How to Estimate the Cost of Support of Excavation for Foundation Installation

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Section 1 - Introduction

This Technical Paper is intended to educate the reader about procedures required to evaluate the need for, budget, solicit, and evaluate subcontractor bids for support of excavation required to facilitate the installation of foundations. This work is often not called out specifically on the drawings and can be extremely costly and time consuming if it is missed in an estimate. During bid preparation general contractors are required to coordinate the work called for by the various design disciplines as well estimating work which will be required as part of the means and methods of construction. When reviewing foundations the estimator must consider how the depth of the excavation required to install the foundations and whether temporary support of excavation will be required. The exact scope of work will determine if sub pricing for shoring needs to be included in the estimate or if a budget price derived from the General Contractors' historical cost database will provide adequate coverage.

Main CSI (Construction Specifications Institute 2004 MasterFormat) Division

Division 31 00 00 Earthwork

Main CSI (Construction Specifications Institute 2004 MasterFormat) Subdivision

Division 31 40 00 Shoring and Underpinning

Brief Description

Designers often note 'SUPPORT OF EXCAVATION IF REQUIRED BY OTHERS' on their construction documents as a way to address the potential need for temporary support of excavation without coordinating the Architectural, Structural and Civil drawings to determine if this work is required for the completion of the project or what that specific scope of work is. It is left up to the general contractor to coordinate the contract documents from the various disciplines as well as the bidding subcontractors' means and methods to create a scope of work for, and price any temporary support that will be required to install foundations. In mountainous regions of the country where virgin sites commonly vary 20 to 40 feet or greater in elevation, it is imperative the general contractor evaluate the depths of the footings

during the bid process to determine how deep of an excavation will be required to install the foundations. A three story building can have a finish floor elevation on the lowest level that is only 6' below finished grade, which requires a cut of 12' below finished grade to reach the bottom of footing. In urban and suburban locations, it is important to analyze the location of foundations on existing buildings to determine if excavation activities will undermine the foundations of existing structures or if the buildings' proximity to the adjacent property lines will create a situation where temporary support is required. It is not uncommon for general contractors to overlook this situation until the project is underway and the Superintendent realizes that the foundations are too deep to open cut. The project team is then left in a situation where they are scrambling to get pricing for shoring, they do not have anything budgeted for the work, and they are losing time on their schedule. By addressing these situations during the estimating process contingency money can be allocated in the bid, and tighter markups can be put on the job knowing that potentially detrimental circumstances have been addressed. As a general contractor, these situations can be covered in an estimate with an appropriate allowance based on a takeoff or with subcontractor pricing. One way to address these situations for excavations less than 14 feet deep is with soldier beams and lagging or with sheet piling. These will be the two methods addressed in this paper. Excavations deeper than 14 feet require more complex shoring systems and require thorough pricing by a specialty subcontractor. Excavations of these depths are usually addressed specifically by the design engineer because of the impact that they can have on the engineering for the entire project. Attempting to use allowances to cover excavations of this depth in a construction document estimate is extremely risky. These deep excavation situations can easily cost over $300,000 which is more than enough money to swing a bid or crush the budget of a project.

Section 2 - Types and Methods of Measurements

Measure of sheeting and shoring requires getting the linear footage, depth and square footage of the area that is going to be shored. If the area being shored is not a square a profile will need to be created that represents the area being shored. This can be done by reviewing the grading plan in the civil drawings and measuring the distance between elevation contours then plotting the elevations on a profile. The foundation plan must be overlaid on the grading plan and the bottom of footing elevation added to the finish grade profile. Doing this takeoff requires review of the Civil and structural plans and comparing the elevations shown on each. Typically structural plans will show the top of footing elevation in plan view and the estimator must use the footing schedule to determine the bottom of footing elevations by subtracting the footing depth from the top of footing elevation. These two profiles are combined to create a complete profile for the area being shored. If the profile is done in a program such as AutoCAD, it is a simple process to get the total area that is being shored. If the profile is completed by hand, it should be broken down into sections a maximum 8 foot long to create polygons that can be added up separately and summed up to come up with a total square foot area. To obtain budgetary pricing from a shoring contractor the estimator must provide the length and depth of the excavation. If the excavation has a varying depth, it should be broken down into 2 foot increments and a length for each of the various depths provided. A plan view of the shoring should also be provided so that the subcontractor understands where corners will be placed.

If the general contractor has their own labor forces and excavation equipment the estimator can price a soldier beam and lagging wall using the following procedures. After dividing the profile into 8 foot section, number each section, including each end. This will be the number of piles that will need to be installed. Using the square areas created between each 8 foot pile; calculate the total area of lagging boards that will be required.

