

## GENERAL INSTRUCTIONS FOR THE DESIGNER

These general instructions for the designer are provided to ensure the proper selection and installation of Simpson Strong-Tie Company Inc. products and must be followed carefully. These general instructions are in addition to the specific design and installation instructions and notes provided for each particular product, all of which should be consulted prior to and during the design process.

- a) The term "Designer" used throughout this catalog is intended to mean a licensed/certified building design professional, a licensed professional engineer, or a licensed architect.
- b) All connected members and related elements shall be designed by the Designer and must have sufficient strength (bending, shear, etc) to resist the loads imposed by the anchors.
- c) When the allowable stress design method is used, the design service loads shall not exceed the published allowable loads.
- d) When the ultimate strength design method is used, the factored loads shall not exceed the design strengths calculated in accordance with the published design data.
- e) Simpson Strong-Tie® strongly recommends the following addition to construction drawings and specifications: "Simpson Strong-Tie products are specifically required to meet the structural calculations of plan. Before substituting another brand, confirm load capacity based on reliable published testing data or calculations. The Engineer/Designer of Record should evaluate and give written approval for substitution prior to installation."
- f) Local and/or regional building codes may require meeting special conditions. Building codes often require special inspections of anchors installed in concrete or masonry. For compliance with these requirements, it is necessary to contact the local and/or regional building authority. Except where mandated by code, Simpson Strong-Tie® products do not require special inspection.
- g) Allowable loads and design strengths are determined from test results, calculations, and experience. These are guide values for sound base materials with known properties. Due to variation in base materials and site conditions, site-specific testing should be conducted if exact performance in a specific base material at a specific site must be known.
- h) Unless stated otherwise, tests conducted to derive performance information were performed in members with minimum thickness equal to 1.5 times the anchor embedment depth. Anchoring into thinner members requires the evaluation and judgment of a qualified Designer.
- i) Tests are conducted with anchors installed perpendicular ( $\pm 6^\circ$ ) to the surface of the base material. Deviations can result in anchor bending stresses and reduce the load carrying capacity of the anchor.
- j) Allowable loads and design strengths do not consider bending stresses due to shear loads applied with large eccentricities.
- k) Metal anchors and fasteners will corrode and may lose load-carrying capacity when installed in corrosive environments or exposed to corrosive materials. See Supplemental Topic G3.
- l) Mechanical anchors should not be installed into concrete that is less than 7 days old. The allowable loads and design strengths of mechanical anchors that are installed into concrete less than 28 days old should be based on the actual compressive strength of the concrete at the time of installation.
- m) Nominal embedment depth (embedment depth) is the distance from the surface of the base material to the installed end of the anchor and is measured prior to application of an installation torque (if applicable). Effective embedment depth is the distance from the surface of the base material to the deepest point at which the load is transferred to the base material.
- n) Drill bits shall meet the diameter requirements of ANSI B212.15. For adhesive anchor installations in oversized holes, see Supplemental Topic A1. For adhesive anchor installations into core-drilled holes, see Supplemental Topic A2.
- o) Threaded-rod inserts for adhesive anchors shall be UNC fully threaded steel.
- p) Allowable loads and design strengths are generally based on testing of adhesive anchors installed into dry holes. For installations in damp, wet and submerged environments, see Supplemental Topic A3.
- q) Adhesive anchors should not be installed into concrete that is less than 7 days old. The allowable loads and design strengths of adhesive anchors that are installed into concrete less than 28 days old should be based on the actual compressive strength of the concrete at the time load is applied.
- r) Adhesive anchors can be affected by elevated base material temperature. See Supplemental Topic A4.
- s) Anchors are permitted to support fire-resistive construction provided at least one of the following conditions is fulfilled: a) Anchors are used to resist wind or seismic forces only. b) Anchors that support gravity load-bearing structural elements are within a fire-resistance-rated envelope or a fire-resistance-rated membrane, are protected by approved fire-resistance rated materials, or have been evaluated for resistance to fire exposure in accordance with recognized standards. c) Anchors are used to support nonstructural elements.
- t) Some adhesives are not qualified for resisting long-term sustained loads. These adhesives are for resisting short-term loads such as wind or seismic loads only. See Supplemental Topic A5.
- u) Exposure to some chemicals may degrade the bond strength of adhesive anchors. Refer to the product description for chemical resistance information. Information is also available in Simpson Strong-Tie Company Inc. Technical Bulletin T-SAS-CHEMRES.

