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Excavation

Swell and Compaction

Excavation is measured by cubic meter, foot or yard. When ground materials are excavated, they expand to a larger volume. When these materials are placed and compacted on a project, they will be compressed into smaller volume than when it was loose. The following table shows common expansion and shrinkage factors for various types of soils related to its natural condition.

Percentage of expansion & Shrinkage		
Material	**Swell**	**Shrinkage**
Sand and Gravel	10 to 18 %	85 to 100%
Loam	15 to 25 %	90 to 100 %
Dense Clay	20 to 35 %	90 to 100 %
Solid Rock	40 to 70 %	130 %

Compacted Volume = Natural Volume X

Shrinkage Loose Volume = Natural

Volume X (1 + Swell) **Example**:

If 100 bank cubic meter (in place at natural density) of dense clay (30% swell) needs to be moved away, how many loose cubic meters have to be moved away by trucks? And, how many loads of 8 m^3 dump trucks will be needed?

Answer:

Volume of loose clay= 100 X (1+ 0.3) = 130 m^3

Loads = 130 ÷ 8 = 16.25 (17 truck-loads will be required)

Example:

If (20m x 50m x 20cm) 200 m^3 of compacted sand is required in-place, how many of 8 m^3 loads would be required? The sand has a swell of 15% and shrinkage of 95%.

Answer:

Compacted Volume = Natural Volume X

Shrinkage Loose Volume = Natural

Volume X (1 + Swell) Natural Volume =

200 m^3 ÷ 0.95 = 210.5 m^3

Loose Volume = 210.5 m^3 X (1 + 0.15) = 242.1 m^3

Number of Loads = 242.1 ÷ 8 = 30.26 (31 truck-loads will be required)

1. Cross-section Method (Grid Method)

Every project site requires cutting and filling to reshape the grade. For any new project, site needs earthwork or grading to remove topsoil or rough ground. Cutting consists of bringing the ground to lower level by removing earth. Filling is bringing soil in to build the land to higher elevation.