Section 3 – Specific Factors that may affect things like pricing and takeoffs

a. Small Quantities vs. Large Quantities

Driving piles or sheeting has a substantial amount of general conditions involved; specifically the mobilization costs involved with the transportation, setup and teardown of the pile driving or drilling equipment. There is a unit price savings realized when a larger quantity is involved as there is more square footage to spread the mobilization cost over. However the lower cost of a large quantity can be driven up if the project requires multiple mobilizations or equipment is required to be broken down and moved to another area of the site to another due to the site logistics or phasing of the project.

b. Geographic Location

The primary geographic impact on sheeting and shoring is the types of soil that is being retained. If the excavation in taking place is limestone or granite shoring may not even be required depending on how stable the rock formation is. Conversely, if the soil is extremely sandy and unstable as would be expected in coastal regions, the cost of shoring would increase because the soil pressure being applied would be higher than in regions with where clay or shale are more prevalent. These are factors that will be reflected in the size of the piles that are used and the depths that they will be required to reach.

c. Seasonal Effect On Work

Depending on the location of the water table on the project site, dewatering may be required if the work is being performed during a rainy season which varies by geographic location. The work can also be delayed by rain which makes the site excessively muddy and unsafe. If the work is planned for the winter month in northern regions snow moving equipment and extra time should be included in the estimate. Shoring can be installed during the winter, but the foundations may require significant cold weather accommodations such as admixtures, temporary enclosures and temporary heat.

d. Impact On Material Quantities

Project specific circumstances will determine if the foundations will be poured against the sheeting and shoring or is formwork will be used. If formwork is used, than the shoring must be installed a minimum of two feet away from the face of the foundation to allow room for the installation and removal of the form system. If the shoring system is used as a form surface, than the steel beams or sheets must be left in place and therefore must be purchased by the G.C. rather than rented. This can be a significant cost that must be included in the estimate. If sheet piling is used as formwork there will be additional concrete required in order to fill the shape of the sheet pile. There will also be additional waterproofing required to conform to the profile of the sheet pile. The additional waterproofing can increase the required quantity by as much as 40% depending on the profile of the sheet pile.

Section 4 – Overview of labor, material, equipment, indirect costs, approach and mark-ups

Labor costs are calculated on a crew day basis with a typical crew being made up of the operators, skilled and unskilled laborers and a superintendent. Labor costs should include all applicable wage rates especially when working on a government project. If the G.C. will be self-performing the work the labor burden can be added to the general estimate but if the G.C. wants to compare their cost to subcontractor's quotes, than the labor burden should be added to the bottom of the shoring estimate and the cost entered into the bid as if it was a subcontractor bid.

Equipment will be based on whether the general contractor or a subcontractor is responsible for site excavation and whether the soil that will be removed to install the shoring system is excess that needs to be hauled off site or whether it will be used for fill on another part of the site. If the soil is going to be used as fill in an area within 200 feet of the shoring a single excavator can be used together with a bull dozer and roller to immediately place the spoils as fill. In this situation, the excavator and operator would be considered part of the shoring crew and the bull dozer and its operator would be considered part of the excavation crew. These lines are more clearly defined if two separate subcontractors are being used for the shoring and site excavation. The breakdown of responsibilities between the shoring subcontractor and the excavation subcontractor needs to be coordinated during the bid process unless the general contractor is self-performing both functions. Even if the G.C. is preforming both operations the equipment and crews should still be separated on paper in order to capture the true cost of each activity for use in preparing future estimates. If the soil is being disposed of offsite, than a loader with operator, and dump trucks with drivers would be required as well. Equipment will also include a crane with operator for pile driving. This could be a crane owned and operated by the G.C. or it could be a crane owned and operated by a subcontractor specifically for the installation of the piles.

If a subcontractor is used for the pile driving they will need to know the size, quantity, and length of the piles being driven as well as the soil conditions that they will be driven in. Generally speaking, these

subcontractors have the experience to safely assume the size of the piles that will be used based on the height of the shoring, pending an engineer's evaluation if the project is successful. If the project is for a public entity, either local, state, or federal the general contractor must clearly communicate the required wage rates for the project to the bidding subcontractors and carefully scope out their bids to ensure that they include those wage rates.

