UNIT 1 ESTIMATION OF EARTHWORK

Structure

1.1 INTRODUCTION

The types of earthwork that most commonly are to be dealt with by practicing civil engineers comprise cutting and filling in the construction of embankments, road and rail formations, canals; and in the foundations of a building as well as finishing upto below floor levels. A good grounding in mensuration forms the basic skill that every civil engineer should possess to be able to compute the quantities involved in every type of earthwork. A reasonably developed faculty of imagination is a welcome asset to comprehend the drawings pertaining to any type of earthwork in order to be able to calculate the quantities with ease.

Objectives

After studying this unit, you should be able to

- calculate the earthwork, filling and cutting separately, that goes into the making of a piece of work : road, rail track, canal, and a building,
- comprehend the various modes of mensuration that can be employed in these calculations, and
- conceptualise the basic knowledge about the general specifications that must be followed to bring any such earthwork to the standard requirements.

1.2 ESTIMATION OF EARTHWORK IN ROAD AND RAILWAY TRACK

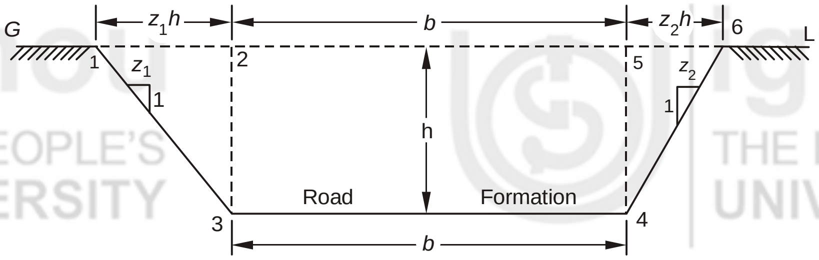
The basics of any computational methodology that may be adopted in the mensurational procedure, vis-à-vis, road/rail consist of calculating the average cross-sectional areas of filling/cutting, from point to point, along the given alignment, and then multiplying by the distances between any two consecutive sections in order to obtain the desired volumetric quantity of the earthwork between these two points.

1.2.1 Calculating Cross-sectional Areas of Road Formations

Figure 1.1 shows a simple (typical) cross-section of road (or rail) formations wholly in cutting : the same figure, when reversed vertically about line 1-3-4-6 represents the cross-section totally in filling. Herein the side slopes ($1 : z_1$ and $1 : z_2$) are taken different from each other as a generalization – usually in simple cases, while the soil is homogeneous, $z_1 = z_2 = z$ (say). Knowing the formation width, depth of cutting (or height of filling), and side slopes the sectional areas (A), as explained in Figure 1.1, works out to be :

$$(b \times h) + z\,h^2 \qquad \ldots (1.1)$$

Note : z_1 (or z_2) is the side slope–Generally $z_1 = z_2 = z$



Cross sectional area, A of 1-3-4-6-1 = (Area 2-3-4-5) + (Area 1-2-3) + (Area 4-5-6)

$$= (b \times h) + \frac{1}{2}(z_1 h)h + \frac{1}{2}(z_2 h)h$$

$$= (b \times h) + (zh)^2\text{—if } z_1 = z_2 = z$$

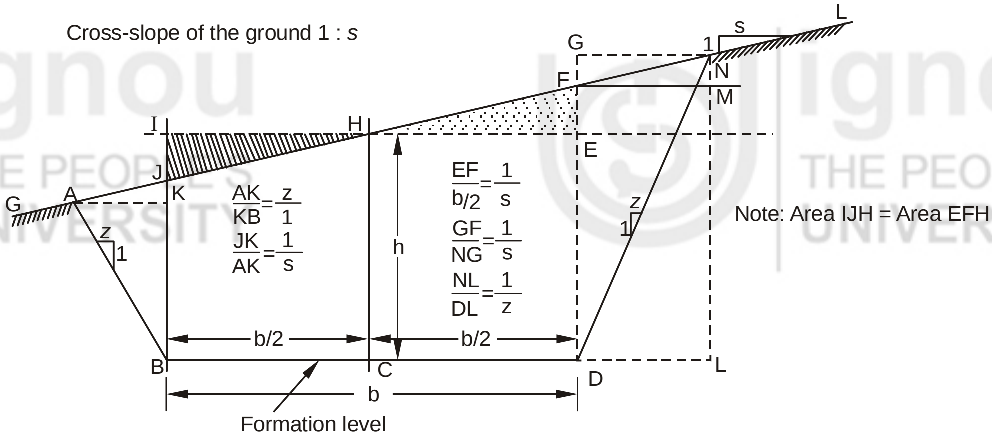
Figure 1.1 : Simple Section of a Real Formation in Cutting (When Inverted it Depicts Formation in Filling)

