CHAPTER

4

MEASURING SITEWORK, EXCAVATION AND PILING

Generally

Measuring sitework and excavation work is different from measuring most other work of a construction project because tender drawings usually provide very little detail about the specific requirements of sitework operations. The drawings will give details of the new construction required for the project but information about what is currently to be found at the site of the proposed work may not provided. Contractors are usually advised in the "Instructions to Bidders" to satisfy themselves as to the present condition of the site. Furthermore, the size and depth of foundations may be defined in detail on the drawings, but there is typically nothing disclosed about the dimensions and shape of the excavations required to accommodate these constructions. Before the estimator can measure the site work, he or she has to make an assessment of excavation requirements from what data there is in the specifications and drawings and from information gathered on visits to the site. As the site conditions will also impact upon the pricing of many other items in the estimate, the estimator should make use of a checklist of items to consider on a site visit so that important information is not overlooked. This is discussed in chapter 2 under Site Visit.

Soils Report

Another source of site information which is available on most large projects and also on some of the smaller jobs is the soils report. The report can sometimes be found bound with the specifications, or if it is not, it may be accessible at the design consultant's office. Even when a soils report is included with the specifications it is usually not a tender document. The estimator is cautioned to read the contract documents carefully to determine the true status of the soils report because, while some contracts contemplate extra compensation to a contractor who is misled by information contained in the report, other contracts may state that . . . the contractor should not rely upon information provided by the soils report but should make its own investigation of subsurface conditions . . . In this latter situation the prudent contractor has to assess the risk imposed by this contract condition and adjust the bid accordingly.

The soils report provides information about the subsurface conditions at the site obtained from bore holes and/or other investigations made by the soils engineer. The purpose of the report is to furnish data about the site which is necessary to undertake the design of the foundation system. Indeed, the report usually includes advice about the type of foundation systems suitable for the conditions encountered. However, the information contained in the report can also be very useful to the excavator as it not only discloses the type of soil that will probably be found at the site, but also provides an indication of the moisture content of the soil. Both of these factors can profoundly affect the cost of excavation work.

A soils report usually begins with an introduction identifying the name and location of the project, the name of the owner, and the prime consultant, and states the objective of the study. Details of the investigation follow including the date the site was examined, the method of investigation undertaken, and general details of the bore hole procedures. Next the report addresses the nature of the subsurface conditions encountered and goes on to provide comments and recommendations about the foundation system together with detailed information about the test hole results.

See the section entitled "Subsurface Conditions" in Appendix A, "Extract from Typical Soils Report."

Comments on the Sample Soils Report

The kind of information that the estimator would highlight and note from the soils report shown in Appendix A would include the following points:

1. Topsoil is 8" deep and is to be stripped from both the building area and the parking area.
2. Most of the excavation on this project will be in the top silt-sand layer. This material is not usually difficult to excavate but in wet conditions it can turn into a sticky mud that can bog down equipment.
3. The moisture content of the silt-sand encountered was quite low and there was little ground water at the time of the investigation. However, the report indicates that "ground water levels are subject to wide fluctuations," so a contingency sum for dewatering may be necessary in the estimate.

4. Soil compaction factors of a fairly high value are required. In order to obtain the factors specified there will be a need for some rigorous compaction procedures and the water content of the soil will have to be carefully controlled.
5. It is recommended that the sides of excavations (see section on Excavation Safety Considerations) be cut-back to a slope of 1.5 Horizontal to 1.0 Vertical. This is a low slope ratio which will result in wide cuts at the top of excavations. Shoring may be necessary if space is limited.

   The estimator should also keep in mind the OSHA (see section on Excavation Safety Conditions) requirements for cut-back of excavations of different depths.
6. Good positive drainage of the finished grades is important on this project.
7. Foundation concrete does not have to contain sulfate resisting cement.

All of the soils report recommendations should be checked to determine if they are consistent with the contents of the project specifications. Note that it is the specifications that the contractor is required to follow and they may vary from the recommendations of the soils engineer.