The materials involved in pricing a soldier beam and lagging wall include steel HP shape piles and 3" random width lagging boards. The lagging boards are priced by the board foot so the square footage of the area being shored must be converted into board feet. If the area being shored is 1,500 square feet than the number of 3" thick lagging boards would be 1,500 square feet x 3" = 4,500 board-feet. The piles are priced by the pound and can be priced by a steel supplier and sized based on previous project experience. Since steel and lumber are both commodities if the contractor keeps up to date market data on prices a supplier's quote is not necessarily required. Even if quotes are solicited from material suppliers an appropriate amount of contingency should be added to the material cost based on market trends and when the work will be performed. After evaluating current market pricing compared to the five year historical price range, it is not unreasonable to put a 10-40% contingency on material cost if the work is more than 1 year out depending on how the market is trending.

Indirect cost should include an engineered design done by a registered PE. A quote for this service can be obtained by providing an engineering firm with a copy of the profile that was created during the takeoff process and a plan view of the layout. Mobilization cost should be included for all equipment as well as setup cost for pile driving equipment that needs to be assembled onsite. If a subcontractor is used to drive piles these cost will be incorporated into their pricing, however the estimator must ensure that the mobilization and setup costs are included and do not need to be added separately to the lump sum price. Also, the estimator must evaluate the number of mobilizations or equipment relocations onsite that

will be required as most quotes will only include one mobilization in the price and will give an add price for additional mobilizations.

Section 5 – Special Risk Considerations

The type of soil onsite can play a significant role in pricing. If the soil is to dense to allow piles to be driven but too unstable to allow for an open cut excavation, as is the case in some shale formations, than the pile may have to be drilled in which case concrete and grout will be required to support the piles in a vertical position. If piles are drilled and placed one subcontractor can be used to drill the holes and to set the piles. In this situation, 3000 psi concrete is used to support the portion of the piles that will remain below grade and flowable fill, which is cheaper and softer than concrete, can be used to fill the portion of the pile where the lagging will be installed. The flowable fill hardens to a clay like stiffness which can be easily chipped away to install the lagging boards. The Geotechnical report will give the estimator the necessary information on the soil type and physical properties.

Section 6 – Ratios and analysis (tools used to test the final bid)

To evaluate pricing, sub-bids should be broken down on a cost per linear foot basis between competitive bids as well as historical cost data. When comparing historical cost data to current bids it is important to make sure that the depth of the excavation being shored is similar. An excavation that is within 4 feet in depth of the excavation being analyzed should be adequate for comparison purposes but the closer the better. Comparison prices should also have a quantity of work that is comparable to the work being estimated since mobilization cost is amortized across the total quantity of work. It is ideal for the historical data being used for evaluation to be within 15-20% of the quantity in the bid.

Section 7 – Miscellaneous Pertinent information

The proximity of the proposed building to adjacent buildings and to property lines should be evaluated early on as indicators of locations where shoring may be required. Situations can exist where there is enough physical space for an open cut excavation but the close proximity to a property line prevents the excavation from being laid back. The estimator must also evaluate the likelihood of undermining the foundations of adjacent buildings during excavation. If as-built drawings of an adjacent building are not available at the time of the bid, the estimator must use their judgment during site visits to estimate the location and elevation of the existing foundations. In this situation a profile of the shoring that may be required should be created and historical unit prices applied in order to evaluate the potential risk and include money in the estimate to cover that risk. This kind of circumstance tends to get noticed by estimators a few days into their takeoff, leaving limited time to develop a solution and solicit solid pricing. Having historical price data and a good working relationship with a reliable shoring subcontractor can prove invaluable when trying to cover these kinds of conditions in a bid. For a general contractor, providing reasonable internal allowances in the bid to cover these kinds of situations allows for tighter markups because there is a higher level of confidence that risks have been evaluated and planned for.