## SUPPLEMENTAL TOPICS FOR ANCHORS

### GENERAL

#### G1. Base Materials

"Base material" is a generic industry term that refers to the element or substrate to be anchored to. Base materials include concrete, brick, concrete block (CMU) and structural tile, to name a few. The base material will determine the type of fastener for the application. The most common type of base material where adhesive and mechanical anchors are used is concrete.

**Concrete** – Concrete can be cast in place or precast concrete. Concrete has excellent compressive strength, but relatively low tensile strength. Cast-in-place (or sometimes called "poured in place") concrete is placed in forms erected on the building site. Cast-in-place concrete can be either normal-weight or lightweight concrete. Lightweight concrete is specified when it is desirable to reduce the weight of the building structure.

Lightweight concrete differs from normal-weight concrete by the weight of aggregate used in the mixture. Normal-weight concrete has a unit weight of approximately 150 pounds per cubic foot compared to approximately 115 pounds per cubic foot for lightweight concrete.

The type of aggregate used in concrete can affect the tension capacity of an adhesive anchor. Presently, the relationship between aggregate properties and anchor performance is not well understood. A recent study based on a limited test program has shown that in relative terms, concrete with harder and more dense aggregates tend to yield greater anchor tension capacities. Conversely, use of softer, less dense aggregates tends to result in lower anchor tension capacities. Research in this area is ongoing. Test results should not be assumed to be representative of expected performance in all types of concrete aggregate.

# SUPPLEMENTAL TOPICS FOR ANCHORS

Prefabricated concrete is also referred to as "precast concrete". Precast concrete can be made at a prefabricating plant or site-cast in forms constructed on the job. Precast concrete members may be solid or may contain hollow cores. Many precast components have thinner cross sections than cast in place concrete. Precast concrete may be either normal or lightweight concrete. Reinforced concrete contains steel bars, cable, wire mesh or random glass fibers. The addition of reinforcing material enables concrete to resist tensile stresses which lead to cracking.

The compressive strength of concrete varies according to the proportions of the components in the mixture. The desired compressive strength of the concrete will be specified according to the application. Water and cement content of the mix is the main determinant of the compressive strength.

The compressive strength of concrete can range from 2,000 psi to over 20,000 psi, depending on the mixture and how it is cured. Most concrete mixes are designed to obtain the desired properties within 28 days after being cast.

**Concrete Masonry Units (CMU)** – Block is typically formed with large hollow cores. Block with a minimum 75% solid cross section is called solid block even though it contains hollow cores. In many parts of the country building codes require steel reinforcing bars to be placed in the hollow cores, and the cores to be filled solid with grout.

In some areas of the eastern United States, past practice was to mix concrete with coal cinders to make cinder blocks. Although cinder blocks are no longer made, there are many existing buildings where they can be found. Cinder blocks require special attention as they soften with age.

**Brick** – Clay brick is formed solid or with hollow cores. The use of either type will vary in different parts of the United States. Brick can be difficult to drill and anchor into. Most brick is hard and brittle. Old, red clay brick is often very soft and is easily over-drilled. Either of these situations can cause problems in drilling and anchoring. The most common use of brick today is for building facades (curtain wall or brick veneer) and not for structural applications. Brick facade is attached to the structure by the use of brick ties spaced at intervals throughout the wall. In older buildings, multiple widths, or "wythes" of solid brick were used to form the structural walls. Three and four wythe walls were common wall thicknesses.