Bank Measure, Swell and Compaction Factors

The soil that is extracted from an excavation is less dense than before it was excavated, so it will occupy more space than it did when it was in the ground. For example, if a hole of 10 cubic yards volume is excavated, the pile of soil removed from the hole might occupy 13 cubic yards, therefore, 13 cubic yards of material will have to be transported if it is required to be removed from the site. The difference between the volume of the hole and the volume of the material once it has been dug out is known as the swell factor.

A similar adjustment factor is required with regard to filling operations. If a hole of 10 cubic yards capacity is to be filled with gravel, 14 cubic yards of loose gravel may be required because the material will have to be compacted, that is, it will be more dense after it is deposited and there will also be some wastage of gravel to consider. Here the difference between the volume of the hole to be filled and the volume of fill material is referred to as the compaction factor.

In accordance with the general principle of measuring net quantities, excavation and backfill quantities are calculated using "bank measure." "Bank measure" amounts are obtained by using the dimensions of the holes excavated or filled with no adjustment made to the quantities obtained for swell or compaction of materials. Swell factors and compaction factors will be accounted for when the take-off items are priced.

Excavation Safety Considerations

The potential danger to workers in trenches and by the sides of excavations due to cave-ins of the earth embankments is a safety hazard that must be considered in every quantity take-off of excavation work. The federal Occupational Safety and Health Administration (OSHA) *Construction Safety and Health Regulations* require that the sides of all earth embankments and trenches over 5'0" deep be adequately protected by a shoring system or by cutting back the sides of the excavations to a safe angle. As a consequence, the estimator must allow extra excavation for cutting back the face of excavations to a suitable angle wherever this is possible. Where restricted space or other circumstances prohibit cut-backs, the estimator may have to include for a system of shoring and bracing, but this is usually an inferior choice as it is a far more expensive alternative.

It is important that the estimator carefully studies the OSHA requirements for excavations since excavation rules are so strongly enforced by OSHA. The estimator will also need to consider particular state regulations regarding excavation safety requirements as specific details may vary from state to state. For instance, some states require that shoring systems, over a certain depth, be designed by, and constructed under the supervision of a professional engineer. This will have cost implications that cannot be ignored in the estimate.

Use of Digitizers

Digitizers are electronic devices that enable the user to take measurements from drawings and input the data directly into a computer program. There are two main types of digitizers: sonic and tablet. Both of these types of digitizers employ a pointer or cursor to locate points and lines. With the sonic digitizer the cursor emits a sonic code that is identified by two receivers that are used to calculate the precise location of the cursor. Using this system, any drawing can be scanned regardless of its size or the type of surface it is placed upon. The sonic receivers have to be set up so that there is no obstruction between them and the cursor as it travels across the drawing and the estimator has to ensure that measurements recorded are in accordance with the scale of the drawing. Clearly, drawings have to be drawn to scale for any type of digitizer to provide accurate data.

With tablet digitizers drawings have to be laid out on an electronic tablet which functions to identify the specific location of the cursor as it moves over the surface of the tablet. Because of the size of construction project drawings, tablets as large as 42" × 60" and larger may have to be used if all the information on a drawing is to be accessible at one time.

The information gathered by the digitizer is then available for processing in computer programs so that lengths, areas, volumes, item counts and sophisticated calculations such as cut and fill volumes can be determined very swiftly. Digitizers can also be linked to estimating software systems and used as an alternative to the keyboard for inputting the data into the system. Some estimating systems can be operated directly from the digitizer eliminating any.need to handle the keyboard. This setup provides a powerful tool for estimators because it allows large amounts of data to be quickly and accurately inputted into the computer without having to "key in" long lists of numbers.