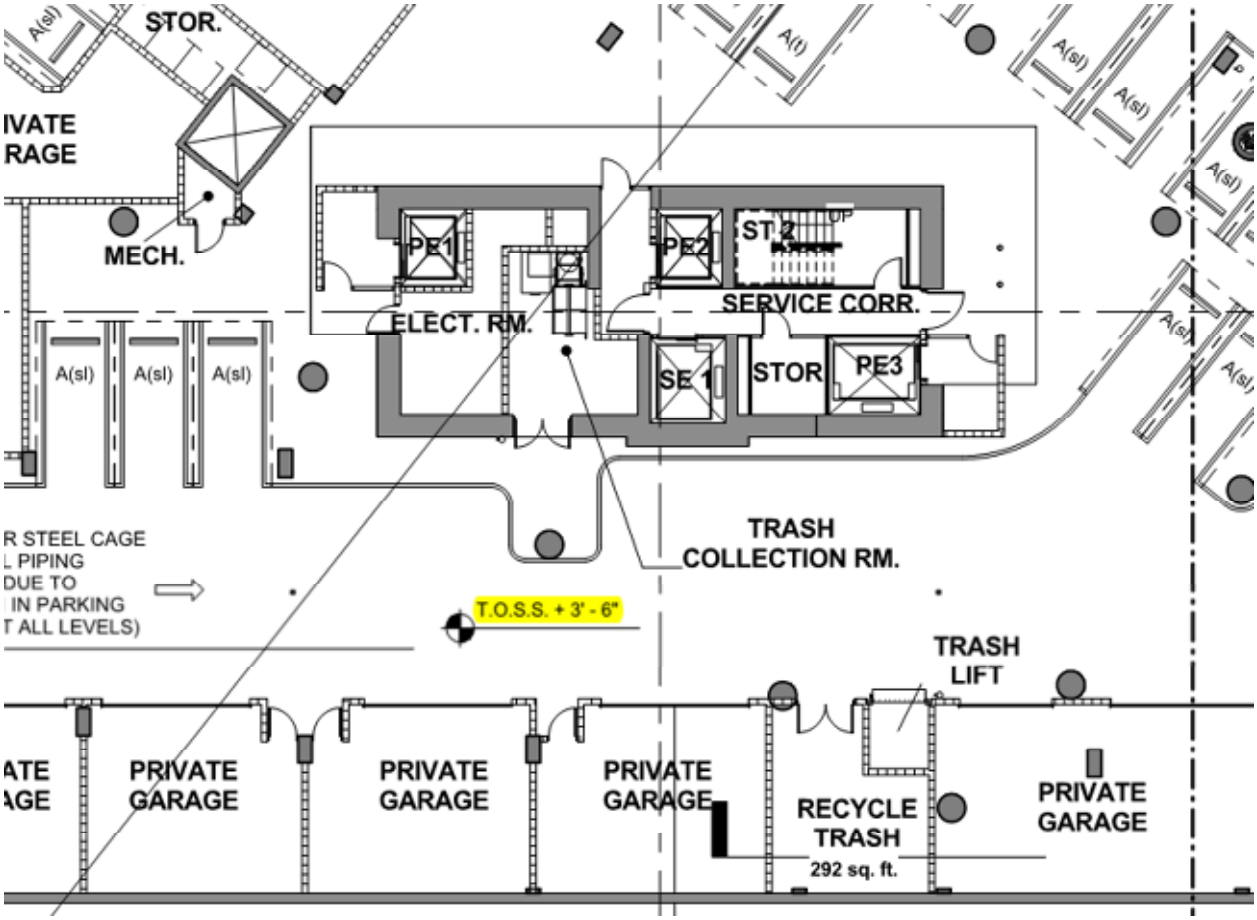


Figure 1

Figure 1 above shows the Top of Structural Slab Elevation from the architectural drawings. In this case, the lowest building level is a parking garage so there is no architectural floor finish therefore, the Finish Floor Elevation is the same as the Top of Structural Slab Elevation. If there were a floor finish such as marble tile or wood than the thickness of the flooring material would need to be subtracted from the Finished Floor Elevation in order to determine the Top of Structural Slab Elevation.

