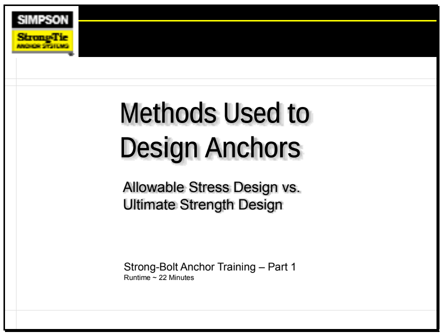
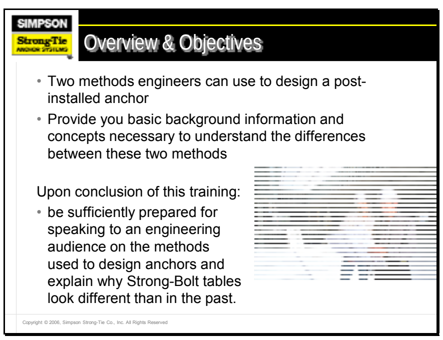
SCRIPT FOR PRESENTATION



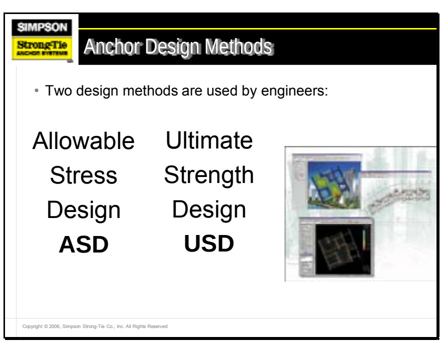
Methods Used to Design Anchors
Part 1 of the Strong-Bolt Anchor Training Course
Presented by Simpson Strong-Tie
The leader in structural connectors and other related building products



This training module will cover the two methods engineers can use to design a post-installed anchor.

This training is intended to provide you with the basic background information and concepts necessary to understand the differences between these 2 methods and why the Strong-Bolt design tables look different than how anchor load tables have looked like in the past.

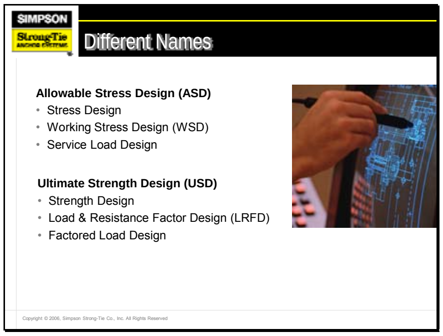
Upon conclusion of this training, you should be sufficiently prepared to speak with an engineering audience on the methods used to design anchors and explain why the Strong-Bolt design tables look different than how anchor load tables have looked like in the past..



There are two design methods used by engineers. Whether they are designing an anchor, beam, bolt or column, and whether it be made of steel, wood, masonry, or concrete; there are two methods to design it.

The Allowable Stress Design method (also know an ASD)
OR
The Ultimate Strength Design method (also referred to as USD.

To keep things simple, from this point forward we'll only discuss these methods as they relate specifically to anchor design.

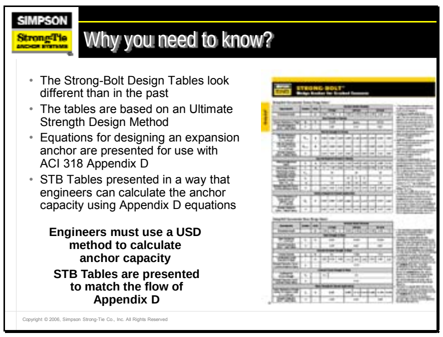


Both ASD and USD can be referred to by many different names.

Allowable Stress Design, or ASD, is also referred to as: Stress Design, Working Stress Design (WSD) and Service Load Design.

Ultimate Strength Design, or USD, can also be referred to as: Strength Design, Load and Resistance Factored Design (LRFD) and Factored Load Design.

Whatever terms an engineer uses – don't get confused. They're either referring to the ASD or USD Method.



