Commentary on

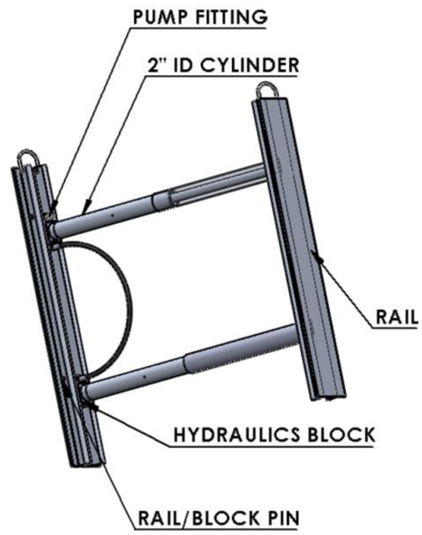
Aluminum Hydraulic Shoring Tabulated Data and Applications

As an engineer I have been working with aluminum hydraulic shoring in shoring plan applications for contractors and with manufacturers of the shores to engineer their product, write, and stamp their tabulated data since 1990. Throughout these years I have had hundreds of inquiries about interpretation and use of these shores. This commentary is intended to provide insight and hopefully some clarification on the questions I have received over the years. It is directed at essentially any person involved in the use or acceptance of aluminum hydraulic shoring applications such as instruction/trainers, engineers applying hydraulic shores in site specific plans, engineers that are reviewing hydraulic shoring submittals for their projects, OSHA officers and inspectors of hydraulic shoring in the field and competent person seeking to acquire additional information than is provided in normal competent person training.

Tabulated data and instruction on the use of aluminum hydraulic shores has been confusing. There seem to be two major reasons for this:

1. Lack of standardization. OSHA has one set of tabulated data, Subpart P-Appendix C, and manufacturers have developed similar but different tabulated data (written by each and every manufacturer of aluminum hydraulic shores).

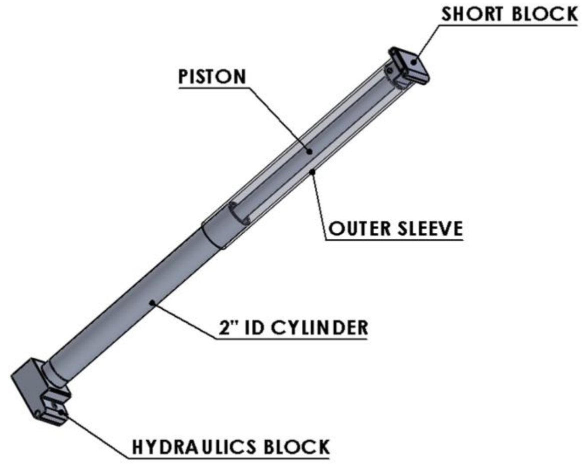
2. Details, depictions and notes within these sets of tabulated data are not always clear or inclusive of all possible situations.



By looking at the development of the hydraulic shore and the tabulated data behind it should help to understand and interpret the data.

Basic Principals of Hydraulic Shores

2" Cylinder Aluminum Hydraulic Shores are basically all the same. The cylinder is 2" inside diameter, the rail is 8" wide, and the blocks are designed to allow the shore to swing into place and lock.



- The area of the 2" cylinder is 3.14 square inches. Axial testing reports indicate that at short lengths the aluminum cylinder will burst at around 33,000 pounds, or a pressure of

  $$\frac{32{,}000\ \text{lb}}{3.14\ \text{in}^2} = 10{,}000\ \text{psi}$$

  Using a **factor of safety of 1.5**, the **safe working load** of these cylinders is **22,000** lbs. Virtually all hydraulic shore spacing vertical and horizontal is based on not exceeding this number.

  Longer cylinder lengths fail in buckling. A 3" round over sleeve is used to prevent buckling and after 8 ft extension a larger stronger over sleeve is required.

  The initial set pressure required is 800 psi to 1200 psi. This pressure stabilizes the hydraulic shore in the trench. Based on the 1.5 factor of safety the cylinder will safely hold 6,500 psi of pressure. That pressure is developed on the cylinder through soil and surcharge loading. The cylinder does not have to be pumped up to this pressure in order for it to resist that pressure; it just resists higher pressures until it fails.

- There are two types of rails, standard duty and heavy duty.