Figure 1.2 presents a typical cross-section of a road in cutting, in a hilly region, where the cross-slope of the ground is quite large ($1 : s :: V : H$). The total area in cutting (A) is the summation of three component areas : $ABJ + BDFJ + DFN$, where,

$$\text{Area } ABJ = \frac{1}{2}(BJ \times AK)$$

$$= \frac{1}{2}[h - IJ][z\,K\,B]$$

$$IJ = \frac{\left(\frac{b}{2}\right)}{s}$$



Cross-sectional area ABDNA = Area ABJ + Area BIED + Area DFN

Figure 1.2 : Cross-section of a Road, in Cutting, in a Hilly Region with a Marked Cross-slope of the Ground

Also, $BJ = KB + KJ$

$$= \frac{AK}{z} + \frac{AK}{s} = AK\left[\frac{s + z}{s\,z}\right]$$

$$\therefore\ AK = \left[\frac{sz}{s + z}\right] BJ$$

$$\therefore \qquad = \frac{s\,z}{(s + z)}\,[h - IJ]$$

$$= \frac{s\,z}{(s + z)}\left[h - \frac{b}{2s}\right]$$

Hence, $\text{Area } ABJ = \frac{1}{2}\left[h - \frac{b}{2s}\right]\left[\frac{s\,z}{(s + z)}\left(h - \frac{b}{2s}\right)\right]$

$$= \frac{z}{8s\,(s + z)}\,[2sh - b]^2$$

Area $BDFJ = 2 \times$ Area $BCHI$

(where, shaded and dotted triangular wedges balance each other)

$$= 2 \times \frac{b}{2} \times h = (b \times h)$$

and, area $DFN = \frac{1}{2}\,DF \times NG$

Here, $DF = ED + EF$

$$= h + \frac{\frac{b}{2}}{s}$$

$$= \left(\frac{2hs + b}{2s}\right)$$

$NG = DL = z\,NL$

whose, $NL = GD = GF + FE + ED$

$$= \frac{NG}{s} + \frac{\frac{b}{2}}{s} + h$$

$$\therefore \qquad NG = z\left[\frac{NG}{s} + \frac{b}{2s} + h\right]$$

or $$NG\left(1 - \frac{z}{s}\right) = \frac{z\,(2sh + b)}{2s}$$

$$NG = \left[\frac{z\,(2sh + b)}{2} \times \frac{1}{(s - z)}\right]$$

Hence, area $DFN = \frac{1}{2}\left(\frac{2hs + b}{2s}\right)\left[\frac{z}{2}\,\frac{(2hs + b)}{(s - z)}\right]$

$$= \frac{z}{8\,(s - z)\,s}\,(2sh + b)^2$$

Therefore,

$$\text{Total area A} = \frac{z}{8s\,(s+z)}\,(2sh-b)^2 + (b\times h) + \frac{z}{8s\,(s-z)}\,(2sh+b)^2 \qquad \ldots (1.2)$$

Figure 1.3 depicts a cross-section of the formation wholly in filling, in a hilly region, with marked cross-slope of the ground. Eq. (1.2) is applicable also to this situation. Students must derive this equation for this geometry as a matter of exercise.

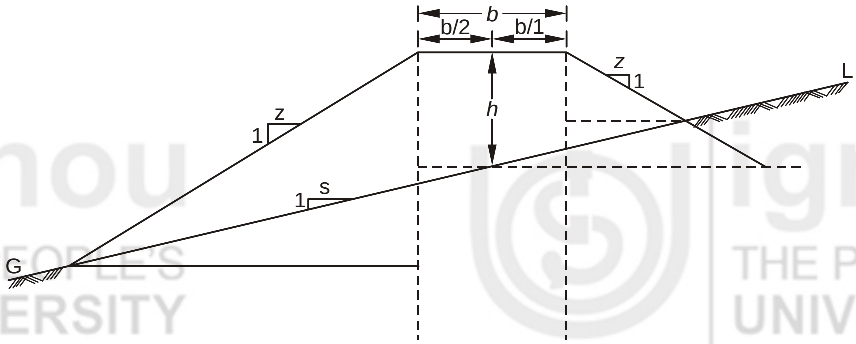


Figure 1.3 : Cross-section of Road Formation in Filling (in Embankment) in a Hilly Terrain with Marked Cross-slope of the Ground