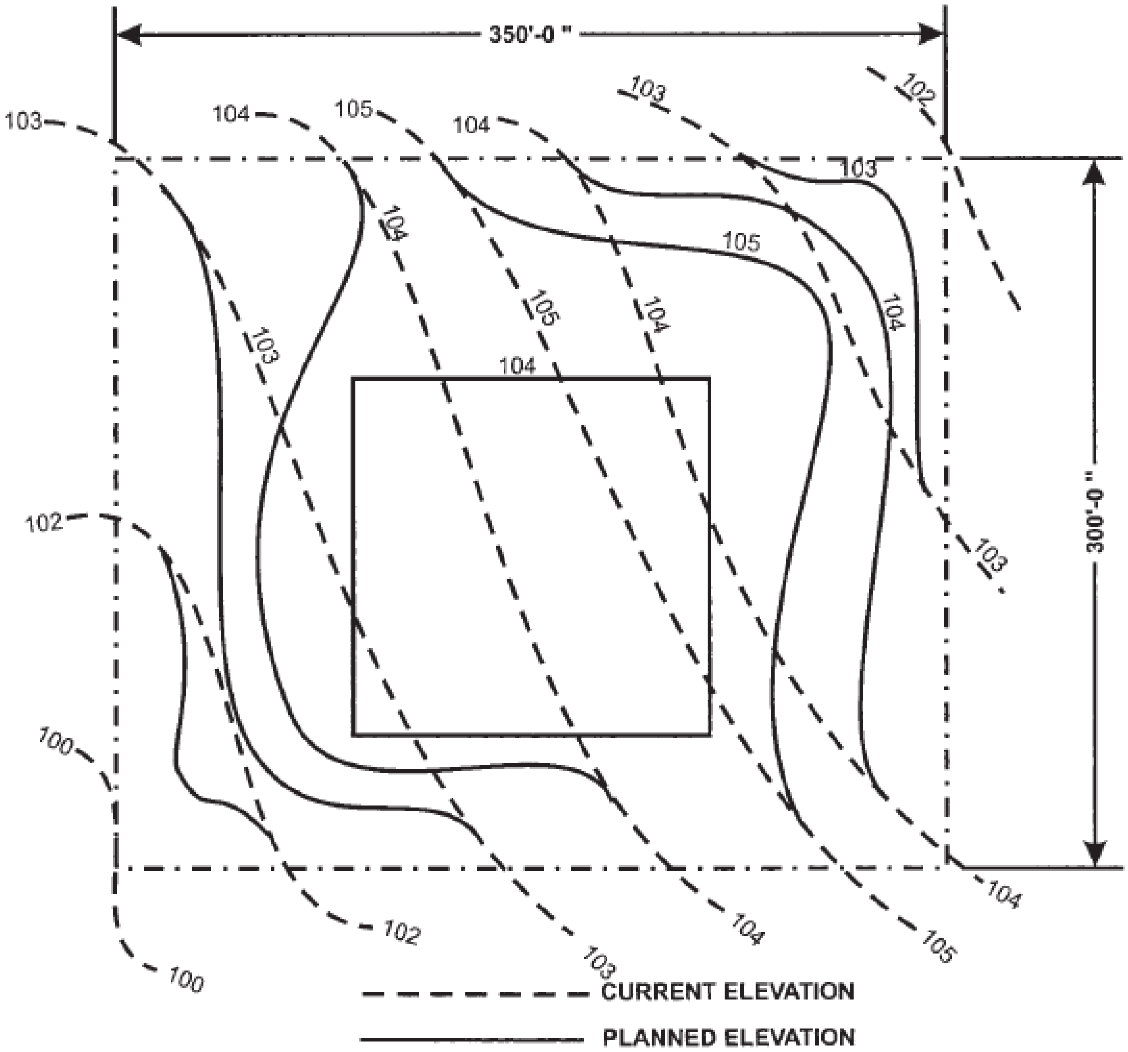
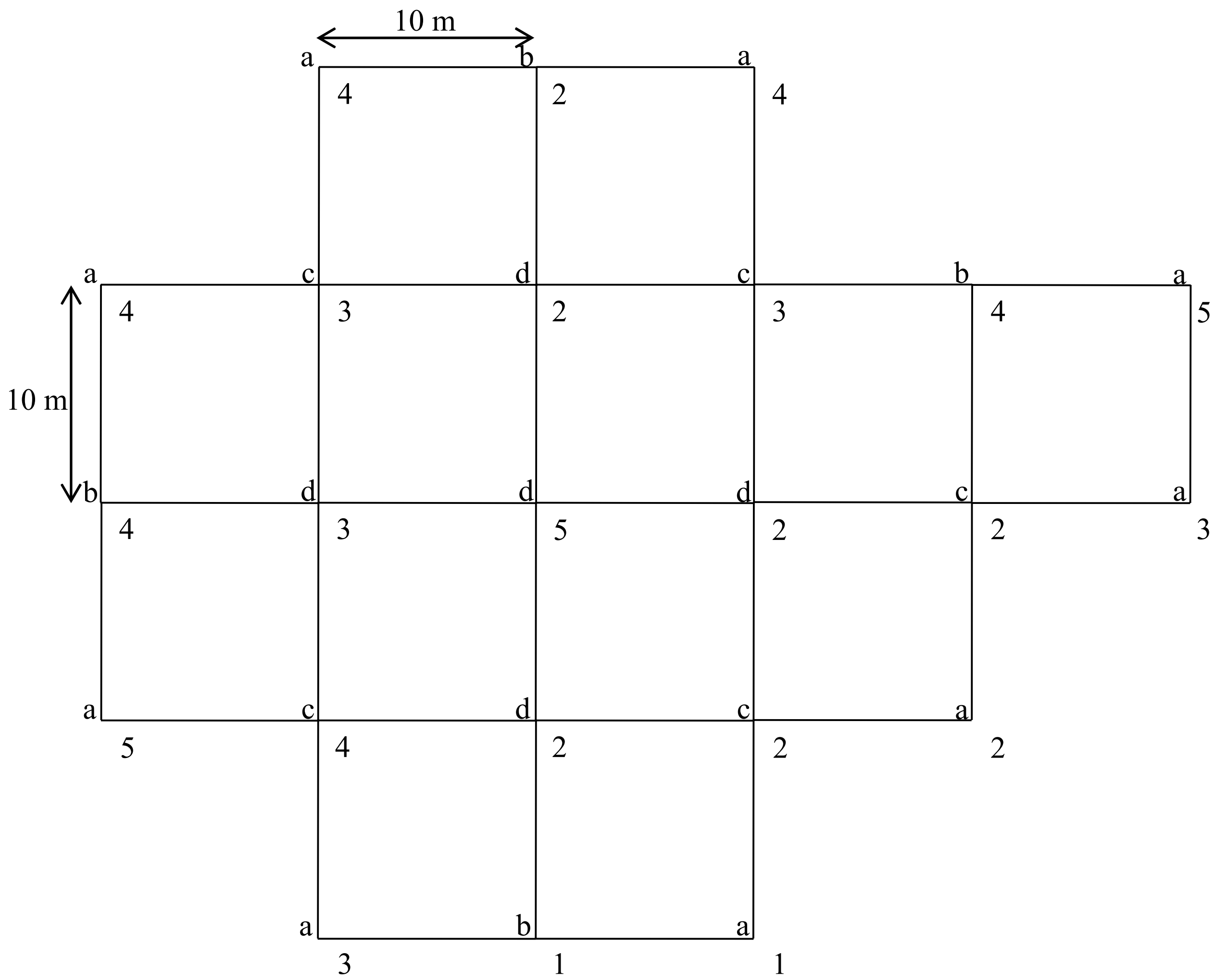


FIGURE 9.3. Sample Site Plan.