Let's discuss why you need to know about these different design methods.

The Strong-Bolt Design Tables look much different than how anchor design tables have looked like in the past. Many designers may ask you why the new tables look different than the 'old' tables. The reason they look different is because the newer Building Codes, such as IBC 2003, require expansion anchors be designed using an Ultimate Strength Design Method (USD), not an Allowable Stress Design Method (ASD).

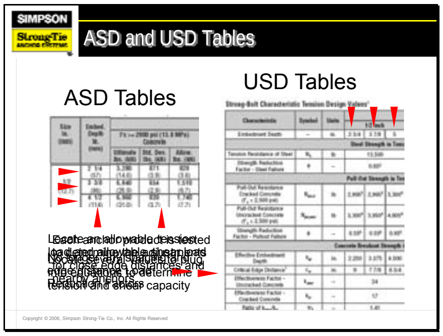
The Ultimate Strength Design Method and equations for designing an expansion anchor are presented in a document called ACI 318 Appendix D. And the Strong-Bolt Tables are presented in a way such that engineers can calculate the anchor capacity using the Appendix D equations.

As Sales Reps, you are not required to know <u>how to design</u> with the Strong Bolt, nor understand all the Appendix D equations, but rather just know the following:

1.) The engineer must use an Ultimate Strength Design Method to calculate the anchor capacity, and

2.) The information in the Strong-Bolt tables are presented to match the flow of the Appendix D equations.

For detailed information on how to use the STB tables in conjunction with a Strength design method, you should refer engineers to our catalog example and/or a Simpson Field Engineer.



Without going into too much detail right now, take a look at a typical old ASD based table and the new USD based table. Shown here are 3 embedments for a single ½" diameter anchor. As you can see there is much more information presented in the new USD table versus the old ASD table.

In the ASD table, engineers can quickly locate an allowable tension load and the allowable shear load at a given embedment.

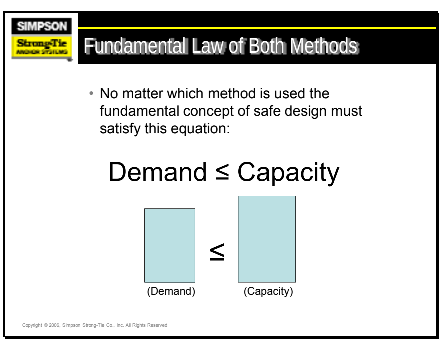
In the USD table, engineers are required to locate several values in order to plug into several equations to determine the tension and shear capacity for each possible anchor failure mode.

In addition, under the ASD method, each anchor product is tested to determine the adjustments required for close edge distances and nearby anchors. The anchor tension and shear loads are then adjusted accordingly.

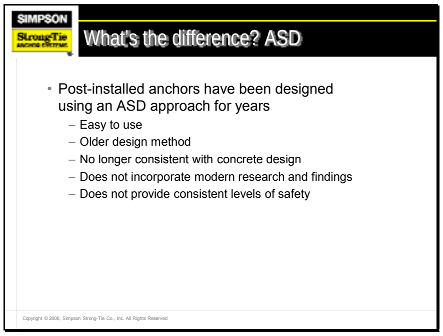
Under the new USD method there will no longer be any spacing and edge distance Load Reduction Factors published. Instead, adjustments for spacing and edge are accounted for directly in Code equations.

The USD method bases modifications for spacing and edge almost entirely on the anchor location and geometry, but not so much on the product itself.

So as you can see, understanding the differences between the two anchor design methods will also provide an increased understanding of why the Strong-Bolt Design tables look different than how anchor tables looked like in the past.



Although there are some definite differences between these two methods there is also one very common concept. No matter which method is used (ASD or USD), the fundamental concept for safe designs must satisfy this basic equation: the Anchor Capacity must be greater than or equal to the anchor Demand.