Figure 1.4 presents the simplest case of a road section in a hilly region : in actuality BC may not always equal to CD, and calculations will have to be different as discussed below :

Area in filling = Area ABC,

Area in cutting = Area CDE

$$\frac{AG}{BG} = \frac{z_1}{1}, \text{ or } \frac{AG}{h_1} = \frac{z_1}{1}, \text{ or } AG = z_1 \times h_1$$

and $$\frac{AG}{FG} = \frac{s}{1}, \text{ or } FG = \frac{AG}{s} = \frac{z_1 \times h_1}{s}$$

$$BF = BG - FG$$

$$= h_1 - \frac{z_1\,h_1}{s} = h_1\left[1 - \frac{z_1}{s}\right]$$

∴ $$\text{Area } ABF = \frac{1}{2}\,AG \times BF = \frac{1}{2}\,(z_1 \times h_1)\,h_1\left[1 - \frac{z_1}{s}\right]$$

$$\text{Area } CBF = \frac{1}{2}\times b_1\ BF = \frac{b_1}{2}\times h_1\left[1 - \frac{z_1}{s}\right]$$

∴ Area ABC (Filling) = Area ABF + Area CBF

$$= \frac{1}{2}\left[1 - \frac{z_1}{s}\right] h_1\,[z_1\ h_1 + b_1]$$

$$= \frac{1}{2}\left[1 - \frac{z_1}{s}\right][z_1\,h_1^2 + h_1\,b_1] \qquad \ldots (1.3)$$

and, Area CDE (Cutting) = Area DEH + Area CDH . . . (1.4)

$$\frac{EI}{DI} = \frac{z_2}{1}$$

or $$\frac{EI}{h_2} = \frac{z_2}{1}, \text{ or } EI = z_2\,h_2$$

and, $\frac{EI}{HI} = \frac{s}{1}$, or $HI = \frac{EI}{s} = \frac{z_2 h_2}{s}$

$$HD = ID - IH = h_2 - \frac{z_2 h_2}{s} = h_2 \left(1 - \frac{z_2}{s}\right)$$

$\therefore$ Area $DFH = \frac{1}{2} \times IE \times HD$

$$= \frac{1}{2} z_2 \; h_2 \times h_2 \left(1 - \frac{z_2}{s}\right)$$

and, Area $CDH = \frac{1}{2} \times b_2 \times HD$

$$= \frac{1}{2} b_2 \times h_2 \left(1 - \frac{z_2}{s}\right)$$

$\therefore$ Area CDE (i.e., from Eq. 1.4) $= \frac{1}{2} \times h_2 \left(1 - \frac{z_2}{s}\right)(z_2 \; h_2 + b_2)$

$$= \frac{1}{2} \left(1 - \frac{z_2}{s}\right)(z_2 \; h_2^2 \; + b_2 \; h_2) \qquad \ldots (1.5)$$

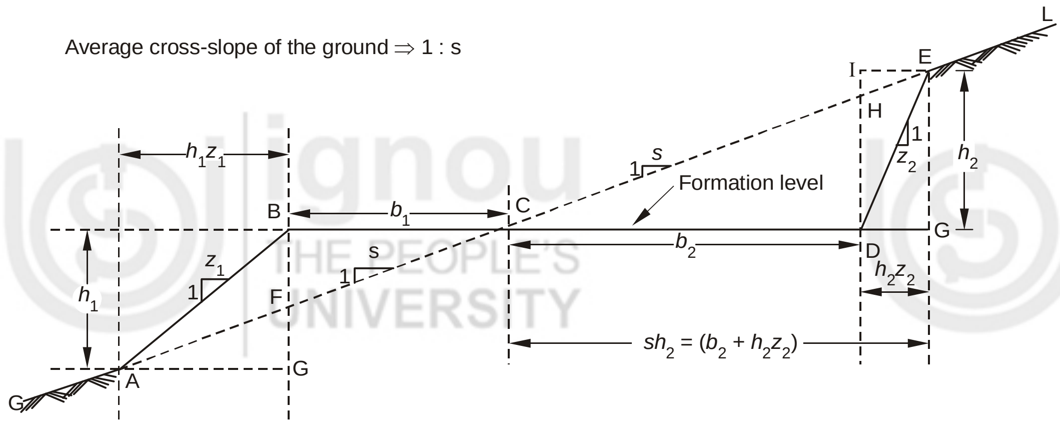


Figure 1.4 : Cross-section of a Road Formation in Cutting-cum-filling (i.e. Cutting-cum-Embankment) in a Hilly Terrain