The primary drawing for site excavation is the site plan. It shows contour lines that connect points of equal elevation. Also, it shows the position of the site, as shown in the previous figure. In the figure, the existing elevations are shown with dashed contour lines while the proposed new elevations are denoted with solid lines. The new proposed contour lines will change the site area into a level area at elevation 104.

2. *Simple Grid Method*

When a project site is divided with a grid of equal squares or rectangles, and all the grid intersections require only cut or only fill, then we can use the following method.



The volume of cutting or filling is calculated as follows:

$$Volume = \frac{Area\ of\ one\ rectangle}{4} \times (a + 2b + 3c + 4d)$$

$$a = 4 + 4 + 4 + 5 + 3 + 5 + 2 + 3 + 1 = 31$$

$$b = 2 + 4 + 4 + 1 = 11$$

$$c = 3 + 3 + 2 + 4 + 2 = 14$$

$$d = 2 + 3 + 5 + 2 + 2 = 14$$

$$Volume = \frac{10 \times 10}{4} \times (31 + 2 \times 11 + 3 \times 14 + 4 \times 14) = 3775\ m^3$$

General Excavation

Included under general (mass) excavation is the removal of all types of soil that can be handled in fairly large quantities, such as excavations required for a basement, mat footing, or a cut for a highway or parking area.

To determine the amount of general excavation, it is necessary to determine the following:

1. Building dimensions.

2. The distance of footings beyond the project wall.

3. The amount of working space required between the edge of the footing and the beginning of excavation.

4. The elevation of the existing land, by checking the existing contour lines on the site plan.

5. The type of soil that will be encountered.

6. Whether the excavation will be sloped or supported.

7. The depth of the excavation.

Material	Angle		
	Wet	Moist	Dry
Gravel	15-25	20-30	24-40
Clay	15-25	25-40	40-60
Sand	20-35	35-50	25-40

FIGURE 9.29. Earthwork Slopes.

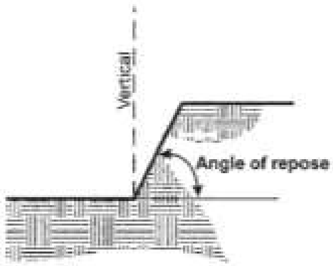


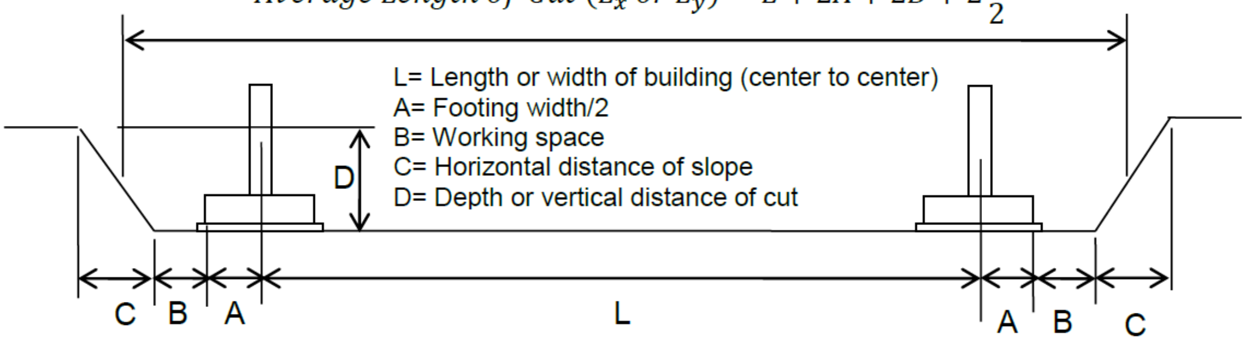
FIGURE 9.28. Angle of Repose.

If job conditions will not allow the sloping of soil, the estimator will have to consider using sheet piling or some type of bracing to shore up the bank.

When sloping sides are used for mass excavations, the volume of the earth that is removed is found by developing the average cut length in both dimensions and by multiplying them by the depth of the cut.