**Clay Tile** – Clay tile block is formed with hollow cores and narrow cavity wall cross sections. Clay tile is very brittle, making drilling difficult without breaking the block. Caution must be used in attempting to drill and fasten into clay tile.

## G2. Anchor failure modes

### Anchor Failure Modes

The failure modes for both mechanical and adhesive anchors depends on a number of factors including the anchor type and geometry, anchor material mechanical properties, base material mechanical properties, loading type and direction, edge distance, spacing and embedment depth.

Six different failure modes are generally observed for mechanical and adhesive anchors installed in concrete under tension loading: concrete cone breakout, concrete edge breakout, concrete splitting, anchor slip, adhesive bond, and steel fracture. Three failure modes are generally observed for mechanical and adhesive anchors installed in concrete under shear loading: concrete edge breakout, pryout and steel failure.

### Concrete Cone Breakout Failure

This failure mode is observed for both mechanical and adhesive anchors installed at shallow embedment depths under tension loading. This failure mode is also observed for groups of mechanical and adhesive anchors installed at less than critical spacing.

### Concrete Edge Breakout Failure

This failure mode is observed for both mechanical and adhesive anchors installed at less than critical edge distance under either tension or shear loading. For this failure mode neither the adhesive nor mechanical anchor fail, but rather the concrete fails. According to Simpson Strong-Tie testing, the tension load at which failure occurs is correlated to the concrete aggregate performance. Other factors may also influence tension load.

### Concrete Splitting Failure

This failure mode is observed for both mechanical and adhesive anchors installed in a "thin" concrete member under tension loading.

### Anchor Slipping Failure

This failure mode is observed for mechanical anchors under tension loading in which the anchor either pulls out of the member (e.g. - a Drop-In Anchor installed through metal deck and into a concrete fill) or the anchor body pulls through the expansion clip (e.g. - a Wedge-All® anchor installed at a deep embedment depth in concrete).

### Adhesive Bond Failure

This failure mode is observed for adhesive anchors under tension loading in which a shallow concrete cone breakout is observed along with an adhesive bond failure at the adhesive/base material interface. The concrete-cone breakout is not the primary failure mechanism.

### Steel Fracture

This failure mode is observed for both mechanical and adhesive anchors under tension or shear loading where the concrete member thickness and mechanical properties along with the anchor embedment depth, edge distance, spacing, and adhesive bond strength (as applicable), preclude base material failure.

### Pryout Failure

This failure mode is observed for both mechanical and adhesive anchors installed at shallow embedment under shear loading.

## G3. Corrosion resistance

Metal anchors and fasteners will corrode and may lose load-carrying capacity when installed in corrosive environments or exposed to corrosive materials. There are many environments and materials which may cause corrosion including ocean salt air, fire-retardants, fumes, fertilizers, preservative-treated wood, dissimilar metals, and other corrosive elements.

Some types of preservative-treated woods and fire-retardant woods are known to be especially caustic to zinc and can cause anchors and fasteners to deteriorate. Zinc-coated anchors and fasteners should not be placed in contact with treated wood unless the treated wood is adequately verified to be suitable for such contact. See page 16 in this catalog and contact the wood supplier for additional information.

Some products are available with additional coating options or in stainless steel to provide additional corrosion resistance.

Highly-hardened fasteners can experience premature failure due to hydrogen-assisted stress corrosion cracking when loaded in environments producing hydrogen. Simpson Strong-Tie® recommends that such fasteners be used in dry, interior and non-corrosive environments only.

## MECHANICAL ANCHORS

### M1. Pre-Load Relaxation

Expansion anchors that have been set to the required installation torque in concrete will experience a reduction in pre-tension (due to torque) within several hours. This is known as pre-load relaxation. The high compression stresses placed on the concrete cause it to deform which results in a

relaxation of the pre-tension force in the anchor. Tension in this context refers to the internal stresses induced in the anchor as a result of applied torque and does not refer to anchor capacity. Historical data shows it is normal for the initial tension values to decrease by as much as 40–60% within the first few hours after installation. Retorquing the anchor to the initial installation torque is not recommended, or necessary.

