by an expansion device in the anchor. The greater the friction, the greater the holding value.

Both the spacing between expansion anchors and the distance they sit from the edge of the base material are important. There are two rules of thumb for spacing: First, you should never place any anchor closer to the edge than the embedment depth. Second, the center-to-center spacing should be twice the embedment depth. This means that for

an embedment of 3 inches the closest edge should be at least 3 inches away from the center of the anchor, and the nearest anchor should be 6 inches away. Closer spacing means reduced holding values.

Self drill. Many of the major manufacturers are dropping these anchors from their line, but they are still available in the market. Self-drill anchors are thick-walled, sleeve anchors for use in shallow embedment applications. The sleeve itself is the drill bit, and this makes installation difficult because the self-drill teeth are not as good as carbide drill bits.

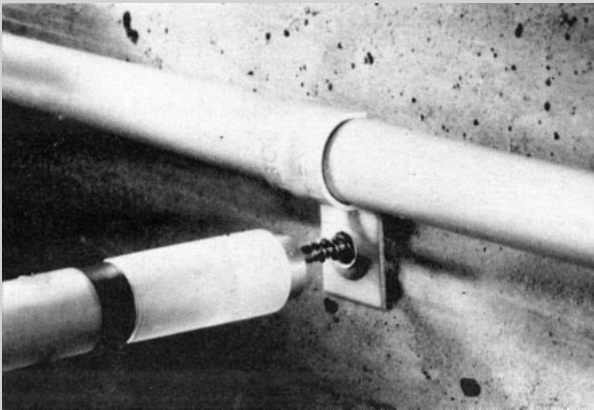
Self-drill anchors are available in diameters of 1/4 to 7/8 inch. The size is determined by the internal thread

Summary: Concrete Screws

Concrete screws are quickly installed and are good for relatively weak base materials such as concrete block. They have a fair load capacity and are available with fairly good corrosion-resistant finishes. They are inexpensive.

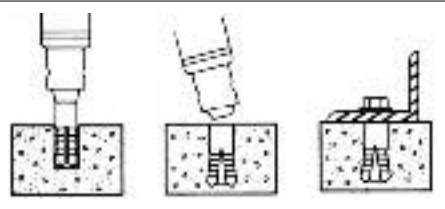


Screw anchors (right) provide their own holding power by tapping into the masonry material. The anchors (below) are threaded into a pilot hole using a screw driver or power tool.



Summary: Self-drilling Expansion Anchors

Self-drilling anchors are difficult and time consuming to install. Unless they are inspected for possible failure, the design loads can be considerably less than their ICBO rating. If installed properly, however, they do have high holding values. The coatings applied to these anchors are mostly for looks and provide very little corrosion protection. They are in the medium price range.



After a hole is drilled (left), a cone is placed in the end of the anchor. The anchor is set by impact; its top is broken off by tilting the Rotohammer (middle). Brackets can be attached to the stud (right).

The sleeve of the self-drill anchor, shown here with its cone in place (right), is the drill bit. This is one reason they are hard to install.



install with the same ease as the drop-ins.

There are two advantages to the sleeve anchors. First, the hole can be drilled through the item you are attaching, eliminating a lot of measuring to line up holes. Second, the anchors are not “depth sensitive,” so the hole can be deeper than necessary. (Sometimes these are called “bottomless” anchors.) Once the hole is drilled, the anchors are installed through the base plate or attachment. As the nut is tightened, a cone at the end of the stud is drawn into the sleeve, expanding it against the masonry material. The design load for an anchor sized for a 3/8-inch hole (5/16-inch bolt) is 785 pounds in 3,000 psi concrete. Sleeve anchors can be set at deeper embedments to increase their load carrying capability. Here, too, finishes provided on these anchors are not effective against corrosion.

Wedge anchors. Of all expansion anchors, these anchors provide the highest design load for the smallest hole size. For a 3/8-inch wedge anchor at 3-inch embedment in 3,000 psi con-

crete, the design load is 1,205 pounds. As with the sleeve anchor, deeper embedments mean increased load-carrying capability. For the same 3/8-inch wedge anchor with a 4-inch embedment-a 1-inch increase - the ICBO report lists a value at 1,800 pounds, a 595-pound increase.

The expansion device for wedge anchors is a small sleeve at the bottom of the anchor, which is wrapped around a conical-shaped expander. You install these the same way you install the sleeve anchor. Generally, the wedge anchors offer the builder better performance, which means fewer required anchors per given load, but this efficiency is made up for by higher cost. These anchors are load-assisted and provide fair resistance to vibration and shock loads. The coatings applied are not very effective against corrosion.