Basement Excavation

$$Average\ Length\ of\ Cut\ (L_x\ or\ L_y) = L + 2A + 2B + 2\frac{c}{2}$$



$$General\ Excavation = Length \times Width \times Depth = L_x \times L_y \times D$$

Example:
Determine the amount of general excavation required for the basement portion of the building shown in the following figure. Assume the workspace between the edge of the footing and the beginning of the excavation will be 0.5 m, by checking the existing contour lines on the site plan the expected depth of the cut is 3 m after a deduction for the topsoil that would have already been removed, and a slope of 2:1 for soil will be used, which means for every 2 m of vertical depth an additional 1 m of horizontal width is needed, rather than using shoring or sheet piling.

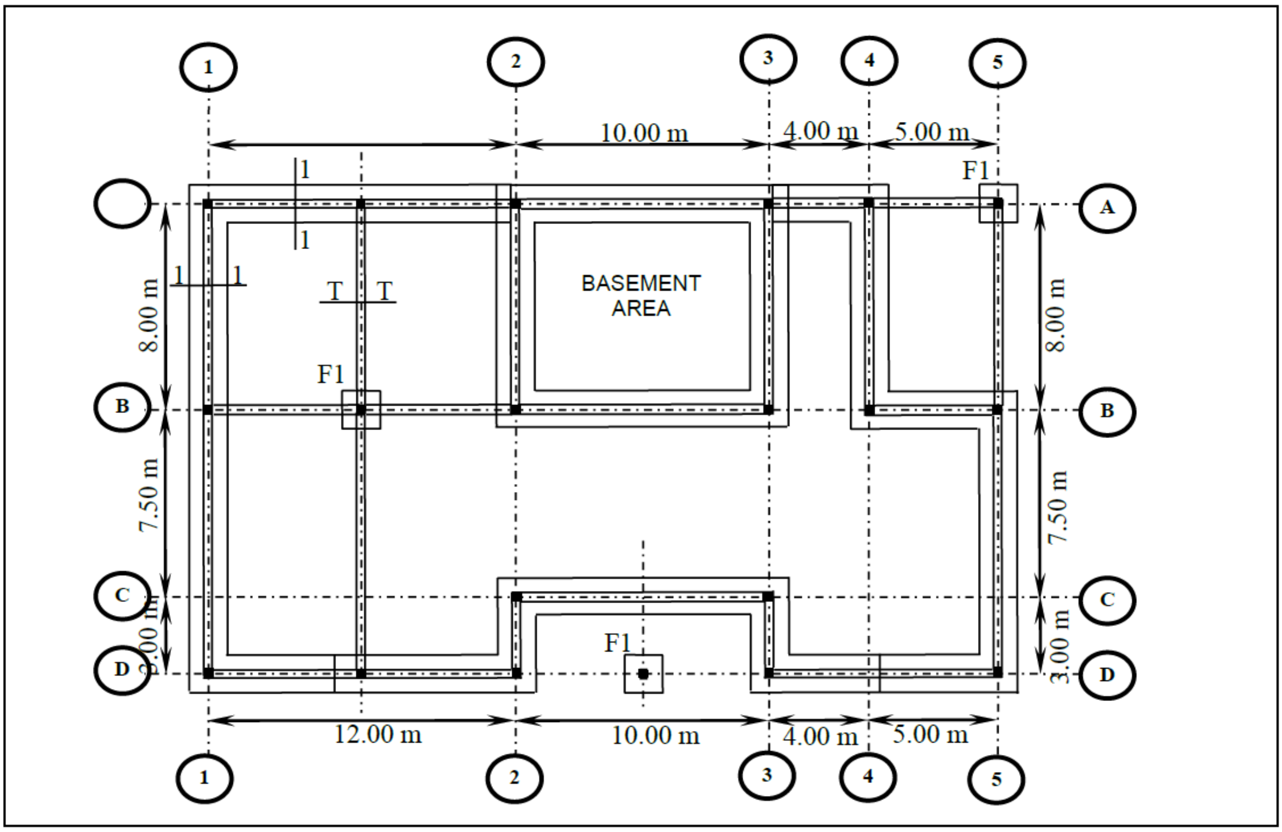
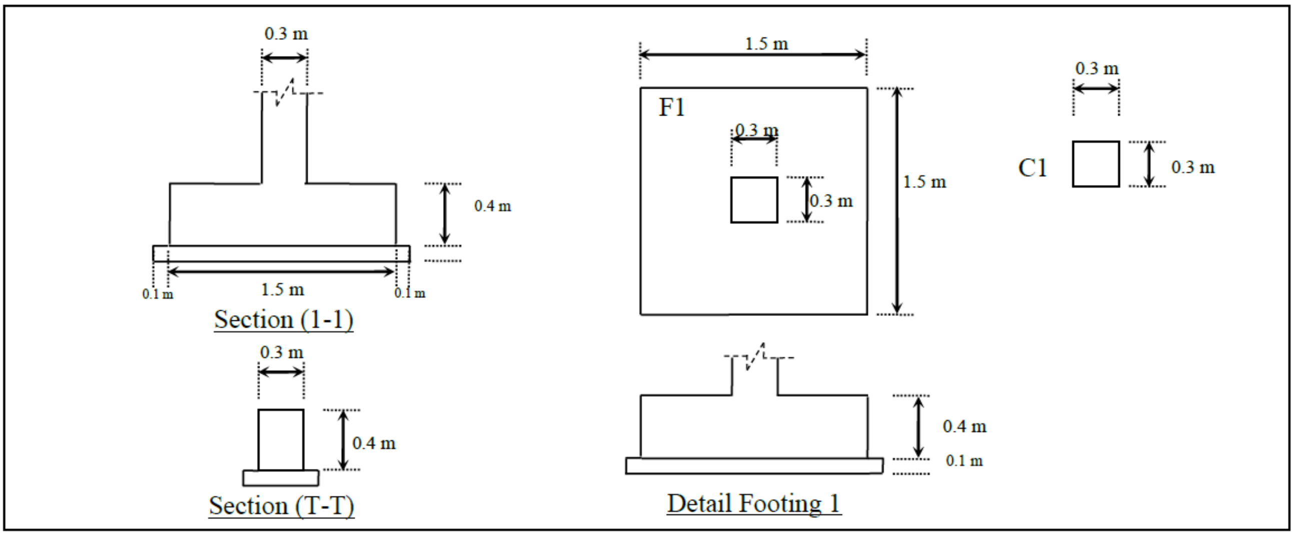