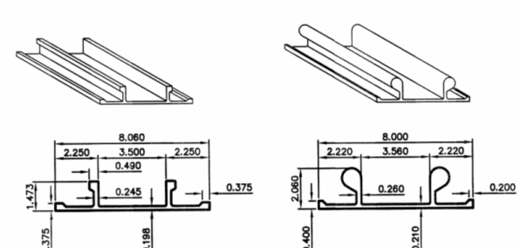
  One function of the rails is to hold the blocks and cylinders in place and facilitate the fold in installation of the shore. The rail is not a structural member; it is designed based on durability, (holds up to handling and installation for long periods of time).

  The other function of the rails is to keep the cylinder block from punching into the soil.

  There is nothing in the tabulated data that indicates when a standard duty rail or heavy duty rail has to be used.

VERTICAL RAIL SPECIFICATION SHEET

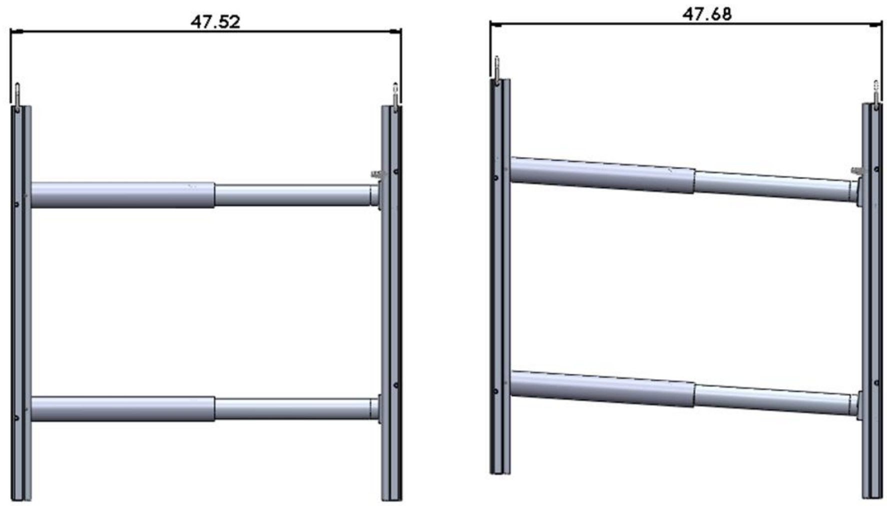
SECTION PROPERTIES	STANDARD RAIL	HEAVY DUTY RAIL
MATERIAL	ALUMINUM	ALUMINUM
ALLOY	6061–T6	6061–T6
AREA	2.45 in^2	3.47 in^2
WEIGHT	2.94 plf	4.17 plf
SECTION–MODULUS – TOP (LEG SIDE)	0.44 in^3	1.25 in^3
SECTION–MODULUS – BOTTOM (BLADE SIDE)	1.29 in^3	2.38 in^3
EQUIVALENT TIMBER SIZE * (#2 DOULAS FIR)	3x10 (FLAT)	4x10 (FLAT)



CROSS SECTION OF STANDARD VERTICAL RAIL

CROSS SECTION OF HEAVY DUTY VERTICAL RAIL

- A basic principal of hydraulic shores is that they lock into place.



The rotation of the rail block requires that distance between the two rails is wider during rotation than when it is pressurized into place. Conversely it means that once it is pressurized the trench would have to get wider in order for it to rotate back up.

This is the reason that the jacks need to be set with the cylinder perpendicular to the trench wall and the trench walls be parallel. It is easier to state this than to do it in the field so reasonable effort and care should be taken to make it happen. A sloped excavation pad will cause an excavator to dig a trench that is out of plumb. Trench jacks set in this trench will produce cylinders that are out of level. This is why on some tabulated data there is a tolerance of about 5 degrees from level or about 2” in a 4 ft wide trench.

Attempting to set trench jacks when they are initially extended wider than the trench width will require that the cylinder pressure bleed off and allow them to contract. This will require that the swing in leg be pushed down before the shore is pressurized. Doing this is dangerous and should not be done. The proper way to do it is to decompress the jack prior to inserting it.

- A basic principal of hydraulic shores is that they lock into place.