Adhesive Anchors

There are two types of adhesive anchors: the styrene-based anchors and

diameter. Generally speaking, the outside diameter for a 1/4-inch self-drill is 7/16 inch, while the 7/8-inch anchor has a 1 1/8-inch outside diameter. These larger sizes are very difficult to install correctly. For instance, if the hole is made too large by overdrilling, the holding values may be drastically reduced (see “Diagnosing Anchor Failures,” previous page).

To install the self drill, drill with the anchor until the Rotohammer chuck holder is flush with the masonry surface. then remove the sleeve from the hole, and place a cone in the bottom of the anchor. Replace the sleeve and cone in the hole and hammer the sleeve onto the cone - using impact only. The sleeve walls expand and grip the masonry material. The top attachment of the anchor is then broken off by tilting the Rotohammer sharply. Insert the threaded stud into the sleeve, and your fastener is ready. Since you supply the stud, you determine the shear and tension values by the grade of stud you select.

Here a distinction needs to be made between load-assisted and non-load-assisted anchors. With load-assisted anchors, the friction (or holding value) is increased when a load is applied. Non-load-assisted anchors, on the other hand, may be weakened when the anchor is loaded. The self-drill anchor is not a load-assisted anchor, because the load applied to the stud tends to pull the sleeve away from the cone used to expand and set the

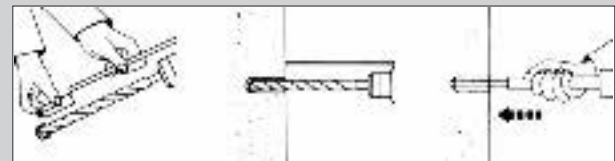
anchor. This makes the anchor very poor in resistance to vibration or shock loads. With a hole size of 7/16 inch (1/4 inch bolt size) the ICBO design value is 630 pounds for 3,000 psi concrete, for well-installed anchors.

Drop-in. These anchors are well designed and good for shallow embedment in poured concrete. ITT Ramset/Red Head, Hilti, Molly, Use Diamond, and Unifast supply these anchors. Drop-ins are thick-walled sleeve anchors with the expansion cone located within the anchor. A setting tool is used to force the force onto the sleeve. These anchors are generally available from 1/4 to 3/4 inch. For steel studs made from A307 steel, the acceptable design load listed by ICBO for an anchor with a 3/8-inch outside diameter (bolt size 1/4 inch) in 3,000 psi concrete is 674 pounds. The drop-in anchors are not load-assisted, but they do resist vibration better than the self-drill.

Sleeve anchors. These load-assisted anchors have a thin-walled sleeve around a threaded stud. The stud has an expansion cone on one end that pushes the sleeve wall against the concrete. A 1/4-inch drop-in requires a 3/8-inch diameter hole. For a 3/8-inch hole with a sleeve anchor, your thread size would be 5/16 inch. Design loads for the sleeve anchors increase as the hole size increases. (The price increases as well, because larger studs cost more.) They are better for vibrating loads than either the self-drill or drop-in. They

Summary: Drop-In Expansion Anchors

Drop-ins have good design for a shallow-embedment anchor and can be used in all types of concrete. They are easier to set correctly than the self-drill anchors, but the hole must be predrilled to the correct depth (they are depth-sensitive). Like the self-drill anchors, the protective coating on these anchors provides little protection. They are in the medium price range.



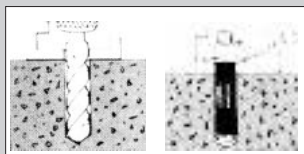
Drop-ins must be placed in a hole predrilled to the correct depth (left and middle). An impact tool (right) sets the anchors in place.



Drop-in anchors (above) are threaded to receive studs that expand the anchor when installed.

Summary: Sleeve Expansion Anchors

Sleeve anchors are designed well, with good holding values. They can be applied through the item they are attaching and they are not depth-sensitive, that is the hole can be drilled more deeply than the fastener. They are in the medium price range.



The holes for the sleeve anchors can be drilled with brackets in place (above left). Tightening the nut draws the cone up, expanding the sleeves walls (above right). As the load pulls on the stud of the sleeve anchor (right), it sets the anchor more firmly.



epoxy anchors. Styrene-based anchors usually come in glass capsules. There are two types of these as well: polyester resin and vinylester resin.

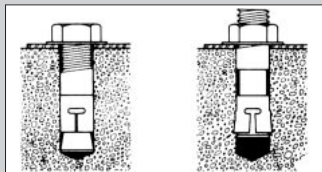
Both styrene and epoxy anchors have excellent resistance to vibration and shock loads, but they are somewhat temperature sensitive. The holding values for these anchors are very high.

types of anchors.)