Figure 9.32. Building Plan.



Cross-Sections of Footings

Solution:

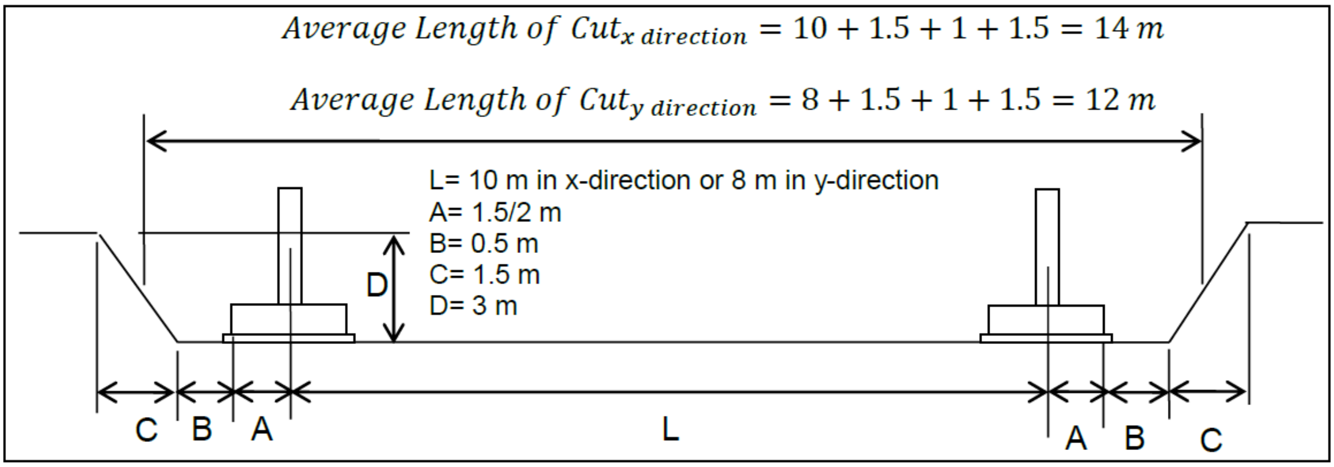


Figure 9.33. Basement Cross-Section

$$General\ Excavation = Length \times Width \times Depth$$

$$General\ Excavation = 14 \times 12 \times 3 = 504\ m^3$$

H.W #01

If the natural soil is dense clay and the excavated soil needs to be moved away, how many loose cubic meters have to be moved away by trucks? And, how many loads of 8 m^3 dump trucks will be needed?