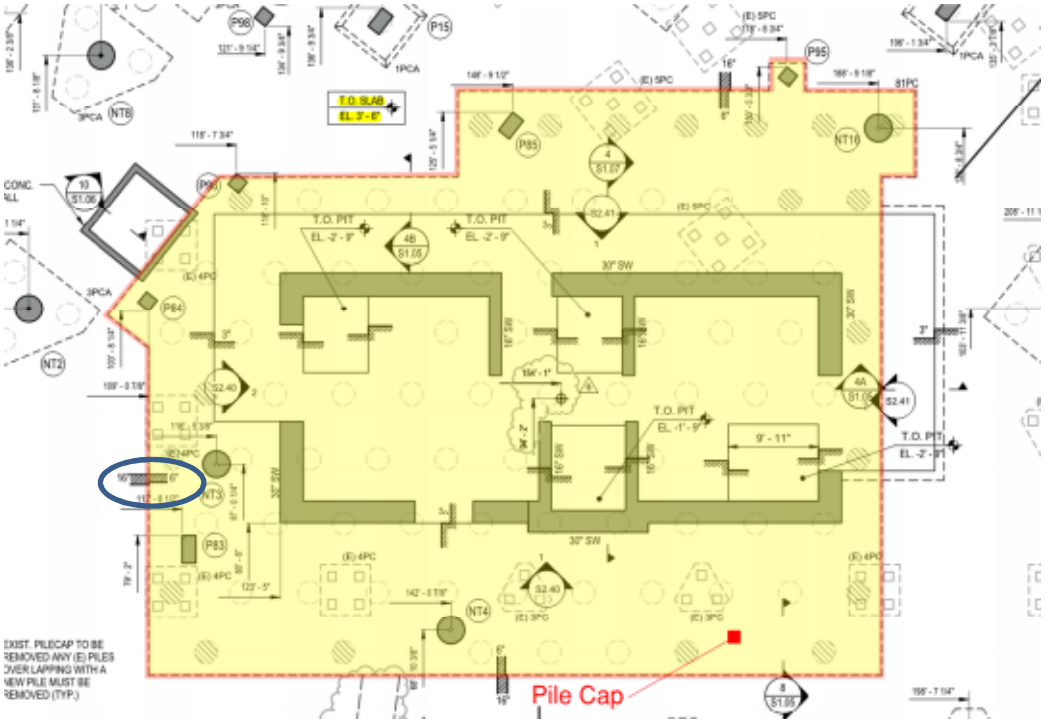


Figure 2

Figure 2 shows the outline of the main pile cap and the Top of Slab Elevation on the structural Drawings. In this situation the Architectural and structural drawings show the same elevation for Top of Slab. This is not always the case and should be one of the first items checked when reviewing the Structural Drawings. Also, circled in blue above is the thickness of the Slab-On-Grade. This is necessary to determine the subgrade elevation.

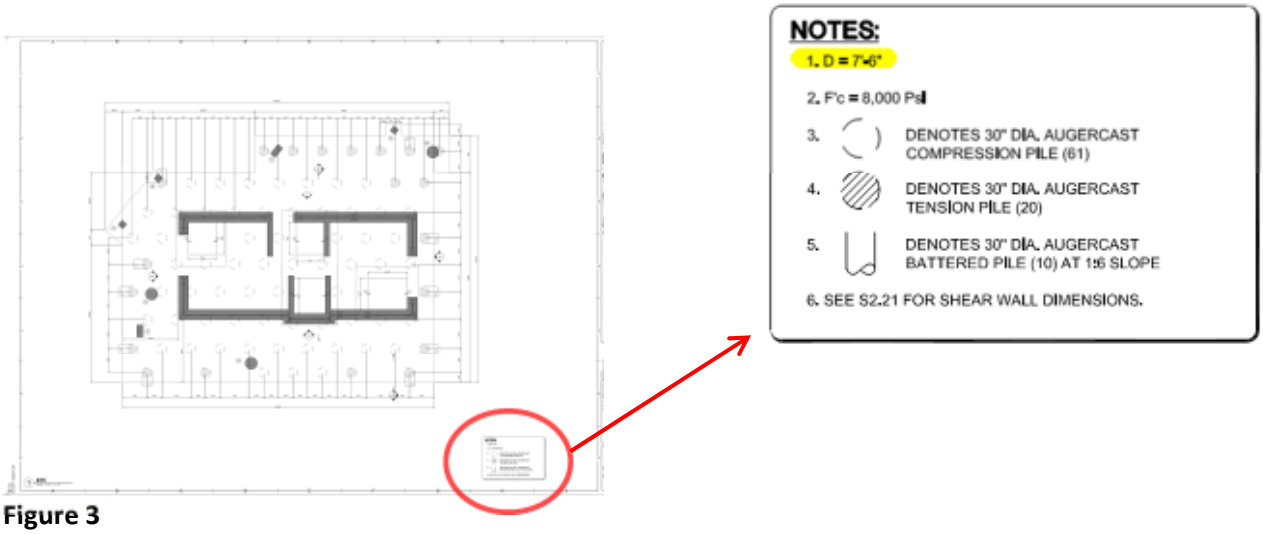


Figure 3

Figure 3 shows the depth of the pile cap. The depth of the pile cap will be subtracted from the Top of Pile Cap Elevation to determine the elevation at the bottom of the excavation. The elevation at the bottom of the excavation can then be compared to the subgrade elevation to determine the total depth of the excavation.

Based on the elevations above we can determine the following.