  It is possible for the shores to roll up even if they are locked into place due to uneven pressure on one side of the trench causing an uplift or heave failure. This can occur for many reasons such as the excavation spoils are on one side of the trench, or moving equipment surcharge loads parallel or perpendicular on one side only. This is most likely to occur with jacks that have only one or two cylinders.

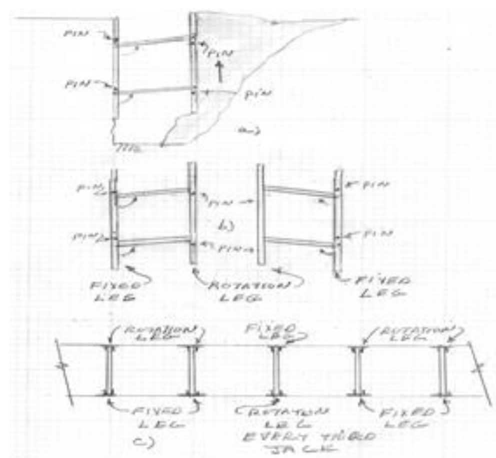


Figure 7. **a)** Trench jack fold up failure, **b)** leg rotation, **c)** jack rotation to prevent fold up

The solution to this is to rotate the swing in side of the jack after every other set.

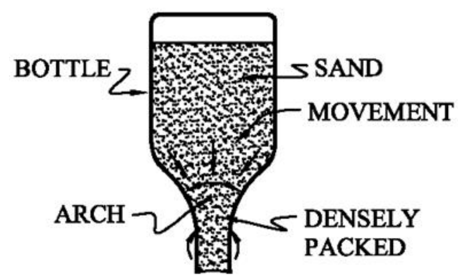
- Sheeting is only used to prevent sloughing and raveling, it is not a structural member. The sheeting needs to be able durable, (standing on edges and drug around during movement), and have the ability to prevent gravel, small rocks, and mud from coming off the trench wall and hitting the workers. ¾" plywood of any grade will do this as well as steel plate and 1-1/8" plywood will do this.

  The OSHA tabulated data requires ¾" Artic Birch Finform only because the manufacturers of this material were sitting at the table when the standard was being developed. As long as the material being used does the job the stamp or grade of material is insignificant.

  The key to sheeting preventing sloughing and raveling is to decrease the shore spacing until it is not occurring. Allowable spacing based on cylinder strength, like as much as 8 ft on center may have to be reduced because rock and gravel are falling out between the plywood spaces.

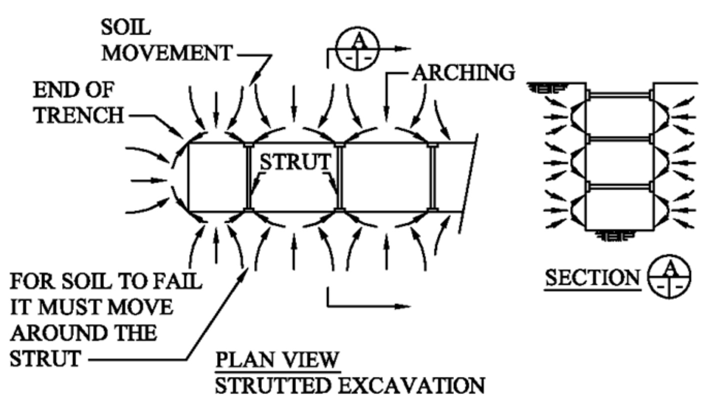
How Aluminum Hydraulic Shores interact with the soil

To an inexperienced observer of hydraulic shores being used in a trench without sheeting behind them the question that immediately comes to mind is, "what protects the worker from cave-in between the shores?" The answer is that soil arching is at work. Without this basic principal hydraulic shores would not be safe. It is clear that where the soil contacts the trench jack it cannot cave-in unless it can flow around it. As the soil tends to flow around and collapse between the jacks the particles jamb together (on a microscopic level) and an arch is set up between the shores. This happens both horizontally and vertically between the points where the cylinders are pressurized against the trench wall. This also happens between the bottom corners of the trench and the jack and also at the end of the trench between the corners of the. This explains why trenches do not cave in at the end of the trench.



There is no question that soil arching works and is primary reason that hydraulic shores work. It is important for the installer of the shores to understand that the arching must be set up properly, it is simple and easy but it must be paid attention to or an unsafe situation can be set up.