One of the main disadvantages of the use of digitizers is that the accuracy of the system depends entirely upon the accuracy of the drawings that are scanned. A fundamental take-off principle is that the estimator should only rely on scaled dimensions as a last resort; sizes may be changed in the design process and are often carried out by modifying the figured dimensions without changing the actual size of objects shown on the drawings to comply with their new dimensions. This results in drawings that wind up out of scale, and the digitizer system that scans these drawings generates erroneous output.

Measuring Notes—Excavation and Backfill

1. Excavations, backfill and fill material shall be measured in cubic yards "bank measure."
2. If different types of material will be encountered in the excavations, each type of material shall be described and measured separately.
3. Excavations shall be classified and measured separately in the following categories:
   a. Site clearing
   b. Excavation over site to reduced levels
   c. Basement excavations
   d. Trench excavations
   e. Pit excavations
4. Hand excavation shall be measured separately.
5. Quantities of different types of fill and backfill materials shall be kept separate.
6. Fill and backfill materials shall be measured separately in the following categories:
   a. Fill over site to raised levels
   b. Backfill to basements
   c. Backfill to trenches
   d. Backfill to pits
   e. Gravel under slabs on grade
7. An item of disposal of surplus soil shall be measured when excess excavated material is required to be removed from the site. Measurement of this item can be left until quantities are recapped ready for pricing, then the total volumes of excavation and common backfill can be used to determine the amount of surplus material.

Alternatively, the price of disposal of surplus excavated materials can be included with the excavation price in which case the description shall state the type of excavation "including removal of surplus soil."

Calculation of Cut and Fill Using the "Grid Method"

Certainly the fastest and, probably, the most accurate way to calculate volumes of cut and fill over a site, when true scale drawings are available, is to use an electronic digitizer in conjunction with a software program specifically for this type of application (as discussed previously). Here we consider two alternative "manual" methods of obtaining the quantities of cut and fill beginning with the "grid method":

Calculation by the "grid method" requires a survey of the site showing the elevation of the existing grade at each intersection point on the grid. The elevation of the required new grade is also plotted at each intersection point and from these two elevations the depth of cut or fill can then be obtained at each point. From here on, cut calculations are separate from fill calculations. To figure the volume of cut at an intersection point the depth of cut at this point is multiplied by the area "covered" by that intersection point. Then adding together all the individual cut volumes computed in this way will give the total volume of cut on the site. Following the same process using the fill depths will establish the individual and total fill volumes for the site. The area "covered" by an intersection point means the area that point applies to as shown in figure 4.1.

The accuracy of this method of calculating cut and fill volumes depends upon the grid spacing; generally the closer the grid spacing the more accurate the results are. However, a closer grid spacing leads to more calculations and a longer processing time. As this process is very repetitive, the processing time can be much reduced by using a computer program to perform the calculations.

See figure 4.2 for a complete calculation of volumes of cut and fill over a site using this "grid method" with a computer spread sheet program.

Calculation of Cut and Fill by the Section Method

This method of calculating volumes of cut and fill is mostly used with long, relatively narrow areas of cut and fill of the type encountered in road and railroad construction. Procedure:

1. At regular intervals (stations) along the centerline of the construction, survey the existing ground elevations on each side of the centerline.

   Alternatively, make use of a general survey of the site. On this survey, locate the centerline of the project and mark off stations at regular intervals along its length. Then determine the existing ground elevations to each side of the centerline at each station.

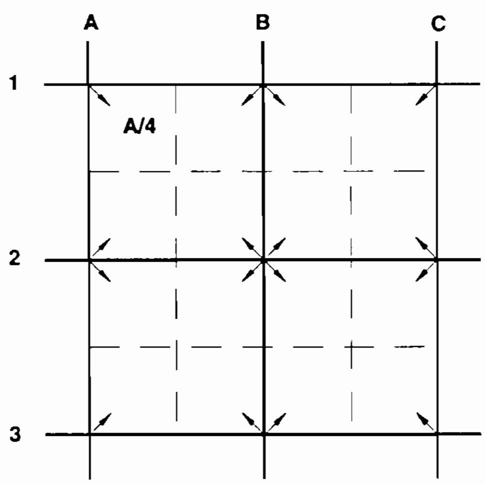
Mass Excavation Calculations by the Grid Method

The use of the "grid method" to calculate volumes of cut and fill requires the estimator to consider the depth of cut or fill at each point where the grid lines intersect (station) on the survey grid and then determine the "area covered" by that station.