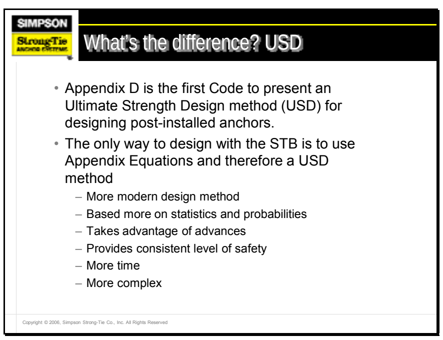


Let's review some more differences between the two methods.

Post-installed anchors have been designed using an ASD approach for years. ASD is easy to use but it also has some drawbacks. ASD is considered an "older" design method. It use to be the design method used to design structures made of concrete and most other construction materials, but this is no longer the case. Now concrete structures are designed using a USD method so using ASD to design anchors is no longer consistent with the concrete design that it is being anchored into.

And since it's an older method, ASD also does not incorporate more recent research and findings in the fields of material science, structural response, and structural loading. As a result, ASD does not provide consistent levels of safety with current day design, since it treats all loads and failure modes the same whereas recent studies indicate otherwise.

However, until just recently there hasn't even been another method to design expansion anchors any differently. So as you can imagine, there will be many engineers who are unaware another method even exists.

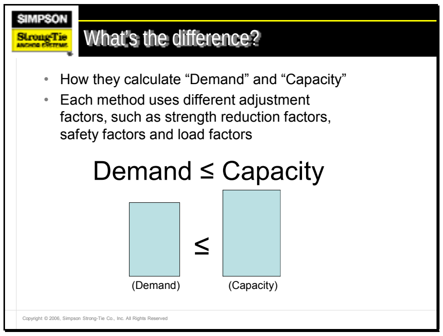


ACI 318 Appendix D is the first Code to present an Ultimate Strength Design method (USD) for designing post-installed anchors.

The only way to design with the Strong-Bolt is to use the equations of Appendix D and therefore use a USD method.

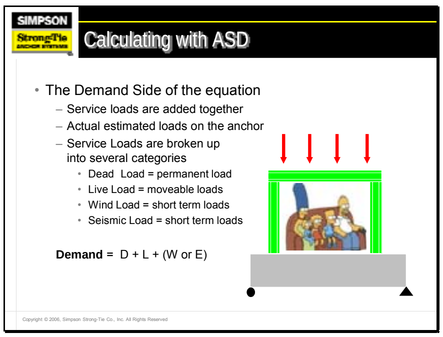
USD is considered to be a more modern design method and is based more on statistics and probabilities. USD takes advantage of the many advances in material science and structural research. As a result, USD provides more consistent levels of safety with current practice, as loads are treated differently based on the probability of them occurring at the same time.

The downside to all this is that it takes more time and is a lot more complex to design with.



But perhaps the most important difference for you to know about these two methods is how they calculate the "Capacity" and the "Demand" side of the equation we presented earlier. Each method uses different adjustment factors, such as strength reduction factors, safety factors and load factors, to determine each side of the equation. And again, although each method calculates each side differently, the bottom line in each anchor design method is that the Capacity has to be greater than or equal to the Demand.

Let's take a closer look at how each method calculates Capacity and Demand for the equation.



First we will review calculating with ASD, the method that has been used for all post-installed anchor design up until now.

In this method, Service Loads are added together to get the total figure for Demand. Service Loads are the actual estimated loads on the anchor and are either supplied by or calculated from the Building Code.

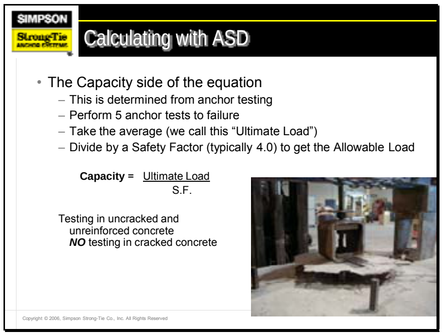
Service Loads are broken up into several categories. Some of the more common Service load categories include Dead Load, Live Load, Wind Load and Seismic Load.