- **To obtain the soil arching effect there must be contact between the trench wall and the hydraulic shore. To achieve this, the cylinder must be pressurized and there must be contact between the rail and the soil near the hydraulic cylinder.**



Be aware of the following:

1. Soil can still slough or ravel out between the theoretical arch and the trench wall. In an 8 ft horizontal spacing the arch line is approximately back 6” to 12” from the face of the trench. This is why sheeting is required where sloughing or raveling occur.

2. When there is no soil contact between the cylinder the soil arching is not taking place. Shores set at 8 ft on center with no contact at one of the shores will result in a 16 ft arch with 2 ft to 3 ft of soil in front of the arch that can abruptly fall on the workers.

3. When hydraulic shores are being released and removed the support for the soil arch is being removed and soil collapse is more likely. The hazard that is created is “worker falling into trench due to soil collapse where he is standing”. There should be no person in the trench when the shores are being released

Differences between Appendix D-Aluminum Shore Tabulated Data and Manufacturers Tabulated Data

There are two basic versions of Aluminum Hydraulic Shore tabulated data, Data developed by OSHA and data developed by manufacturers. The details, depictions and notes within these sets of tabulated data are not always clear. The following focusses only on differences between the two:

- Appendix D States-This appendix must be used when design of the aluminum hydraulic protective system cannot be performed in accordance with 1926.652(c)(2).

  1926.652(c)(1) states-Designs for aluminum hydraulic shoring shall be in accordance with paragraph (c)(2) of this section, but if manufacturer's tabulated data cannot be utilized, designs shall be in accordance with appendix D.

  1926.652(c)(2) contains-Option (2)-Designs Using Manufacturer's Tabulated Data.

  By far the most confusion come from the fact that OSHA does not state that “This appendix ~~must~~ **cannot** be used when design of the aluminum hydraulic protective system ~~cannot~~ **can** be performed in accordance with 1926.652(c)(2)”. They did not clearly state this so it must be an option to use Appendix D in all instances.

  Is it, use whichever data you want? Is it, use the most stringent requirements? Is it mix and match?

  There are good **reasons to use appendix D in leau of manufacturers data;**
  - ✓ It is more conservative
  - ✓ It appears to conform to what OSHA prefers
  - ✓ It is a standard set of data that is generally referred to in competent person training. Easier to teach than sorting through different data developed by different manufacturers.
  - ✓ Maintaining different sets of data in your safety binders for several different shoring manufacturers is confusing and cumbersome.

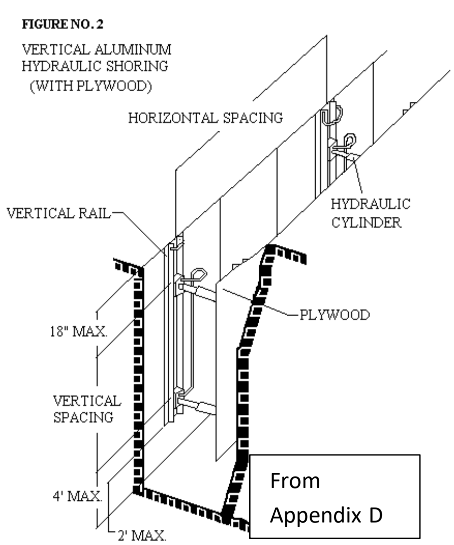
- ✓ The manufacturer of the hydraulic shoring you own is no longer in business and therefore the data is not available or backed up
- ✓ Your hydraulic shores are a mixture of parts from different manufacturers so the true manufacturer is unknown.

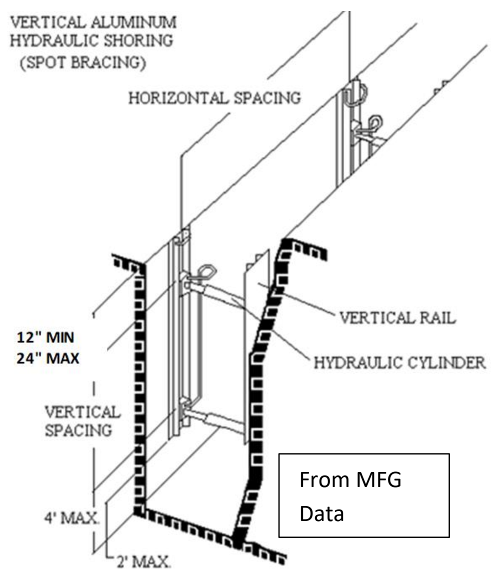
Reasons to use the manufacturer's data are:

- ✓ Less conservative but more reliable because it is developed and backed up by the manufacturers history and experience with the product
- ✓ Appendix D does not have tabulations for type C-60 Soil
- ✓ The manufacturer of the shoring equipment is pulled into the lawsuit should there be one.
- ✓ Can use hydraulic shores to 25 ft deep with mfg data and only 20 ft deep with Appendix D
- ✓ Appendix D does not allow 2" cylinders in trenches over 12 ft wide, 3" cylinders are required. The trench width does not affect the cylinder loading; the loading is the same regardless of the trench width. Buckling is the issue and is controlled by the over sleeve. Using an engineered design an effective over sleeve could be designed for any trench width.
- ✓ Appendix D requires 3 shores in the trench at all times, mfg tabulated data requires only 2
- ✓ The single jack 6 ft deep trench is an option

- Confusion about how far from the surface must the first cylinder be set.

  Appendix D says no more than 18" , MFG Data says 12" to 24"





- The appendix D data allows a maximum 9 ft-6” trench depth for a 2 cylinder hydraulic shore and the MFG data allows a 10 ft deep trench.
- There is no minimum distance to cylinder depth with the OSHA version. From an engineering perspective there is a problem with getting the cylinder too close to the surface because the pressure can cause the surface soils to fail.
- If the cylinder falls above the surface the rail will bend out when it is being initially pressurized, the surface the soil cannot arch to it and consequently there is only one cylinder doing the work. **Cylinders set above the surface are out of conformance with the tabulated data.**
- From a training stand point for vertical cylinder spacing it is simple to remember the two numbers, 2 and 4. **No more than 2 ft from the surface, no more than 4 ft from the bottom of the excavation and no more than 4 ft between the cylinders.**

- Confusion about the 2 ft max call out from the bottom of the trench to the bottom of the rail.

Some aluminum hydraulic shores have an 18” spacing between the bottom cylinder and the end of the rail. If this is the shore you are using the cylinder will have to be set no more than 3’-6” from the bottom of the trench.

The reason for the 2 ft spacing in all shoring applications, (hydraulic shore rail, shields, sheeting, etc.) is due to discussions leading up to the adoption of Subpart P when OSHA sponsored stake holder meetings in regions across the US A. There was a need to hold the shoring up off the bottom of the trench so that lateral pipe installations could pass under the shoring. Arguments from zero clearance to 4 ft were put forward and finally 2 ft was settled on resulting in:

> Subpart P 1926.652(e)(2)(i) Excavation of material to a level no greater than 2 feet (.61 m) below the bottom of the members of a support system shall be permitted, but only if the system is designed to resist the forces calculated for the full depth of the trench, and there are no indications while the trench is open of a possible loss of soil from behind or below the bottom of the support system.

Arguments with OSHA, on my part with different jurisdictions, to as an engineer exceed this 2 ft rule have resulted in final responses like:

> “Whats to stop you from allowing 4 ft or 6ft or 50 ft if you want?”

> “2 ft is the limit; we can discuss anything you want about it except the reasonableness or practicality of it, there are no exceptions ever”

Over the years I have come to agree with them and enforce it in my engineering work.

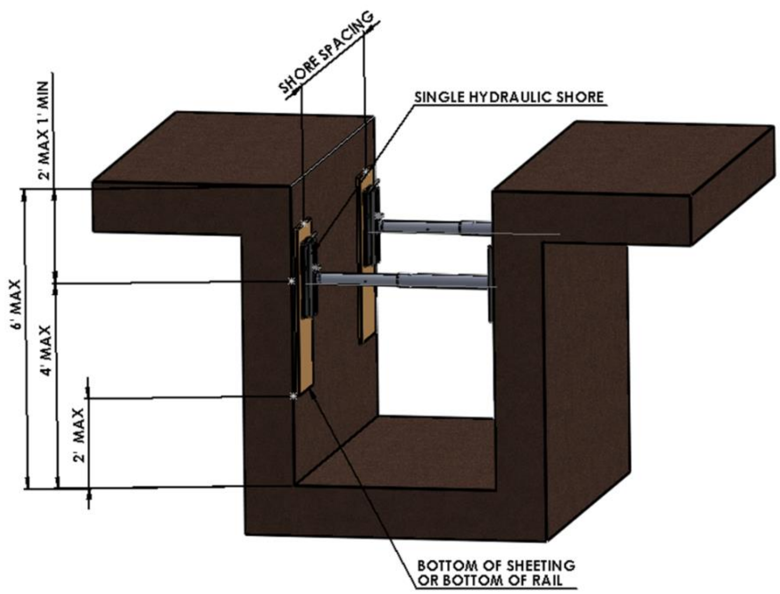
With aluminum hydraulic shore use the argument gets kind of squirrely because there can be as much as 8 ft between the shores horizontally with no structural element so what is the big deal about the rail being another 6” higher off the bottom. The response here was;