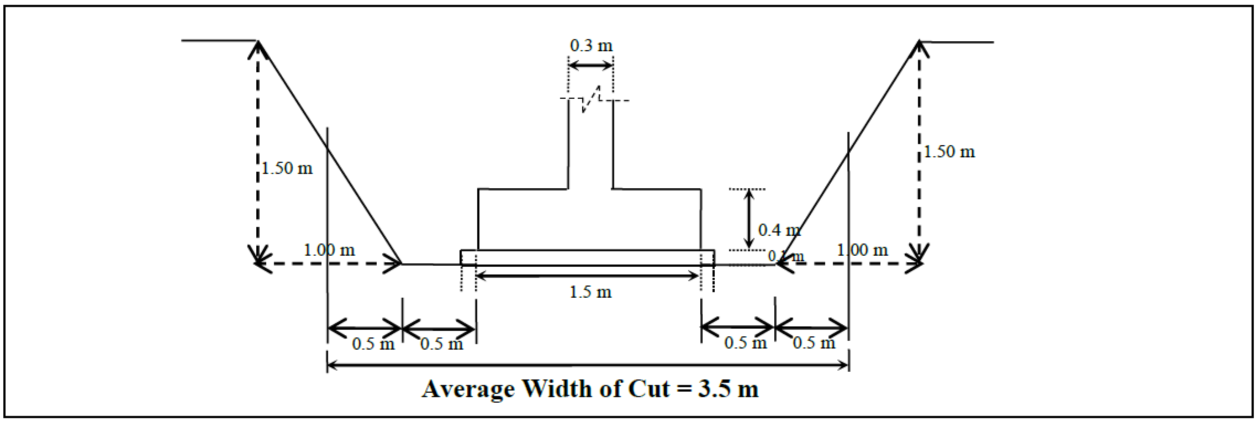
What are the costs of excavation and moving soil?

Continuous Footing Excavation

Example:

Determine the amount of general excavation required for the continuous footings of the building shown in the building plan and the cross-sections drawings. Assume that the slope of the soil will be 1.5:1, the working area will be 0.5 m, and the depth of excavation will be 1.5 m.

Solution:

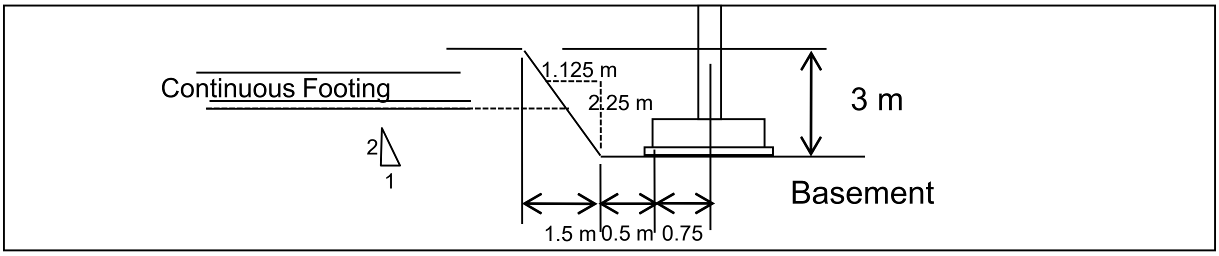


Width of Cut = 3.5 m Depth of

Cut = 1.5 m

Length of Cut = A1toA2 + A3toA4 + A4toB4 + B4toB5 + B5toD5 + D5toD3 + D3toC3 + C3toC2 +

C2toD2 + D2toD1 + D1toA1 – Width of cut already calculated in the basement excavation



Length of Cut = 12+4+8+5+7.5+3+5+4+3+10+3+12+3+7.5+8 – 2 x (0.75+0.5+0.75)

= 91 m

$$Volume\ of\ Continuous\ Footing\ Excavation = Length \times Width \times Depth$$

$$Excavation = 91 \times 3.5 \times 1.5 = 465.9\ m^3$$

H.W #02

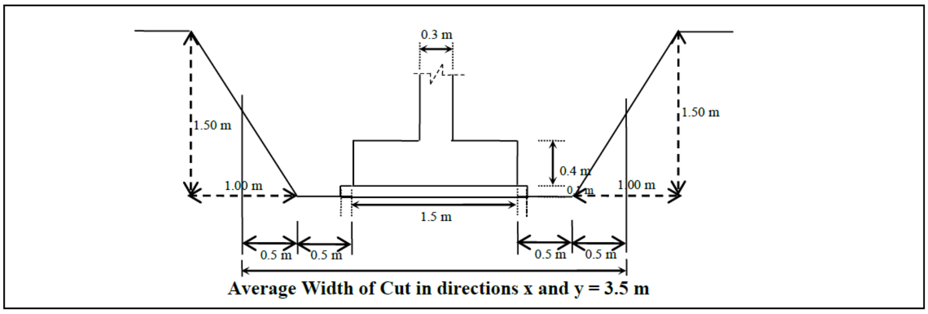
If the natural soil is dense clay and the excavated soil needs to be moved away, how many loose cubic meters have to be moved away by trucks? And, how many loads of 8 m^3 dump trucks will be needed?

What are the costs of excavation and moving soil?