A Dead Load is a permanent load, such as the weight of the structure – the beams, columns, roof and floor. This load can be estimated with a very high level of confidence since the weight of different construction materials is known.

A Live Load is a load that may fluctuate over time, such as people in a room or furniture. Since there is some uncertainty as to how many people will be in the room at a given time this load cannot be estimated as confidently as a Dead Load.

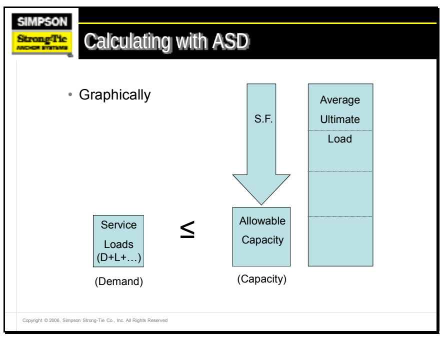
Wind and Seismic are other types of Service Loads. These are short term loads and they vary depending on location of the project and data collected from previous wind and seismic events.

In ASD, the demand side of the equation is calculated by simply adding up all the Service Loads.



In the ASD method, the Capacity side of the equation is determined through anchor testing. Historically, manufacturers have been testing anchors in "un-cracked" and un-reinforced concrete. They perform 5 tests and take the average of the failure loads and call it the "Ultimate Load". This "Ultimate Load" is then divided by a Safety Factor (typically 4.0) in order to get the "Allowable Load".

In the ASD method, the engineer does not know and is not concerned with, how the anchor failed on the tests: whether the steel failed, the concrete failed, or the anchor pulled out of the hole. The published "Allowable Load" simply gives the lowest capacity of all possible failure modes and the engineer uses that number for the anchor Capacity. The engineer then makes sure the anchor Capacity is greater than the anchor Demand.

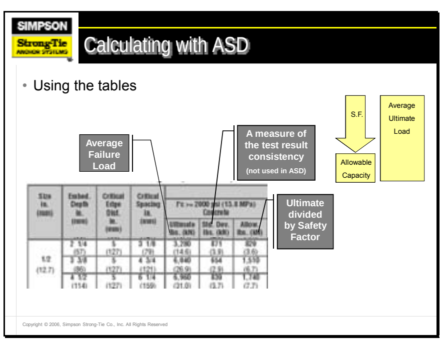


Graphically, the ASD calculation looks like this.

Demand: the estimated Service Loads are added together

Capacity: the average failure load of the anchor ("Ultimate Load") is reduced by dividing by a Safety Factor.

The Safety Factor acts as a "catch-all" and attempts to consider things such as material variability, uncertainty in anchor loading and installation errors.

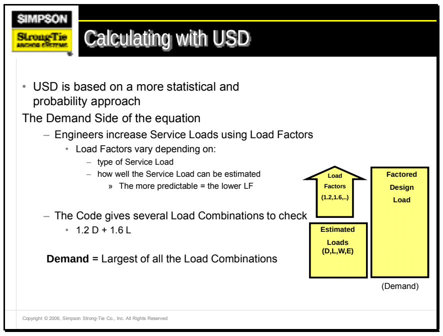


Now looking at a sample ASD table in the Simpson catalog. Here, the following load information was given from the test results:

The Ultimate Load, which is the average of all failure Loads

The Standard Deviation, which is a measure of the test result consistency.

And the Allowable Load, which is the Ultimate Load divided by the safety factor
To design an anchor using this table, the engineer only needs to know the allowable load.



Now let's review calculating with the USD Method.

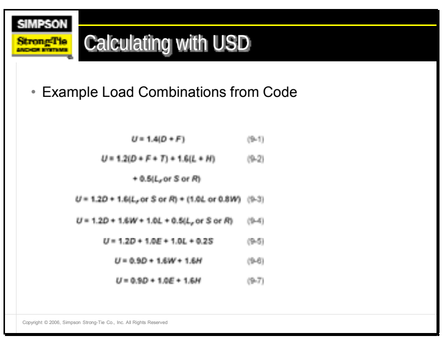
USD is based on a more statistical and probability approach. Unlike ASD, rather than using one safety factor as a 'catch-all' for all the uncertainties involved in the loading, testing, and failure mode; USD uses a factor for each of these.