# SUPPLEMENTAL TOPICS FOR ANCHORS



## ADHESIVE ANCHORS

### A1. Oversized Holes

The performance data for adhesive anchors are based upon anchor tests in which holes were drilled with carbide-tipped drill bits of the same diameter listed in the product's load table. Additional static tension tests were conducted to qualify anchors installed with SET, ET, EDOT™ and Acrylic-Tie® adhesives for installation in holes with diameters larger than those listed in the load tables. The tables indicate the acceptable range of drilled-hole sizes and the corresponding allowable tension-load reduction factor (if any). The same conclusions also apply to the published allowable shear load values. Drilled holes outside of the range shown below are not recommended. Please note that the use of oversized holes is NOT permitted for anchors installed with SET-XP™ adhesive or the IXP™ Anchor with SET-XP™ adhesive.

### A2. Core-Drilled Holes

The performance data for adhesive anchors are based upon anchor tests in which holes were drilled with carbide-tipped drill bits. Additional static tension tests were conducted to qualify anchors installed with SET, ET and Acrylic-Tie® anchoring adhesives for installation in holes drilled with diamond-core bits. In these tests the diameter of the diamond-core bit matched the diameter of the carbide-tipped drill bit recommended in the product's load table. The test results showed that no reduction of the published allowable tension load for SET, ET and Acrylic-Tie anchoring adhesives is necessary for this condition. The same conclusions also apply to the published allowable shear loads. Please note that the use of core-drilled holes is NOT permitted for anchors installed with EDOT, SET-XP™ adhesive or the IXP Anchor with SET-XP™ adhesive.

### A3. Installation in Damp, Wet and Submerged Environments

**SET-XP™:** The performance data for adhesive anchors using SET-XP™ epoxy anchoring adhesive are based upon tests according to ICC-ES AC308. This criterion requires adhesive anchors that are to be installed in outdoor environments to be tested in water-saturated concrete holes that have been cleaned with less than the amount of hole cleaning recommended by the manufacturer. A product's sensitivity to this installation condition is considered in determining the product's "Anchor Category" (strength reduction factor).

#### Based on Reliability Testing per ICC-ES AC308

- **Dry Concrete** – Cured concrete whose moisture content is in equilibrium with surrounding non-precipitate atmospheric conditions.
- **Water-Saturated Concrete** – Cured concrete whose internal aggregate materials are soaked with moisture.
- **Submerged Concrete** – Cured concrete that is covered with water and water saturated.
- **Water-Filled Hole** – Drilled hole in water-saturated concrete that is clean yet contains standing water at the time of installation.

**SET, ET, EDOT, Acrylic-Tie® and VGC:** The performance data for adhesive anchors using SET, ET, EDOT, Acrylic-Tie® and VGC adhesives are based upon tests in which anchors are installed in dry holes. Additional static tension tests were conducted for some products in damp holes, water-filled holes and submerged holes. The test results show that no reduction of the published allowable tension load is necessary for SET, ET, EDOT™, and Acrylic-Tie® adhesives in damp holes, or for SET and Acrylic-Tie adhesives in water-filled holes. For SET, ET, and Acrylic-Tie adhesives in submerged holes, the test results show that a reduction factor of 0.60 is applicable. The same conclusions also apply to the published allowable shear load values.

#### Based on Service Condition Testing per ICC-ES AC58

- **Dry Concrete** – Cured concrete whose moisture content is in equilibrium with surrounding non-precipitate atmospheric conditions.
- **Damp Hole** - A damp hole, as defined in ASTM E1512 and referenced in ICC-ES AC58, is a drilled hole that has been properly drilled, cleaned and then is filled with standing water for seven days. After seven days, the standing water is blown out of the hole with compressed air and the adhesive anchor is installed.