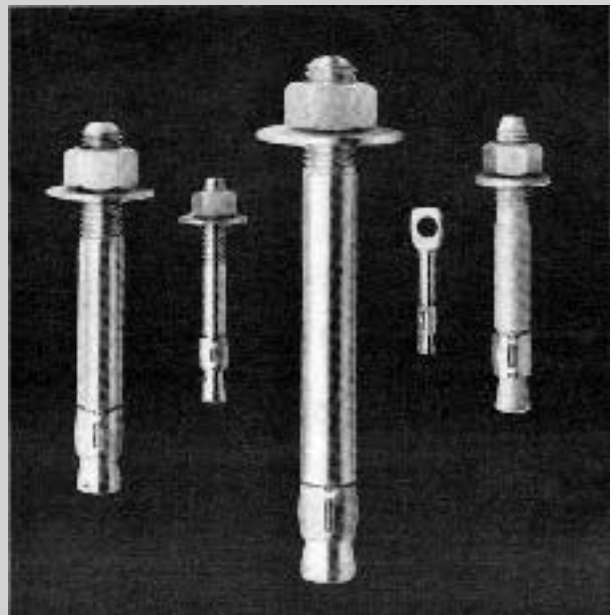
The determining fact for holding values is the bond strength of the adhesive. Values vary, but here's on example: For EPCON product — a caulk-gunlike injection system — the bond strength is 2,140 pounds in 3,500 psi concrete at 3 3/8-inch embedment for 3/8-inch anchor.

Summary: Wedge Expansion Anchors

Wedge anchors have the best design of all the expansion anchors, with fair corrosion protection. Like sleeve anchors, a deeper embedment means an increased load capacity. They are in the high end of the medium price range.



A wedge anchor (far left) has a cone that expands a small wrap-around sleeve as the nut is tightened (left). Like sleeve anchors, wedge anchors (below) are load-assisted.



Different brands vary considerably, so review the design-load ratings. If you plan on attaching high loads, use high-strength steel studs. (all manufacturers produce stainless-steel studs for all

Since adhesive anchors become part of the base material, they can be spaced closer together than expansion anchors. Follow the manufacturer's recommended spacing. These anchors

Summary: Adhesive Anchor Systems

For high-strength jobs, epoxy systems are the best value for your anchoring dollar. All adhesives have excellent resistance to vibration and shock. They are excellent for corrosion resistance, and they have the highest load capabilities.



After the glass capsule (left) is inserted, a stud is put in place, breaking the capsule, and mixing the epoxy components together. Another type of system uses a caulk-gunlike applicator (below) and achieves a higher bond strength.



perform best in rough holes, so pneumatic or Roto hammered propelled drills are preferred to core drills, which leave very smooth holes. After drilling the hole must be cleaned thoroughly with a soft brush. (A wire brush would tend to smooth the hole.) Cleaning the hole with compressed air is ideal.

Installation techniques for both types — polyester/vinylester resin and epoxy is mixed in or out of the hole. When it is all mixed, ready, and in the hole, the anchor stud (or rebar) is inserted. Two things are critical here: pot life (the time before the product gels) and cure time (the time before you can place the design loads on the anchor). You need a pot life long enough to allow you to set the anchor, and a cure time short enough that it doesn't slow the job down. So you want a maximum pot life and a minimum cure time. After the resin or epoxy is cured — completely hardened — the fastener is ready. Cure times vary, so check the manufacturer's listing.

Most polyester resin systems are glass-capsule systems in which hardener, resin, and some small aggregate are contained. After a hole is drilled, the capsule is inserted. When the stud is rotated into the hole, it breaks open the capsule, the turning stud mixes the components, and the pieces of glass become part of the aggregate.

Some other systems, both polyvinyl and vinylester, are sold in cartridges, mixed by a static mixer, and injected like caulk. Others are produced in linked-sausagelike or separate containers, which are kneaded by hand and then mixed further by the rotating anchor stud.

Design loads for a 3/8-inch threaded stud, with an embedment of 3 1/2-inches, set in a glass capsule or polyester-resin adhesive, is 1,280 pounds. On the other hand, a polyvinyl-resin anchor with the same stud and embedment has a design load of 2,075 pounds. But the greatest design load is achieved with an epoxy adhesive, where the same stud and embedment yield a design load of 2,140 pounds. The epoxy version also provides the best load/deflection curve: there is less slip when the design load is attached.

All adhesive anchors withstand corrosion well because less of the anticorrosion coating is worn off during insertion. (This is a feature the other anchors can't offer, and it is especially helpful when you have ordered specialty stud coatings.) This type of anchoring system costs about 10 to 15 percent more per anchor than the wedge anchor, but it offers the most performance advantages. All things considered, epoxy and resin system anchors probably end up costing the least per pound of load capacity.

Fasteners differ with respect to installation speed, structural integrity, in-place cost, resistance to various loads (shear, tension, vibration, and shock), and resistance to corrosion. Understanding the various fastener types and how they work will make it easier for you to select the most cost-efficient option. ■

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