**SAFETY FACTORS FOR STRUTS (Part 1)**

**Introduction**

 While the fire service has readily accepted the FEMA structural collapse shoring standard, most firefighters are surprised to learn that *no* *standard can be found for trench rescue shoring systems.* The closest thing we have is “tabulated data” from the manufacturers of struts. The “tab data” is based on the performance (compression strength) of the struts tested in a laboratory setting and the soil forces used in the tab data are estimated “at rest” soil pressures..

 Engineers use the safety factors to determine the strut spacing found in the tab data. It should be noted that the resulting shoring charts (available from strut manufacturers) are written for the underground construction industry and not for rescue (collapse) conditions. Shoring during or immediately after the soil has been excavated (construction shoring) is significantly different than rescue shoring. If you can capture the soil before it begins to move (becomes unstable) a variety of theories can be applied (arching and pressurization zones) and in certain conditions skip or spot shoring can work. *Rescue shoring system designs are at the other end of the spectrum and should always assume unstable soil conditions.* Horizontal strut spacing at rescues, is most often based on the 4 foot horizontal distances which result from the use of rescue panels (4x8 Finnform with uprights) and the need for tight sheeting in unstable soil conditions.

 Since most trench rescue technicians have a rope rescue background we will take a look at a former safety factor requirement for rescue ropes. A rope that has a tested tensile strength of 9,000 pounds has a 15:1 safety ratio for a 600 pound (two person) load. A safety factor is a ratio found by dividing the strength of an item by the load (force that will be imposed on it). Pull out your calculator and do the math. Divide 9,000 by 600. The first NFPA standard on rope rescue required a minimum safety factor for equipment. Unfortunately, there is no standard for safety factors used in trench rescue shoring equipment.

 The MUSAR Training Foundation believes that a minimum safety factor of 2:1 (live victim) should be used to protect rescuers working in a trench or excavation. That safety factor should always be calculated using the lateral forces found in unstable soil conditions. System strengths are calculated based on the following:
 1. Component Strength- Each component must have an individual strength of at least two
 times the force of the soil
 2. System Strength- The entire shoring system (tested in a trench) must resist at
 least twice the force of the soil.

**PART 1- TERMINAL OBJECTIVE**- In this lesson you will learn how to determine the STRUT SAFETY FACTORS.

**PART 1- ENABLING OBJECTIVES**
\* Calculate the Tributary Area of the strut
\* Determine the Lateral Soil Force
\* Measure the Strut Depth
\* Calculate the Strut Safety Factor

**TRIBUTARY AREA-** The tributary area is the **square footage** of the trench wall that the strut will support. Rescuers commonly space struts at four horizontally and four feet vertically. In that case each strut would have a tributary area of sixteen square feet (4’x4’= 16square feet).

**LATERAL SOIL FORCE-** The soil force is measured in pounds per square foot. Engineers have several ways to determine lateral soil forces. In this lesson we will use the soil forces that have been adopted by OSHA, as a result of a consensus standard from the manufacturers of commercial shoring equipment. Those forces are a) 25 pounds per square foot (psf) for Type A soil (A-25), b) 45 pounds per square foot (psf) in Type B soil (B-45) and c) 60-80 pounds per square foot in Type C soil (C-60 and C-80). C-80 soil will not maintain a vertical wall long enough to be shored. Since most rescue incidents have trench walls that have partially collapsed but can be shored, lateral forces of **60 psf** should be used. The method for calculating soil forces found in this self-study is a stepping stone for learning to calculate soil forces of moving (collapse) soil conditions.

**STRUT DEPTH**- The strut depth is measured from the trench lip to the center of the strut.

**SOIL FORCE ON A STRUT**- A simplistic but (fairly) accurate way to determine the lateral force on a strut is to multiply the lateral force (per square foot) times the tributary area times the depth. This method calculates what is referred to as “triangular” strut loads. By using this information you should be able to figure out the potential lateral force on any strut you place in a trench.