Spread Footing Excavation

Example:

There are 3 spread footings shown in building figure. Given that the soil slope should be 1.5:1, the working distance should be 0.5 m, the cut depth will be 1.5 m, and the footing is square. Calculate the excavation volume?



$$Volume\ of\ Spread\ Footings\ (F1)\ Excavation = Length \times Width \times Depth \times Number$$
$$Excavation = 3.5 \times 3.5 \times 1.5 \times 3 = 55.125\ m^3$$

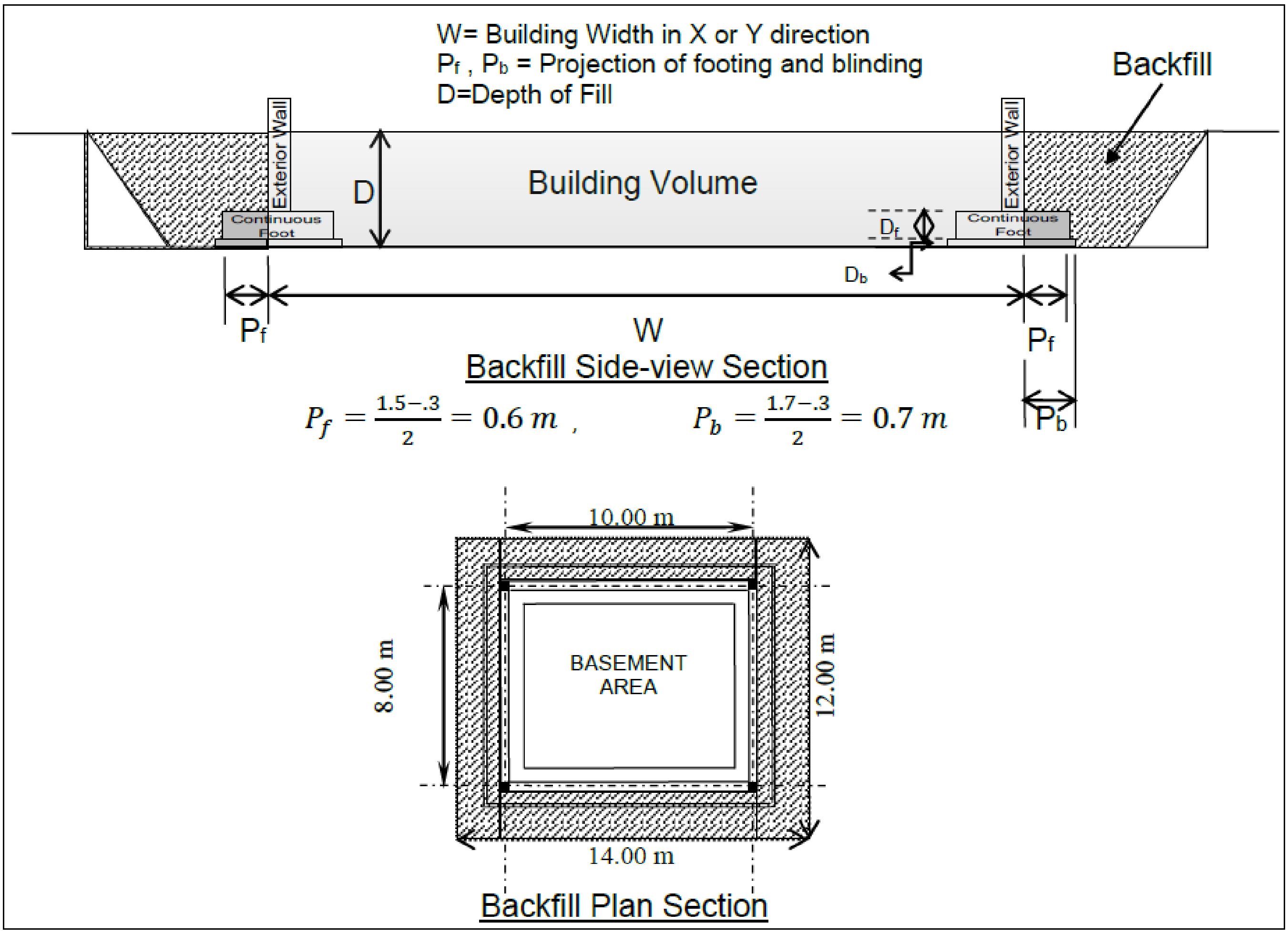
H.W #03

If the natural soil is dense clay and the excavated soil needs to be moved away, how many loose cubic meters have to be moved away by trucks? And, how many loads of 8 m^3 dump trucks will be needed?

What are the costs of excavation and moving soil?