### Epoxy-Tie® (SET and ET)

Insert Diameter (in.)	Acceptable Hole Diameter Range (in.)	Acceptable Load Reduction Factor
3/8	1/2 - 3/4	1.0
1/2	5/8 - 15/16	1.0
5/8	3/4 - 1 1/8	1.0
3/4	7/8 - 1 1/16	1.0
7/8	1 - 1 1/2	1.0
1	1 1/8 - 1 11/16	1.0
1 1/8	1 1/4 - 1 7/8	1.0
1 1/4	1 3/8 - 2 1/16	1.0
1 3/8	1 1/2 - 2 1/4	1.0

### Acrylic-Tie®

Insert Diameter (in.)	Acceptable Hole Diameter Range (in.)	Acceptable Load Reduction Factor
3/8	7/16 - 1/2	1.0
1/2	9/16 - 5/8	1.0
5/8	1 1/16 - 3/4	1.0
3/4	13/16 - 7/8	1.0
7/8	1	1.0
1	1 1/16 - 1 1/8	.75 for 1 1/8 only

1. Anchor diameters over 1" in diameter were not tested for greater than 1/16" hole overdrill.

- **Water-Filled Hole** - A water-filled hole is defined similarly to a damp hole; however, the standing water is not blown out of the hole. Instead, the adhesive is injected directly into the water-filled hole (from the bottom of the hole up) and the insert is installed.
- **Submerged Hole** - A submerged hole is similar to a water-filled hole with one major exception – in addition to standing water within the hole; water also completely covers the surface of the base material as well. Note that drilling debris and sludge should be removed from the drilled hole prior to installation. ASTM E1512 and ICC-ES AC58 do not address this condition.

### A4. Elevated In-Service Temperature

The performance of all adhesive anchors is affected by elevated base material temperature. The in-service temperature sensitivity table provided for each adhesive provides the information necessary to apply the appropriate load-adjustment factor to either the allowable tension based on bond strength or allowable shear based on concrete edge distance based for a given base material temperature. While there is no commonly used method to determine the exact load-adjustment factor, there are a few guidelines to keep in mind when designing an anchor that will be subject to elevated base-material temperature. In any case, the final decision must be made by a qualified design professional using sound engineering judgment:

- When designing an anchor connection to resist wind and/or seismic forces only, the effect of fire (elevated temperature) may be disregarded.
- The base-material temperature represents the average internal temperature and hence, the temperature along the entire bonded length of the anchor.
- The effects of elevated temperature may be temporary. If the in-service temperature of the base material is elevated such that a load-adjustment factor is applicable, but over time the temperature is reduced to a temperature below which a load-adjustment factor is applicable, the full allowable load based on bond strength is still applicable. This is applicable provided that the degradation temperature of the anchoring adhesive (350° F for SET-XP™, SET, ET, and AT) has not been reached.

### A5. Creep Under Long-Term Loads

Creep is the slow continuous deformation of a material under constant stress. Creep occurs in many construction materials, including concrete and steel when the stress is great enough. The creep characteristics of adhesives are product dependent. Adhesive anchors that are not creep resistant can pull out slowly over time when sustained tensile loads are applied.

Because of the creep phenomenon, it is important for Designers to consider the nature of the applied tension loads and to determine if the tension loads will be continuously applied to the anchor over the long-term. If this is the case, a product that is suitable for resisting sustained loads over the long-term must be selected.

All Simpson Strong-Tie anchoring adhesives (SET-XP™, SET, ET, EDOT, Acrylic-Tie® and VGC) have been qualified for resisting long-term loads through ICC-ES AC58 or AC308 "creep tests" in which an anchor is loaded and monitored for movement over time. According to AC58 and AC308, anchors that pass the creep test are determined to be suitable for resisting long-term tensile loads.