"just make sure the lowest element of your shoring is within 24" of the bottom of the trench and OSHA will leave you alone."

Other Hydraulic Shore information you should know and understand

- Universal Hydraulic Shore Tabulated Data

- **Single shore in 6 ft trench**



SINGLE SHORE IN TRENCH 6 FT DEEP

Sometime around 1995 I was asked by a hydraulic shoring manufacturer if I could develop tabulated data for a single shore in a 6 ft deep trench, based on the fact that with this configuration all of the typical shore parameters could be met, cylinder no more than 2 ft from the surface, no more than 4 ft from the bottom. At the time we ignored the requirement that the lowest element of the shoring be within 2 ft of the bottom because the single shores typically have 18" or 24" rails that would leave at best 3 ft from the bottom of the rail to the bottom of the shore. I was nervous about it at the time but based on the fact that the soil arches from the bottom corner of the trench to the first cylinder it made sense that it would work. Since then the single jack 6 ft deep trench has become common practice. Tabulated data sheets from several different manufacturers emerged after that without the 2 ft minimum lowest element requirement. A few years ago a contractor was cited for using this configuration without meeting the 2 ft requirement. I discussed it with OSHA and lost the argument.

- **Spot Shoring**

Single and double hydraulic shores are also used for what could be called spot shoring like:

- Areas around cross lines when shoring shields are being used as the protective system.
- Where there are several lines crossing at different angles and directions.
- Excavations where the final depth or extent is not known until the dig is completed, (exploratory or pipe repairs).

These situations are not well defined in the tabulated data. This type of use is OK under the tabulated data as long as the basics are maintained:

1. Identify the soil type
2. Space the shores in accordance with the soil type
3. Maintain the standard vertical spacing, 2 from the top, 4 ft between, 4 ft from the bottom, lowest element of the shoring must be within 2 ft of the bottom
4. Single shores are equivalent to multiple cylinder shores when spaced vertically spaced the same.
5. Use plywood in accordance with soil type and tabulated data

Also note that when hydraulic shores are placed against steel plates the shoring system does not establish soil arching, it is acting more like a shielding system.

- **Shore spacing-How it is determined**

Tabulated data for hydraulic shoring is determined based on the strength of the cylinders and the tributary area of soil + surcharge loading that it is resisting.

Using a 1.5:1 factor of safety from cylinder bulging the safe working load of a 2” aluminum hydraulic cylinder is 22,000 lbs[1]. After 8 ft of extension the cylinder and over sleeve are subject to buckling. For this reason, from 8 ft to 12 ft of extension the allowable loading is reduced to 18000 lbs.

Soil loading is determined by OSHA Appendix A soil type as follows:

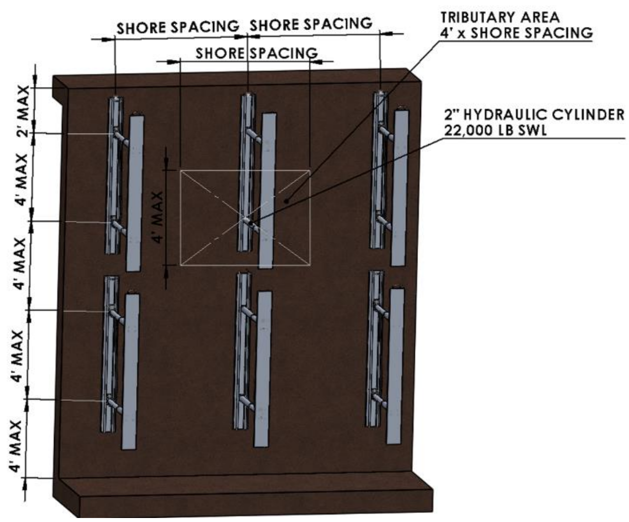
Soil Type A-25	25 x depth of excavation
Soil Type B-45	45 x depth of excavation
Soil Type C-60	60 x depth of excavation
Soil Type C-80	80 x depth of excavation