For the Demand side of the equation, engineers increase the Service Loads using Load Factors. The magnitude of these Load Factors will vary depending on the type of Service Load and how well the Service Load can be estimated. A more predictable Service Load equals a lower Load Factor.

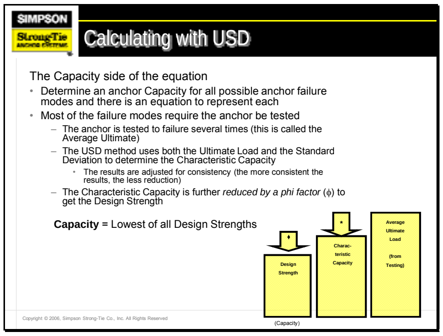
Dead Loads are well known, since the building materials are a known constant, and are therefore typically magnified less than Live Loads. Live Loads are variable and therefore, there is more uncertainty and a higher Load Factor is used.

The Code gives several different Load Combinations that are to be considered by the designer. Shown here is a common Load Combination. 1.2 times Dead Load + 1.6 times the Live Load. As you can see, the dead load factor is increased by plus 20% whereas the Live load factor is increased by plus 60%.

The resulting highest Load Combination becomes the Demand side of the equation.



This is an example of the actual Load Combinations given by the Building Code.



The Capacity side of the equation is more complex.

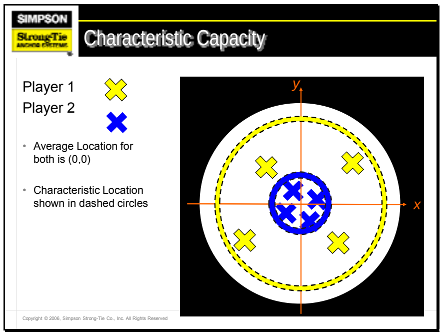
Under the USD method, engineers have to determine an anchor Capacity for all possible anchor failure modes and there is an equation to represent each. As an example there is one equation to determine the capacity based on a steel failure, another equation for the capacity based on a concrete failure, and one for if the anchor pulls out of the concrete.

Most of the failure modes require the anchor be tested accordingly. Again, the anchors are tested several times to failure and the average failure load is called the "Average Ultimate Load".
The details of the new anchor testing are difficult to explain, so for now, it is only important to understand that Simpson, as the anchor manufacturer, must still test our anchors but that the new testing is much more complex and expensive than what was required under the ASD method, and some of this testing is performed in cracked concrete.

Unlike the ASD Method, the USD method uses both the ultimate load and the standard deviation in determining a Characteristic Capacity, which is also referred to as a Nominal Strength.
If the test results show a high level of consistency, the Average Ultimate is reduced less than if the test results show a low level of consistency. By definition, the Characteristic Capacity means we are 90% confident that there is a 95% probability that the actual strength will exceed this value.

This characteristic capacity is then further reduced by a phi factor in order to get a Design Strength. The phi factor takes into account things like the anchor failure mode and the anchor reliability. For our purposes here, just know that a more reliable anchor would mean less reduction is taken on the Characteristic Capacity, whereas a less reliable anchor would mean more reduction is taken on the characteristic capacity.

The lowest Design Strength of all possible failure modes is then used as the Capacity side of the equation.

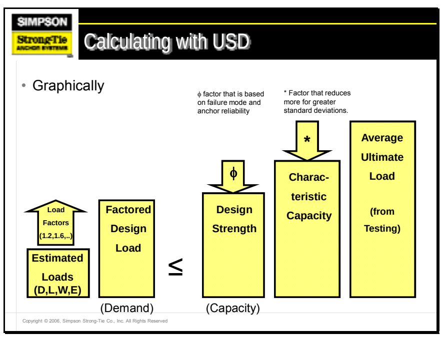


Here's another way to think of the Characteristic Capacity.