Top of Finish Slab Elevation: 3’-6”
Slab-On-Grade Thickness: 16”
Slab-On-Grade Thickness over Pile Cap: 6”
Pile Cap Thickness: 7’-6”

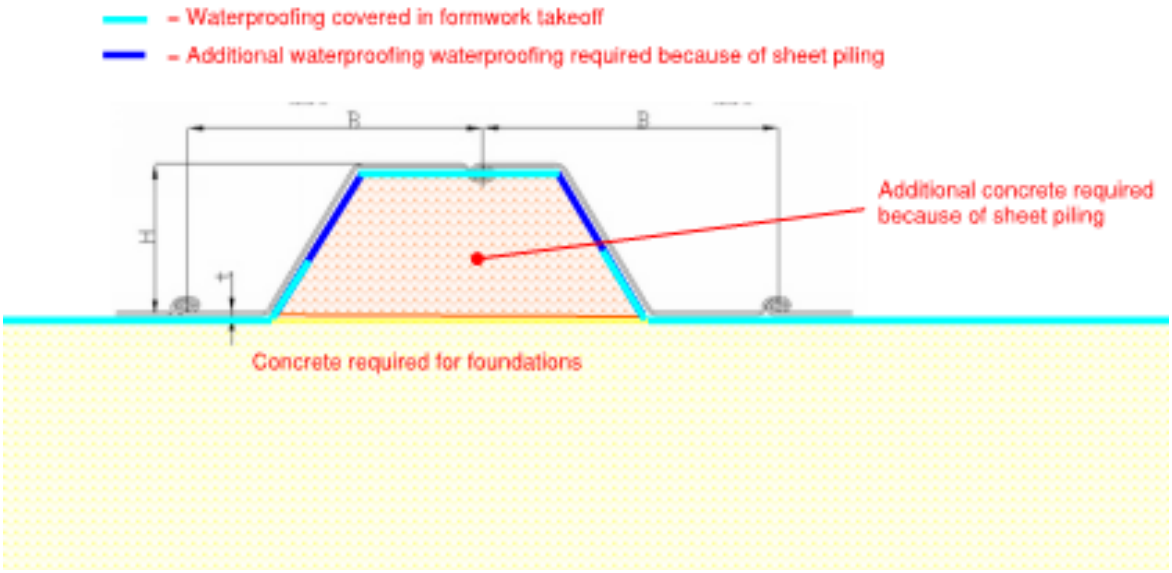
The information above will allow the determination of the depth of excavation for the pile cap as follows.

(Top of Finish Slab Elevation: 3’-6”) – (Slab-On-Grade Thickness: 16”) = Subgrade Elevation: 2’-2”
(Top of Finish Slab Elevation: 3’-6”) – (Slab-On-Grade Thickness over Pile Cap: 6”) = Top of Pile Cap: 3’-0”
(Top of Pile Cap: 3’-0”) – (Pile Cap Thickness: 7’-6”) = (Bottom of Pile Cap Elevation: -4’-6”)
(Subgrade Elevation: 2’-2”) – (Bottom of Pile Cap Elevation: -4’-6”) = (Depth of Excavation: 6’-8”)

The depth of the excavation (6’-8”) will be the height of the shoring. Once the height of shoring is established, the length of shoring needs to be determined. In this situations, it is up to the general contractor to determine the scope of work and effectively communicate it to the bidding subcontractors.

Concrete can either be poured against the shoring or left in place or setback from the face of concrete to allow room for formwork. Because of the high cost of steel, temporary sheet piling should be used unless it is in a location where extraction is not possible because the shoring is holding up an adjacent property or the new constructions prevents a crane from accessing the piles to extract them. On this project the shoring will be offset 2’-0” from the face of the foundation.

If the sheet piling is used as formwork and left in place additional concrete and waterproofing must be added as shown below.