Various other geometrical juxtapositions combining road/rail formation outlines with single or double cross-sectional ground slopes are always encountered in field situations. With these basics in mind one can always compute the areas, either in filling or cutting, with ease. It is in order here to point out that in practice, ground and proposed formation sections are plotted on a graph sheet on a natural scale (i.e. vertical and horizontal scales being kept the same) imposing the proposed outline on the given natural ground slope. It is easy to understand that one can immediately make out the filling and cutting portions that are required to be done in the proposed earthwork. If the chosen natural scale is, say, 1 cm = x metre on the ground, the conversion factor for 1 square cm (on the graph) is x^2 metre on the ground (in vertical plane). Hence, counting the number of square centimetres (n) enclosed directly by a particular geometrical shape (the procedure does away with the necessity of deducting anything from any gross quantity, as was done while deriving the above mentioned formulae) – reckoning half or more than half square on the graph as 1, and neglecting less-than-half squares – one can arrive at the number ($n \times x^2$) of square metres that are represented by the number "n" on the graph.

Example 1.1

A hilly ground has a cross-slope of 1 : 4 (V : H), and the proposed road formation, entirely in cutting, (1) – (2) – (3) – (4) has to be constructed. Calculate the area in cutting (Figure 1.5).

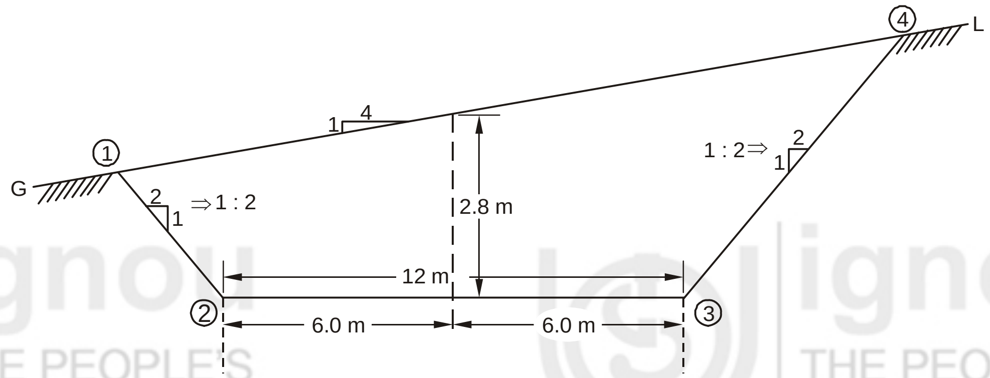


Figure 1.5 : Given Cross-section of a Road Entirely in Cutting (Example 1.1)

Solution

From Eq. (1.2), we have

$z = 2 \quad ; \quad s = 4$

$h = 2.8 \text{ m} \quad ; \quad b = 12 \text{ m}$

Therefore, the total area (A) of the figure (1) – (2) – (3) – (4) is given by :

$$A = \frac{z}{8s(s+z)}(2sh - b)^2 + b \times h + \frac{z}{8s(s-z)}(2sh + b)^2$$

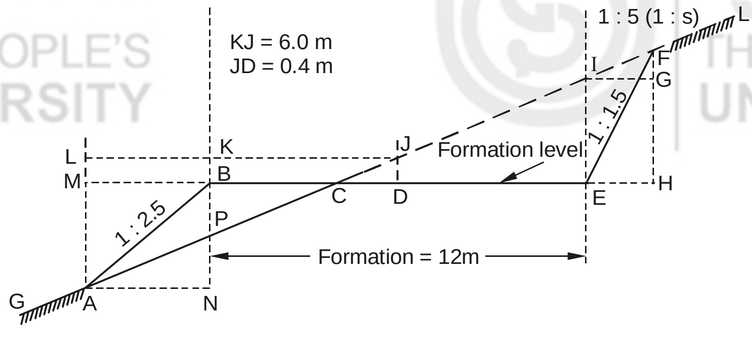
$$= \frac{2}{8 \times 4\,(4+2)}(2 \times 4 \times 2.8 - 12)^2 + 12 \times 2.8 + \frac{2}{8 \times 4\,(4-2)}(2 \times 4 \times 2.8 + 12)^2$$