Example-B-45 soil 15 ft deep has a soil loading of 15 ft x 45 psf per ft of depth=675 lb/sq-ft (psf)

Surcharge loading is a horizontal force on the shoring resulting from a vertical force on the surface. According to OSHA loading from a piece of equipment like a small backhoe weighing 20,00 lb or less or a dirt spoil pile stacked 2 ft high set 2 ft from the edge will produce a 72 psf lateral load on the trench wall.

[1] Lab testing on 2” round x ¼” wall 6061-T6 aluminum hydraulic cylinders finds bulging at the intersection of the block to the tube at 33000 lbs. Applying a 1.5:1 factor of safety the safe working load would be 22000 lbs.

Develop horizontal shore spacing-B-45 soil 20 ft deep



Assume

20 ft deep excavation in OSHA Type B-45 soil

Hydraulic cylinders are never spaced more than 4 ft on center vertically

Allow 22000 lbs safe working load

Surcharge load = 72 psf

Soil load = 20x45=900 psf

Soil + surcharge = 900 +100 psf= 1000 psf

Calculation

Develop Horizontal Shore Spacing

Soil Type B-45	45 psf/ ft of depth	
Depth	20 ft	
Soil Pressure	900 psf	20 ft x 45 psf/ft of depth
Surcharge Loading	72 psf	spoil pile, k-rail and traffic set back 2 ft
Total soil loading + Surcharge	972 psf	

Allowable Cylinder Loading (ACL) = 22000 lb allows 1.5 factor of safety

Tributary Area = 4 ft x Allowable Shore Spacing

Allowable Cylinder Loading (ACL) = (soil loading + surcharge) x tributary area

22000 lb (ACL) =1000 psf x 4 ft x allowable shore spacing

Solve for allowable shore spacing

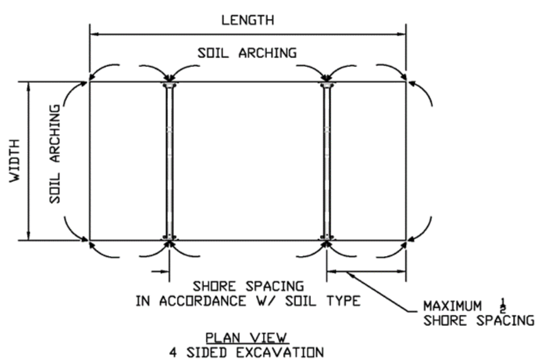
allowable shore spacing =22000 lb/(1000 psf x 4 ft)= 5.7 ft horizontal spacing

Rounds to 6' horizontal Spacing

This calculation is important for a couple of reasons.

1. Surcharge loading varies with the loading and distance from the edge of the excavation. For OSHA tabulations the base line is 2 ft and light equipment weighing less than 20,000 lb . Without doing this calculation engineers and competent persons have no way of knowing the effect on horizontal shore spacing from larger surcharge loads.
2. Over my engineering career of working with aluminum hydraulic shores since 1990 I cannot count the amount of times, I have been asked for the backup calculations to aluminum hydraulic shores. Due to major factors that affect the use of these shores such as soil arching, the effect of the rail on durability of the shore and cylinder punching into the soil, and the effect of adding sheeting the formulation is largely empirical (based on experience). The manufacturers do not hand out their calculations for these shores. The OSHA Appendix C tabulated data was adopted from recommendations by manufacturers and engineers at the time, (pre-1990). Since that adoption shore arch spacing has never gone beyond 4 ft vertical and 8 ft horizontal largely because we have no experience with these shores in those situations. For those who like numerical solutions the above calculation is at least one rule that can be applied to it.