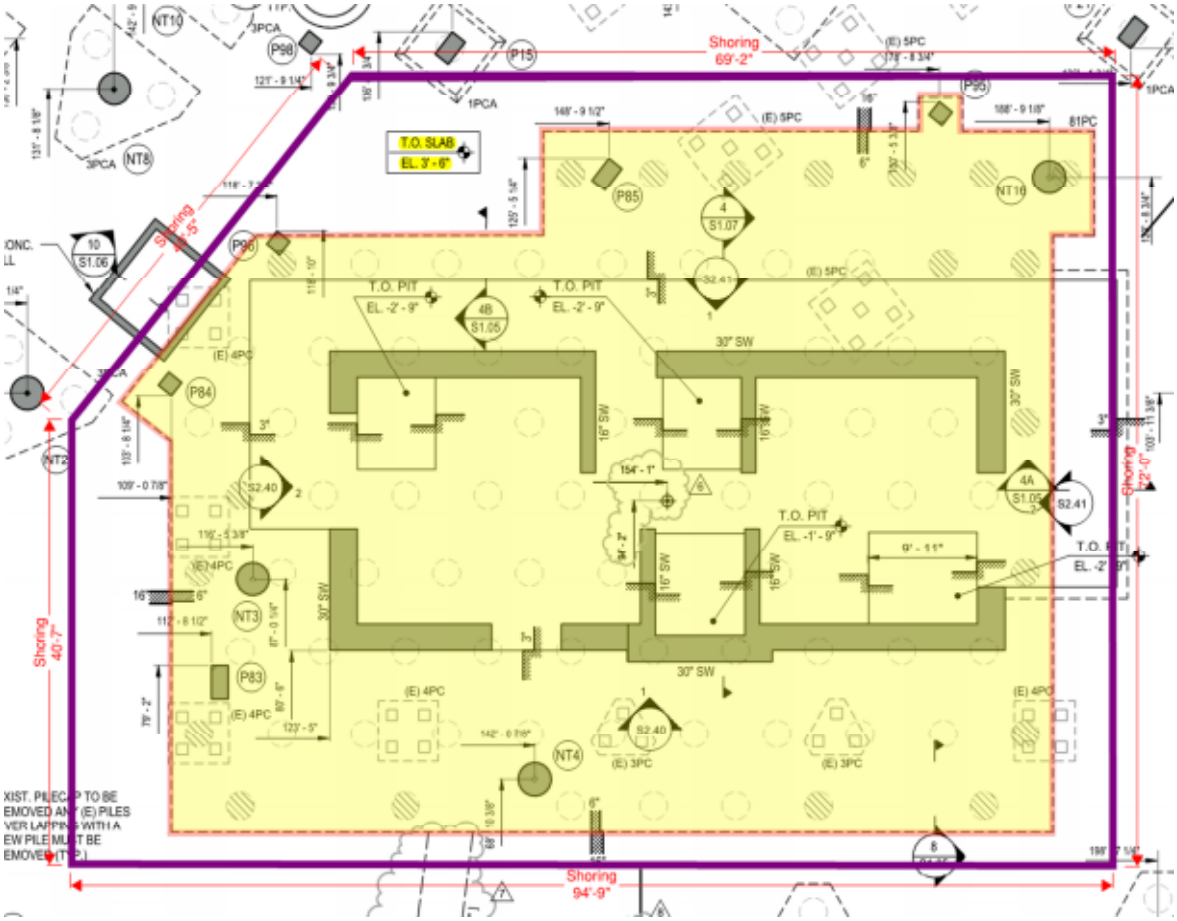


Figure 4

Figure 4 illustrates a typical shoring takeoff. 316’-11”

Section 9 – Sample Budget Estimate

The takeoff above along with the depth of the information can be sent out to all of the bidding subcontractors to ensure that they are all bidding on the same scope of work. To develop a budget the following unit pricing from a project three months prior will work to establish a cost basis for the current project.

Specifically, our scope of work will include the following:

1. Mobilize pile-driving equipment and personnel to the jobsite.
2. Design, furnish and install 1,035 wall feet of temporary steel sheet piling to support up to an 10-ft. excavation for a period of three months. We understand sheet piling will be installed from a working grade of +4 Ft. NGVD. Steel sheet piling length will be as required by our design.
3. Design, furnish and install 270 wall feet of temporary steel sheet piling to support up to an 11-ft. excavation for a period of six months. We understand sheet piling will be installed from a working grade of +11 Ft. NGVD and +12 Ft. NGVD. Steel sheet piling length will be as required by our design.
4. Mobilize pile-driving equipment and personnel to the jobsite and remove 1,305 wall feet of temporary steel sheet piling.

Below is an analysis of this quote that was done to determine the unit price cost of the quoted work and compare it to the cost unit rates that accompanied the quote.

First the unit Cost is determined by dividing the cost by the quantity. The six month duration is what was included in the quote.

QUOTE ANALYSIS FOR 6 MONTH DURATION			
Temp Sheet Piling		1,035	LF
Temp Sheet Piling		270	LF
		1,305.00	LF
Total Cost	$	618,000	
Cost	$	473.56	/LF

Next, the quote is adjusted to show a 3 month duration which is the duration which will be required for this project.

Rental Value (Incld in quote)			
Quanity		1,305.00	LF
Unit Cost		14	/LF-MO
	$	18,270	/MO
Duration Included in LS price	$	6	MO
	$	109,620	
3 month rental cost	$	18,270.00	
Duration	$	3.00	MO
	$	54,810	
ADJUSTMENT FOR 3 MONTH DURATION			
6 Month price	$	618,000	
Less 3 Month Rental Cost	$	54,810	
	$	563,190	

QUOTE ANALYSIS FOR 3 MONTH DURATION			
Temp Sheet Piling		1,035	LF
Temp Sheet Piling		270	LF
		1,305.00	LF
Total Cost	$	563,190	
Cost	$	431.56	/LF

Lump Sum Cost for a 3 month duration

The adjusted unit cost is used to budget the cost for the current project.