Backfilling

Backfilling the Basement Walls



$Basement\ Total\ Excavation = 14 \times 12 \times 3 = 504\ m^3$

$Basement\ Building\ Volume = 10.3 \times 8.3 \times 3 = 256.47\ m^3$

$Footing\ and\ Blinding\ Projection\ Volume = P_f \times D_f \times L_f + P_b \times D_b \times L_b$

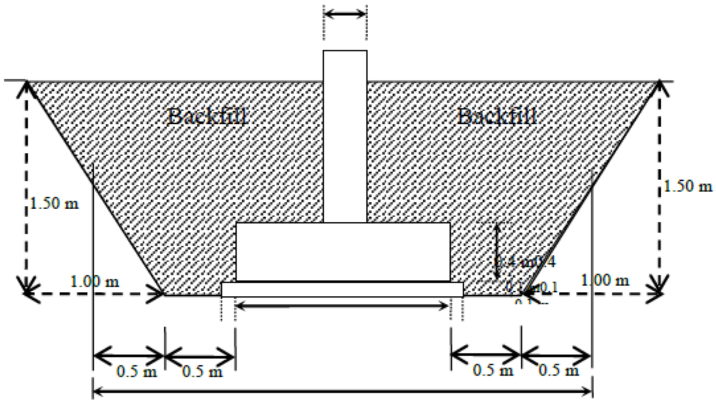
$$Footing\ and\ Blinding\ Projection\ Volume = 0.6 \times 0.4 \times (10.9 \times 2 + 8.9 \times 2) + 0.7 \times 0.1 \times (11 \times 2 + 9 \times 2) = 12.3\ m^3$$

$$Basement\ Total\ Fill = Total\ Excavation - Building\ Volume - Footing\ Volume = 504 - 256.47 - 12.3 = 235.23\ m^3$$

Backfilling the Continuous Foundations

There are two ways in which the quantity of backfill can be determined. Both will yield virtually the same answer. The first is to subtract the area of the footing from the area backfill and multiply that number by the length of the footing. Alternately, the area of backfill can be calculated by figuring the area of backfill and multiplying that amount by the length.

Method 01:



Method 1

$$Volume\ of\ Continuous\ Footing\ Cut\ = 3.5 \times 1.5 \times 88.75 = 465.9375m^3$$

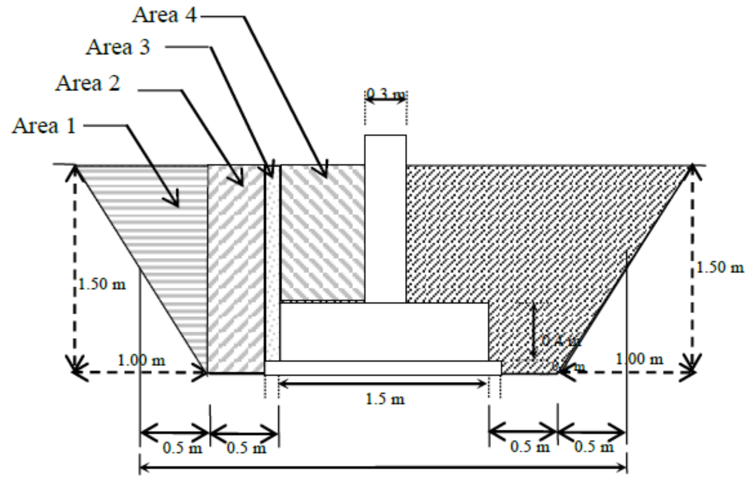
$$Volume\ of\ Concrete = Blinding\ Volume + Footing\ Volume + Wall\ Volume$$

$$= 1.7 \times 0.1 \times 88.75 + 1.5 \times 0.4 \times 88.75 + 0.3 \times 1.0 \times 88.75 = 94.9625m^3$$

$$Volume\ of\ Backfill = Cut\ Volume - Concrete\ Volume$$

$$Volume\ of\ Backfill = 465.9375 - 94.9625 = 370.975m^3$$

Method 02:



Method 2

$$Volume\ of\ Backfill = 2 \times (Area\ 1 + Area\ 2 + Area\ 3 + Area\ 4) \times Length\ of\ Cut$$

$$Volume\ of\ Backfill = 2 \times (0.5 \times 1 \times 1.5 + 0.4 \times 1.5 + 0.1 \times 1.4 + 0.6 \times 1) \times 88.75 = 370.975m^3$$

Keep in mind that the material being brought in is loose and will be compacted on the job. If it is calculated that 100 m^3 are required, the contractor will have to haul in at least 110 to 140 m^3 of soil—even more if it is clay or loam

H.W #04

If the natural soil is dense clay and the compacted soil needs to be backfilled, how many loose cubic meters have to be brought to the site by trucks? And, how many loads of 8 m^3 dump trucks will be needed?

What are the costs of excavation and moving soil?