At each station on the grid the elevation of the existing grade obtained from the site survey is noted in the top right quadrant. The elevation of the required new grade is noted in the top left quadrant. The difference between these grades gives the depth of fill or cut at this location. If it is a fill, the depth is noted in the bottom right quadrant or, if a cut, the depth is noted in the bottom left quadrant in this way:

GRID INTERSECTION	
NEW GRADE ELEVATION	EXISTING GRADE ELEVATION
DEPTH OF CUT	DEPTH OF FILL

Consider the survey grid shown below. If the areas formed by the grid lines are "A" square feet, the "area covered" by point 1-A is one quarter of area "A" but point 1-B applies to two areas so the "area covered" by this point is two quarters of area "A", etc. as shown. The number of quarters of area "A" that the station point applies to is labeled the "frequency" when tabulating this data.



STATION	FREQUENCY		AREA CONSTANT
1-A	1	x	A/4
1-B	2	x	A/4
1-C	1	x	A/4
2-A	2	x	A/4
2-B	4	x	A/4
2-C	2	x	A/4
3-A	1	x	A/4
3-B	2	x	A/4
3-C	1	x	A/4

Figure 4.1

Mass Excavation Calculations by the Grid Method (Grid 20' × 16')

Grid Elevations:

	A		B		C		D		E	
	4.2	6.5	4.4	5.0	4.6	3.0	4.8	1.9	5.0	2.2
1										
	2.3		0.6		0.0			2.9		2.8
	4.4	5.1	4.6	3.2	4.8	2.8	5.0	4.5	5.2	5.2
2										
	0.7			1.4		2.0		0.5	0.0	
	4.6	3.6	4.8	2.0	5.0	5.3	5.2	7.1	5.4	7.9
3										
		1.0		2.8	0.3		1.9		2.5	
	4.8	1.9	5.0	4.0	5.2	8.2	5.4	10.0	5.6	10.3
4										
		2.9		1.0	3.0		4.6		4.7	
	5.0	3.0	5.2	3.8	5.4	6.4	5.6	7.0	5.8	7.5
5										
		2.0		1.4	1.0		1.4		1.7	

Tabulation of Results:

Station	New Elevation	Existing Elevation	Depth Cut	Depth Fill	Frequency	Area Constant	Volume Cut	Volume Fill
1A	4.2	6.5	2.3	0.0	1	80	184	0
1B	4.4	5.0	0.6	0.0	2	80	96	0
1C	4.6	3.0	0.0	1.6	2	80	0	256
1D	4.8	1.9	0.0	2.9	2	80	0	464
1E	5.0	2.2	0.0	2.8	1	80	0	224
2A	4.4	5.1	0.7	0.0	2	80	112	0
2B	4.6	3.2	0.0	1.4	4	80	0	448
2C	4.8	2.8	0.0	2.0	4	80	0	640
2D	5.0	4.5	0.0	0.5	4	80	0	160
2E	5.2	5.2	0.0	0.0	2	80	0	0
3A	4.6	3.6	0.0	1.0	2	80	0	160
3B	4.8	2.0	0.0	2.8	4	80	0	896
3C	5.0	5.3	0.3	0.0	4	80	96	0
3D	5.2	7.1	1.9	0.0	4	80	608	0
3E	5.4	7.9	2.5	0.0	2	80	400	0
4A	4.8	1.9	0.0	2.9	2	80	0	464
4B	5.0	4.0	0.0	1.0	4	80	0	320
4C	5.2	8.2	3.0	0.0	4	80	960	0
4D	5.4	10.0	4.6	0.0	4	80	1472	0
4E	5.6	10.3	4.7	0.0	2	80	752	0
5A	5.0	3.0	0.0	2.0	1	80	0	160
5B	5.2	3.8	0.0	1.4	2	80	0	224
5C	5.4	6.4	1.0	0.0	2	80	160	0
5D	5.6	7.0	1.4	0.0	2	80	224	0
5E	5.8	7.5	1.7	0.0	1	80	136	0
							5200	4416