Lets try one.
Figure the lateral force on a strut placed at 10’ deep with 4 foot horizontal and 4 foot vertical spacing in Type C soil.
FORMULA: Tributary area (4x4=16) times the force per square foot (60) times the depth (10). Do the math. (16 x 60 x 10)
 Tributary area x Force- 16x60= 960
 960 x 10 (depth)=9,600

A strut placed at 10 feet deep with 4 foot horizontal and 4 foot vertical spacing in Type C soil has to hold a lateral force of 9,600 pounds.

**SAFETY FACTOR-** For struts, the safety factor is determined by dividing the strut compression strength (manufacturer’s tab data) by the potential lateral force of the soil. To find the safety factor for that strut you will need to know the results from the compression tests. In this lesson we will provide the compression strengths. You divide the compression strength by the soil force. For example, if the strut failed at (compression strength) 40,000 pounds of force it has just over a 4:1 safety factor for the trench described above. (40,000/9,600= 4.1 to 1). We would call that a 4 to 1 safety factor.

**Review this material and take Quiz #1.** The quiz is written as a Microsoft Word Document.
If you open it with Word you can type your answers on the quiz then save it and send it back as an e-mail attachment.

Send to rescue\_zman@yahoo.com

**DO NOT BEGIN PART 2 UNTIL YOU HAVE COMPLETED QUIZ #1**

**SAFETY FACTORS FOR WALES (Part 2)**

**Introduction**

Make sure that you understand and can compute the safety factors as seen in Part 1. Let’s review the formula before we move on.

LATERAL FORCE ON STRUT REVIEW
Strut Spacing-4’x4’ =16 square feet)
Type C soil= 60 pounds per square foot
Strut Depth- 6 feet
FORMULA: **Square footage** times the **force** per square foot times the **depth**. Do the math.
You should have come up with 5,760

If you didn’t get 5,760 go back and read Part 1.

STRUT SAFETY FACTOR REVIEW
Determining the safety factors for struts (one component of a shoring system) is easy once you can work the formulas. All the numbers you need are available. The Trench Shoring Manufacturers and OSHA have given you the lateral force (per square foot). We assign a lateral force of 60 psf to all unstable soils. Strut manufacturers have tested the struts and have provided the compression strength (ultimate strength) data. You can find the test results in tabulated data (Tab Data). All you must do is determine the depth of the strut and the square footage (tributary area) that the strut will support.Let’s move on to Part 2.

**PART 2- TERMINAL OBJECTIVE**- In this lesson you will learn how to determine the WALE SAFETY FACTORS.

**PART 2- ENABLING OBJECTIVES**
\* Calculate the Tributary Area of the strut
\* Determine the Lateral Soil Force
\* Measure the Wale Depth
\* Calculate the Wale Safety Factor

**TRIBUTARY AREA-** The tributary area is the **square footage** of the trench wall that the wale will support. Rescuers commonly space struts (support) wales at eight feet horizontally and wales are typically spaced four feet vertically. In that case each wale would have a tributary area of thirty-two square feet. (8’x4’=32 square feet)

**LATERAL SOIL FORCE-** The soil force is measured in pounds per square foot. Engineers have several ways to determine lateral soil forces. In this lesson we will use the soil forces that have been adopted by OSHA, as a result of a consensus standard from the manufacturers of commercial shoring equipment. Those forces are a) 25 pounds per square foot (psf) for Type A soil (A-25), b) 45 pounds per square foot (psf) in Type B soil (B-45) and c) 60-80 pounds per square foot in Type C soil (C-60 and C-80). C-80 soil will not maintain a vertical wall long enough to be shored. Since most rescue incidents have trench walls that have partially collapsed but can be shored, lateral forces of **60 psf** should be used. The method for calculating soil forces found in this self-study is a stepping stone for learning to calculate soil forces of moving (collapse) soil conditions. **STRUT DEPTH**- The strut depth is measured from the trench lip to the center of the strut.

 **SOIL FORCE ON A WALE**- A simplistic but (fairly) accurate way to determine the lateral force on a wale is to multiply the lateral force (per square foot) times the tributary area times the depth. This method calculates what is referred to as “triangular” strut loads. By using this information you should be able to figure out the potential lateral force on any wale you place in a trench.