Think of it like a game where each player is trying to hit the center of a circular board.
Player 1 and player 2 each throw 4 darts. The average location of both players is exactly in the middle, at coordinates (x=0,y=0). Whereas, the characteristic location for each is shown by the dashed lines. This location is determined by using both the average dart location as well as dart consistency.

This line represents that if you were to throw 100 darts, there is a 90% confidence that at least 95 of those darts will fall inside this circle.

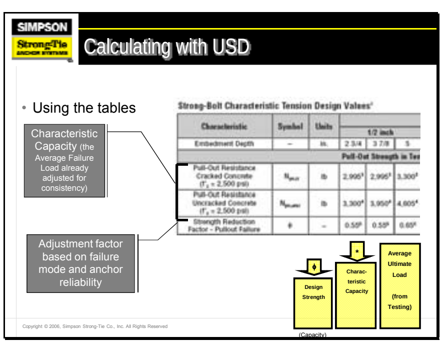
So to compare this to the 2 design methods. According to the ASD method, there is no difference between the 2 players as their average location is dead center at (0,0). Whereas according to the USD method, Player 2 would be rewarded for more consistent results.



Graphically, the USD calculation looks like this.

Demand: the estimated Service Loads are increased using Load Factors

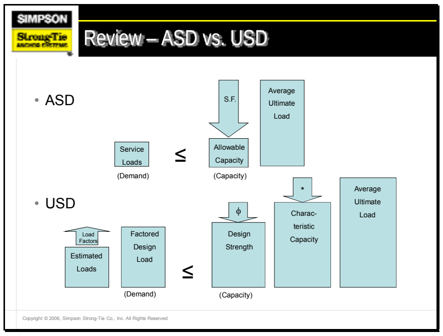
Capacity: the average Ultimate load from testing is reduced based on anchor consistency to get the Characteristic Capacity. It is then further reduced based on the anchor failure mode and the anchor reliability.



The tables in the Simpson catalog for USD are shown here.

Keep in mind this is the information required to complete only one of the 6 possible anchor failure modes.

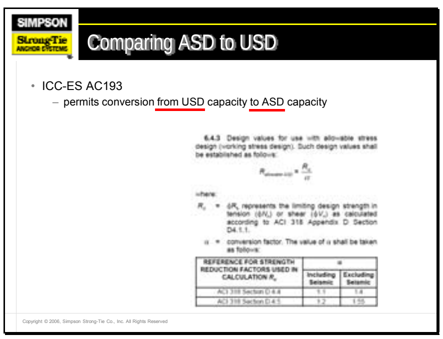
- The Characteristic Capacity, which is the Average Failure Load already adjusted for consistency is published. For this specific failure mode of pull-out, there are two numbers given: one for cracked concrete and one for uncracked concrete.
- The phi factor, which is the adjustment factor based on the anchor failure mode and anchor reliability, is also published in the catalog tables.



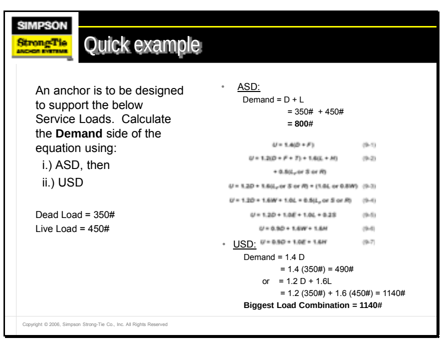
Let's summarize the two methods.

The ASD Method uses one Safety Factor to account for loading, inconsistencies in anchor testing and anchor reliability. Whereas, the USD Method came about from further research and is based more on failure probabilities and statistical data. It has a factor for each of the anchor loading, testing and reliability figures.

It's quite possible you will get asked how the ASD capacity compares to the USD capacity. In general, the calculated USD capacity will be greater than the ASD capacity. However, keep in mind that under the USD method, the USD capacity is compared to service loads that are factored up. Whereas under the ASD method, the ASD capacity is compared directly to un-factored service loads. So when comparing the 2 methods, it's more important to determine by how much does the capacity exceed the demand of each method. This will be better illustrated in an upcoming example with actual numbers.