- **Four Sided Excavations and End Shores**



Hydraulic shoring in 4 sided excavations is a problem because 2 cylinder and longer shores cannot be placed perpendicular to each other. With shores placed in one direction only the issue becomes how wide can the end of a trench be before it will cave-in. Soil arching works across the end of a trench, the supports are the soil at the corners. In keeping with the allowable shore spacing on tabulated data from soil types a general rule can developed:

Allow the end of the trench to be:
allowable shore spacing minus 2 ft

ALLOWABLE TRENCH WITH WITHOUT END SHORING	
Allowable Spacing	Allowable Trench Width
8 ft	6 ft
6 ft	4 ft
4 ft	2 ft
Note-Allowable spacing is developed from tabulated data based on excavation depth and soil type.	

After these trench widths end shores or some other method of end protection should be used. I also suggest limiting the rule to trenches less than 12 ft deep.

Please note that this rule is not found in the OSHA Appendix C-tab data or in any other manufacturers tabulated data. It is presented here as a practical safe solution to a commonly occurring situation.

- Universal Aluminum Hydraulic Shore Tabulated Data

Universal hydraulic shore tabulated data was developed sometime after 2010. There are several different reasons for doing this:

  - The 2" aluminum hydraulic shore has been a standard product since inception back in the 1950's. As it is common with most industries new manufacturers produce a knock-off of the original tried and true product. The parts and materials are so much alike that the shores can be assembled with a combination of pieces from different manufacturers, and the original manufacturer of the part is not identifiable. Essentially there is no legitimate tabulated data for these shores.
  - Contractors that purchase their own hydraulic shores purchase replacement parts from different than the original manufacturer or cannibalize parts from different shores
  - Contractors rent and buy hydraulic shores from different suppliers and consequently their crews have several different sets of tabulated data and possibly different rules and tabulations.

There was a need for a common set of data that could be taught in competent person training and kept on the jobsite regardless of the manufacturer of the brand of shoring in use. Common rules are critical to teaching and retaining the knowledge required to safely use these shores.

In OSHA Subpart P Universal Aluminum Hydraulic Shore Tabulated Data would be in accordance with:

1926.652(c)(3)Option (3)-Designs using other tabulated data.

1926.652(c)(3)(i) Designs of support systems, shield systems, or other protective systems shall be selected from and be in accordance with tabulated data, such as tables and charts.

In this case in theory all liability for the shores would fall with the engineer that produced and stamped the data. In the event of a lawsuit all manufacturers rightfully would disavow any association with the shores. The attorneys would seek to determine if the contractor misapplied the data or if the engineer failed to clearly and completely develop the data. The exception to this would be if the event resulted from a defective manufactured part and could be traced to the original manufacturer.

To this date Universal Aluminum Hydraulic Shore Tabulated Data has been used and accepted as an alternative to manufacturers data and OSHA Appendix C.

Teaching the use of aluminum hydraulic shoring

There are a lot of different aspects of aluminum hydraulic shore applications. It can be categorized as follows:

1. Understanding the tabulated data
2. Learning to maintain and install them
3. Developing safe handling and installation techniques

The first category should be presented during a competent person class. The second category should be accomplished in a separate session in the field that requires actual excavation and installation of the shores. The third item should be accomplished on the jobsite by requiring that any time aluminum hydraulic shores are being used there be a competent person present that has instruction, training, and experience with the use of hydraulic shoring. This is typical of requirements to master any learning process-study and understand basic principles, hands on training, a reasonable apprenticeship period.

Aluminum Shoring Job Hazard Analysis (JHA)

Every single operation on a construction site is unique, environmental conditions, soils, available equipment, crew experience levels, production materials being installed, how long the operation will take (hydraulic shore application can extend over many weeks and many miles), repetative activities have their own unique safety hazards. A JHA should be conducted daily at the start of shift. A short list of the hazards and brief discussion of hazards associated with hydraulic shore applications is given here;

- finger pinch-one of the most common and severe accidents, fingers can be sheared off between the rail and the block when the shore is being moved or set.
- lifting injuries-7 ft long 2 cylinder hydraulic shores can be moved, set, and removed by an experienced 2 man crew. Anything larger than that should be moved with lifting equipment like a backhoe with a spreader bar
- trench wall collapses while inserting or removing the shores-This should be analyzed when the original hydraulic shoring solution is being considered and confirmed at the start of installation.

The information provided in this commentary is strictly intended for background information so that informed decisions can be made when questions arise around the use of aluminum hydraulic shores. This information in no way alters the requirement that that OSHA Subpart P regulations and the tabulated data for the shores being used must be adhered to.