$$= 1.126 + 33.6 + 36.98$$

$$= 71.706 \text{ m}^2$$

Example 1.2

Figure 1.6 shows the cross-section (ABCEF) of a hilly road (made up of cutting and filling too). Compute the cross-sectional area of cutting and banking (i.e. **filling**) separately.



Note : J is the projection of the mid-point on to the hilly slope of the formation width BE.

Figure 1.6 : Cross-section of a Hilly Road : Partly in Cutting and Partly in Banking (Filling) (Example 1.2)

Solution

To arrive at the required elements of Eqs. (1.3) and (1.4), some calculations, with reference to Figure 1.6, are being made as follows :

$$JD = 0.4 \text{ m}, \frac{PK}{JK} = \frac{1}{s} = \frac{1}{5}$$

$$\therefore \quad PK = \frac{JK}{s} = \frac{6}{5} = 1.2 \text{ m}$$

$$BP = PK - KB = 1.2 - 0.4 = 0.8 \text{ m}$$

Also, $$\frac{JD}{DC} = \frac{BP}{BC} = \frac{BP}{BD - DC}$$

$$\therefore \quad \frac{0.4}{DC} = \frac{0.8}{6 - DC}$$

which gives,

$$DC = 2 \text{ m}$$

Further, $$\frac{IE}{EC} = \frac{1}{s} = \frac{1}{5}; \text{ or } IE = \frac{EC}{5}$$

But, $$EC = 6 \text{ m} + CD$$
$$= 6 + 5\,JD = 6 + 5 \times 0.4$$
$$= 8 \text{ m}$$

$$\therefore \quad IE = GH = \frac{8.0}{5} = 1.6 \text{ m}$$

Now, with reference to the overall cross-slope of the hill, we can write :

$$\frac{FH}{CH} = \frac{1}{5}$$

or $$\frac{FH}{HE + EC} = \frac{1}{5}, \text{ or } FH = \frac{HE + EC}{5}$$

Also $$\frac{FH}{HE} = \frac{1}{1.5}, \text{ or } FH = \frac{HE}{1.5}$$

Hence, $$\frac{HE + EC}{5} = \frac{HE}{1.5}$$

or, $$\frac{HE + 8.0}{5} = \frac{HE}{1.5}$$

$$\therefore \quad HE = \frac{12}{3.5} = 3.42 \text{ m}$$

$$FH = \frac{3.42}{1.5} = 2.28 \text{ m}$$

$$\frac{AM}{MC} = \frac{1}{1.5}, \text{ also } \frac{AM}{MB} = \frac{1}{2.5}$$

$$\therefore \quad AM = \frac{MC}{5} = \frac{MB}{2.5}$$

or, $$\frac{MB + BC}{5} = \frac{MB}{2.5}$$

where, $$BC = BD - CD$$
$$= 6.0 - 2.0 = 4.0 \text{ m}$$

$$\therefore \qquad \frac{MB + 4}{5} = \frac{MB}{2.5}$$

which gives, $MB = 4.0$ m

Thus, $AM = \frac{4.0}{2.5} = 1.6$ m

We have by now calculated the required data for use in the above mentioned formulae, and the information is summed up as under :

$$z_1 = 2.5;\ s_1 = 5;\ h_1 = AM = 1.6 \text{ m};\ b_1 = BC = 4.0 \text{ m}$$

and $z_2 = 2.5;\ s = 5;\ h_2 = FH = 2.28 \text{ m};\ b_2 = CE = 8.0 \text{ m}$

Therefore, Area in cutting $= \frac{1}{2}\left(1 - \frac{z_1}{s}\right)[z_2\ h_2^2 + b_2\ h_2]$

$$= \frac{1}{2}\left(1 - \frac{1.5}{5}\right)[1.5(2.28)^2 + 8 \times 2.28]$$

$$= \frac{1}{2}\ (0.7)\ (26.03) = 9.11 \text{ m}^2$$

and, Area in filling $= \frac{1}{2}\left(1 - \frac{z_1}{s}\right)[z_1\ h_1^2 + b_1\ h_1]$