WALER SAFETY FACTORS
Our concern with walers is the area which is between the supports (struts). In this case a waler is a beam supported at two pints (struts). In trench rescue a common span (horizontal spacing) between supports is eight feet. Vertical spacing for walers is variable but is typically used at four feet.
Safety factors for walers can be determined by using the same formula that we used for struts. Let’s try one.

**FORMULA: Square Feet x Force x Depth
Example #1**
Tributary area (Square footage)- If you are spacing your walers 4 feet apart vertically and your struts are spaced 8 feet apart horizontally your tributary area is 32 square feet (4x8=32)
Force- 60 psf (pounds per square feet for Type C soil)
Depth- The waler is @ 10 feet deep
FORMULA: Square footage (32) times the force (60) times the depth (10)
32x60=1,920
1,920 x 10=**19,200**

**Example #2**
Tributary area (Square footage)
 \* Walers spaced 4 feet on center vertically
 \*Struts spaced 8 feet on center horizontal
Force- 60 psf
Depth- The waler for this problem is 6 feet deep
FORMULA: Square footage (32) times the force per square foot (60) times the depth (6)
32x60=1,920
1,920 x 6=**11,520**

You should have come up with 26,880. If you didn’t go back and read Part 1 and Part 2 again.

**WALE SAFETY FACTOR-** In order to compute the safety factor you must also know the strength of the waler. The theoretical strength of a waler depends on its size and material and the span between supports (spacing between struts). Most fire departments use wood (timbers) for walers. Finding the strength of timbers when used as walers in a trench is not an easy task. Finding the strengths of timbers (wales) with a variety of strut spacing is even more difficult.
Eight foot strut spacing on walers is a commonly used span (distance) for trench rescue shoring. We believe that for trench rescue shoring the “gold standard” for waler use should be based on the strength of a waler with struts 8 feet on center. Once that value is found simple calculations can be made to determine the strength of both longer and shorter spans. With MUSAR’s destructive testing and the help of our structural engineer we have come up with the following estimated waler strengths. They are based on an 8 foot strut spacing on wood which is not twisted or split and which does not have large or loose knots.

**Waler Breaking (Failure) Strength**
6”x6” Timber Waler- 14,000
8”x8” Timber Wales- 35,000
7”x7” LVL Wales- 45,000

Note: Our tests on the Paratech aluminum waler permanently deflected (failed ) at just over 14,000 pounds of force.

Now lets go back to the calculations that you made above in Example #1 and #2.

**Question #1**
Example #1 Review-(Horizontal Spacing @ 4’ between walers) (Vertical Spacing @ 8’between supports) (Soil Force @ 60psf) FORMULA- Square feet x Force x Depth
FORCE-**19,200** The force found in Example #1 was (32x60x10=19,200)
BREAKING STRENGTH- 7”x7”LVL waler fails at **45,000**
SAFETY FACTOR FORMULA: Breaking Strength divided by Force

Divide 45,000 by 19,200 and you get a safety factor of slightly over 2.3 to 1. That means if the soil becomes active, the waler will hold the soil force and some additional load/forces (like the load of firefighters working on the lip).

**Question #2**
(Horizntal Spacing @ 4’ between walers) (Vertical Spacing @ 8’between supports) (Soil Force @ 60psf)
FORCE-**11,520** The force found in Example #2 was (32x60x14=26,880)
BREAKING STRENGTH- 6’x6” waler fails at **14,000**
SAFETY FACTOR FORMULA: Breaking Strength divided by Force
Divide 14,000 by 11,520 and you get a safety factor of about one half to one (1.2:1) That means the force is very close to the breaking point of the wale. Firefighters working on the lip are likely to trigger a collapse and break the wale. The 6x6 wale does not met the 2:1 safety factor at and below depths of 6 feet.

Review this material and take Quiz #2. The quiz is written as a Microsoft Word Document. If you open it with Word you can type your answers on the quiz then save it and send it back as an e-mail attachment.

REMEMBER: To get the Safety Factor always divide the STRENGTH by the FORCE not the other way around.

Send to rescue\_zman@yahoo.com