3 Month Duration			
		LENGTH	
		69.17	LF
		72.00	LF
		94.75	LF
		40.43	LF
		40.42	LF
Total		316.77	LF
	$	431.56	/LF
Cost	$	136,706	

Budget Cost

Below is a takeoff and estimate for the same scope of work using soldier beams and lagging.

PILE CAP SHORING TAKEOFF						
	LENGTH		HEIGHT		AREA	
	69.17	LF	6.67	FT	461	SF
	72.00	LF	6.67	FT	480	SF
	94.75	LF	6.67	FT	632	SF
	40.43	LF	6.67	FT	270	SF
	40.42	LF	6.67	FT	270	SF
Total	316.77	LF			2,113	SF
Pile Takeoff				**Lagging Board Takeoff**		
Pile Size	HP10X42			Area	2,113	SF
Spacing	8	' O.C.		Board Thickness	3	inch
Quantity	40	EA		Total Board-Feet	6,339	Bd-Ft
Length/EA	16.68	FT/EA		Waste	10%	
Total Length	667	FT			634	Bd-Ft
Pcs Weight	42	LB/FT		Buy Qty	6,972	Bd-Ft
Total Weight	14	TN				

The quantity of piles is calculated by dividing the length by 8 feet. The depth of the excavation multiplied by 2.5.

	PROJECT:											Date :	
	Estimator:											Bid Date:	
Item#	Description	Quantity	Unit	Unit Cost	Material	Unit Cost	Labor	Unit Cost	Equipment	Unit Cost	Sub	Notes:	
	Soldier Beam and Lagging	317	LF		$ -		$ -		$ -		$ -		
					$ -		$ -		$ -		$ -		
	Engineering	1	LS		$ -		$ -		$ -	5000	$ 5,000.00	Subcontractor Quote	
					$ -		$ -		$ -		$ -		
	HP Piles	14	TN	500	$ 7,000.00		$ -		$ -		$ -		
	Lagging Boards	6972	BF	3	$ 20,916.00		$ -		$ -		$ -		
	3000 psi concrete		CY	100	$ -		$ -		$ -		$ -		
	Flowable Fill		CY	70	$ -		$ -		$ -		$ -		
					$ -		$ -		$ -		$ -		
1	Forman	10	DAY		$ -	280	$ 2,800.00		$ -		$ -		
1	Operator	10	DAY		$ -	160	$ 1,600.00		$ -		$ -		
3	Skilled Laborer	10	DAY		$ -	160	$ 4,800.00		$ -		$ -		
					$ -		$ -		$ -		$ -		
1	JD 270 Track Hoe	10	DAY		$ -		$ -	640	$ 6,400.00		$ -		
					$ -		$ -		$ -		$ -		
	Pile Driving	1	LS		$ -		$ -		$ -	###	$ 40,000.00	Subcontractor Quote	
	Mobilization	1	EA		$ -		$ -		$ -	2000	$ 2,000.00		
					$ -		$ -		$ -		$ -	$	305.33
					$ 27,916.00		$ 9,200.00		$ 6,400.00		$ 47,000.00	$	96,790.96
					$ 27,916.00		$ 9,200.00		$ 6,400.00		$ 47,000.00		
											$ 9,200.00	Labor Bare	
										50%	$ 4,600.00	Labor Burden	
											$ 27,916.00	Bare Material	
											$ 6,400.00	Bare Equipment	
											$ 47,000.00	Bare Sub	
										6%	$ 1,674.96	Sales Tax on Material	
											$ 96,790.96	Subtotal Bare	
										20%	$ 9,958.19	O.P. Labor, Material, & Equip	
										20%	$ 9,400.00	O.P. Sub Contractors	
											$ 116,149.15	Subtotal	
											1,625	Bond	
											$ 117,774	Grand Total	

The process of analyzing historical cost together with assembling a labor and material estimate will allow the estimator to develop a reasonable value for the scope of work in order to determine the level of risk the contractor is at for required work that is not clearly defined on the drawings. On bid day, both of these costs can be used to evaluate sub bids or to justify an allowance amount. The sooner this scope of work is identified and defined the more likely the G.C. is to get tight subcontractor bids.