$$= \frac{1}{2}\left(1 - \frac{2.5}{5}\right)[2.5(1.6)^2 + 1.6 \times 4]$$

$$= \frac{1}{2}\ (0.5)\ (12.8) = 3.2 \text{ m}^2$$

1.2.2 Computing Volumetric Quantities of Earthwork along a Road Alignment

A civil engineer (or the customer: the work executing agency, or the owner) is ultimately interested in knowing the volumetric quantity of earthwork for which arrangements are needed to be made, and payments made as per the agreement entered between the parties. In general, there are three principal methods of computation that are used, namely :

(a) Average cross-sectional area method,

(b) Mid-sectional area method, and

(c) Prismoidal formula method.

Average Cross-sectional Area Method

As the name of the procedure indicates the average cross-sectional area (A) is computed between a given length (l) of the road to be multiplied by 'l' (the distance between the end sections), to obtain the volume of earthwork (V) enclosed as shown in Figure 1.7. This Figure gives a simplified case of a stretch of road that is fully in cutting and characterized by a uniform longitudinal grade. In practice the end sections may be composed of both the filling and cutting – in that case, again the average of filling and cutting areas, respectively, are to be considered and multiplied by "l" to obtain the respective volume of earthwork. It is to be understood that 'l' is the regular chainage length at which cross-sections are profiled;

and any additional cross-sections are recorded at places where the longitudinal formation line registers a change in slope or the ground profile (in longitudinal direction) shows natural changes in grade. Such additional cross-sections help one to attain a better accuracy in the computation of volumes of earth by changing the values of '*l*' appropriately at such locations as mentioned above. The view will change in its contours, as can be easily understood, according to whether the road is entirely in filling or partly so.

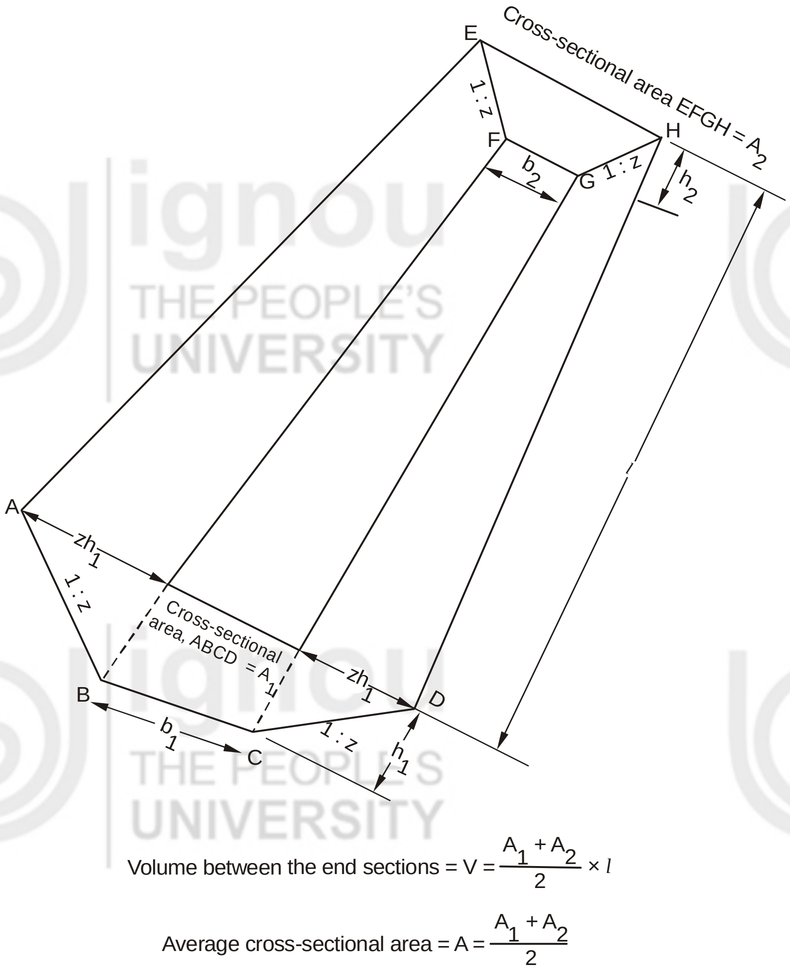


Figure 1.7 : Isometric View of a Road, Fully in Cutting, with End-section '*l*' Metres Apart