Figure 4.2

2. On graph paper, plot the cross-section at each station showing the existing grade and the required new grade.
3. From the plot of the cross-section compute the area of cut and the area of fill at each station.
4. Using the station spacing and the area of cut at each station, calculate the total volume of cut. Similarly, from the station spacing and the area of fill at each station, the total fill volume can be obtained.

   The volume of cut or fill can be calculated by tabulating the data as shown on figure 4.3 or by using the following formula:

$$\text{Volume} = \text{Station spacing}\left(\text{Area 1} + \text{Area N} + \frac{\text{sum of other areas}}{2}\right)$$

Where: N = the number of stations

and Area N = the area at the last station

Closer spacing of the stations can improve accuracy but the quality of the results obtained from this method mostly depends upon the accuracy of the plotting of the section profiles. As with the "grid method," there are a number of computer programs available for use with the section method that can improve the accuracy and productivity of this procedure. Digitizers are a particularly useful tool for analyzing the profile of the sections to determine the areas of cut and fill.

See figure 4.3 for a worked example of the section method of calculating volumes of cut and fill.

Measuring Notes—Piling

Piling is often subcontracted out to companies specialized in this work in which case the subtrade may provide a lump sum for the complete piling system. However, even when such a lump sum quote for the work is obtained, the general contractor will possibly have to perform some work in connection with this trade. Typical general contractor items in connection with piling include:

a. lay-out of piles,
b. cutting off the tops of piles, and
c. removing the excavated material produced in piling operations.

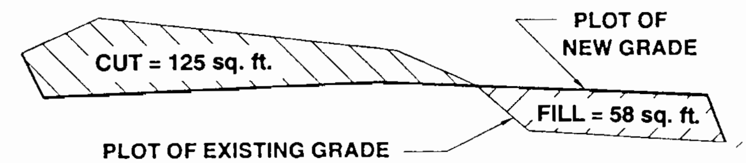
If these, or any other work items, are required of the general contractor they should be measured in the general contractor's take-off.

Some piling subtrades are reluctant to offer a lump sum price for the work but will quote on a per pile or a per linear foot basis for the type of pile specified.

Mass Excavation Calculations by the Section Method

In this example five stations have been laid out at 20 foot intervals across a proposed parking lot area. At each station the existing grade is surveyed and plotted on a cross-section profile and the elevation of the new grade has also been plotted on the cross-section as shown in the illustration below:

AT STATION 1



The following data was obtained:

Station	Area of Cut sq. ft.	Area of Fill sq. ft.
1	125	58
2	92	73
3	51	185
4	27	243
5	75	129

From this data the volumes of cut and fill can be calculated on a spread sheet in the following way: the volume of cut = section spacing × average cut and volume of fill = section spacing × average fill:

Tabulation and Results:

Station	Section Spacing	Actual Cut	Average Cut	Actual Fill	Average Fill	Volume Cut cu. ft.	Volume Fill cu. ft.
1		125.0		58.0			
	20.0		108.5		65.0	2,170.0	1,310,0
2		92.0		73.0			
	20.0		71.5		129.0	1,430.0	2,580.0
3		51.0		185.0			
	20.0		39.0		214.0	780.0	4,280.0
4		27.0		243.0			
	20.0		51.0		186.0	1,020.0	3,720.0
5		75.0		129.0			
						5,400.0	11,890.0
					cubic yards	200.0	440.0

Figure 4.3