The new Acceptance Criteria for mechanical anchors (ICC-ES AC193) allows designers to convert USD anchor capacities to ASD. This is only to be used for converting **FROM** USD **TO** ASD but not vice versa. If this conversion is performed, then the converted ASD capacity is compared to the ASD Demand (adding up all Service Loads with no Load Factors applied).



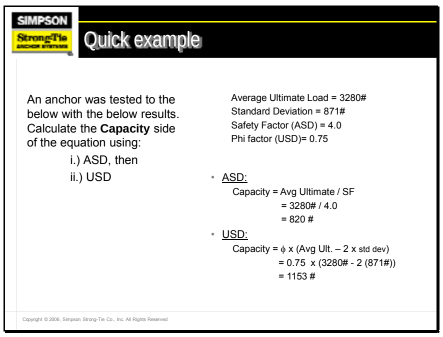
Now let's walk through an example with some actual numbers.

In this example we are going to use ASD and USD methods to analyze an anchor. In the first part we will calculate the Demand side of the equation using both methods.

We will assume the below Service loads: Dead Load = 350 lbs, Live Load = 450 lbs.
To review, the ASD method calculates the demand by simply adding the Service Load figures together, resulting in 800 lbs.

The USD method considers several different load combinations that place Load Factors on each service load based on our ability to estimate those loads. For time constraints, let's assume we only have to consider 2 of these load combinations (1.4D or 1.2D+1.6L). The highest resulting combination of these 2 is 1.2D + 1.6L, resulting in 1140 lbs.

As you can see from this example, for the same Service Loads, the USD method calculates a much higher Demand side of the equation.

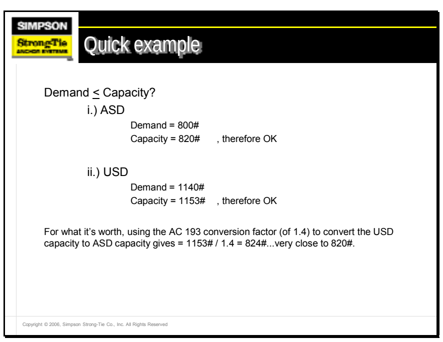


For the Capacity calculation we will assume the following test results to complete our example.

ASD uses the Average Ultimate and divides it by the Safety Factor. The assumption here is a Safety Factor of 4.0, resulting in an 820 pound capacity.

USD uses both the average ultimate and standard deviation to calculate a characteristic capacity, and then this is reduced further by a phi factor to account for the failure mode and anchor reliability, resulting in a 1153 pound capacity.

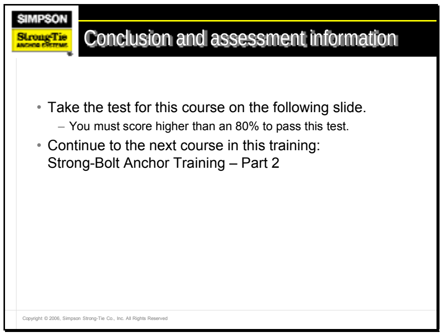
As you can see from this example, USD calculates a much higher Capacity than ASD.



For this example, both methods indicate the Capacity is greater than the Demand. Therefore, using either method the anchor would be OK to use.

Here is information to illustrate how the factor given by AC193 can be used. The USD capacity of 1153# would be divided by this factor (in this case it was 1.4) to calculate a converted ASD capacity of 824#. This converted ASD capacity is very close to the ASD capacity (of 820#) that was calculated using the ASD method.

This example shows that sometimes the two methods can produce similar results. However, keep in mind this is an extremely simple example and several assumptions were made to get this conclusion. If the anchor had tested with more standard deviation, or if there was a different load combination considered, then the two methods would not necessarily be as consistent with each other.



That concludes this portion of the training. Please take the test associated with this course and continue to the next course.