Considering Figure 1.7, we have :

$$\text{Area ABCD } (A_1) = b_1 \times h_1 + 2\left[\frac{1}{2}(z\ h_1)\ h_1\right]$$

$$= (b_1\ h_1 + z\ h_1^2)$$

Similarly, $\quad \text{Area EFGH } (A_2) = (b_2 \times h_2 + z\ h_2^2)$

[In compound cases we can have side slopes as z_1 and z_2; and not $z_1 = z_2 = z$.]

$\therefore$ Average area of cross-section along the length (l) of the road stretch,

$$A = \frac{A_1 + A_2}{2}$$

And, the required volume of earthwork,

$$V = \left(\frac{A_1 + A_2}{2}\right) l$$

$$= \frac{(b_1\ h_1 + z\ h_1^2) + (b_2\ h_2 + z\ h_2^2)}{2} \times l \qquad \ldots (1.6)$$

It may again be pointed out, the areas A_1 and A_2 can as well be calculated through the use of graphical constructions.

These computations can be tabulated as shown below for the ease of recording and inspection, and quick totalling up (its format can be changed, say, if $z_1 \neq z_2$ etc.) :

Chainage or Length (m)	Height or Depth (m)	Area of Rectangular Portion of the Section $b \times h$ (m^2)	Area of Side Triangle, $1/2\ z\ h_1^2$ (m^2)	Area of Second Side Triangle (if $z_1 \neq z_2$) (m^2)	Total Cross-sectional Area (A_1 or A_2) (m^2)	Mean Cross-sectional Area (A) (m^2)	Length (l) – Difference between Consecutive Chainages	Quantity of Earthwork, $A \times l$ (m^3)	
								In Cutting	In Filling

It is quite evident that the grand total of last two sub-columns gives the required quantity of earthwork in cutting and embankment (i.e. filling), respectively.

Mid-sectional Area Method

In this method, the required volume of earthwork is calculated by considering the area of cross-section profiled at the mid-point (A_m) of length 'l' of the road stretch. Or, it is calculated as shown below :

Let the bottom width of the mid-section be = b_m

Height (or depth) of the section be = h_m

$$\therefore \qquad h_m = \frac{h_1 + h_2}{2}$$

$$A_m = b \times h_m + z\ h_m^2$$

So, quantity of earthwork = $A_m \times 1$.

The tabulation of results is done as shown above, with the additional column for recording the values of h_m being incorporated.

Prismoidal Formula Method

Here in this method three cross-sectional areas – one at each end of the stretch (i.e. reach of the road), and one at the mid-point of the reach – are considered, using the following formula :

$$V = \frac{l}{6}\,(A_1 + 4A_m + A_2)$$

This formula is applicable equally both to cuttings and fillings.

Example 1.3

A survey was conducted for the proposed road through a given area, and following data recorded :

Chainage (m)	0	25	50	75	100	125	150	175
RL of Ground (m)	104.0	104.40	104.55	104.80	105.10	105.80	105.60	105.10
RL of Proposed Formation (m)	–	–	–	–	104.80	–	–	–
Proposed Gradient of Road	← Rising Gradient of 1 m in 150 →							
Chainage (m)	200	225	250	275	300	325	350	
RL of Ground (m)	104.70	104.70	104.10	103.80	103.80	104.40	103.70	
RL of Proposed Formation (m)	–	–	–	–	–	–	–	
Proposed Gradient of Road	← Falling Gradient 1 m in 200 →							

[**Note :** RLs of proposed formation at chainage 100 m is prefixed herein to meet some field requirements, whereas RLs at other chainages are to be calculated as per the proposed gradient of the road.]

It is required to workout the quantities of earthwork in cutting and filling for the given length of the reach, 350 m, using the following data as well :

Proposed width of road formation = 12.0 m

Side slopes in cutting = 1 : 2

Side slopes in filling = 1 : 2.5

Assume the cross-slope of the ground as nil.

Draw the longitudinal section (L-section), i.e., longitudinal profile of the ground, showing the formation line all long.

Propose the bill of quantities of earthwork – both in embankment (filling) and cutting. Also prepare the cost of these two items of earthwork separately, and the cost of turfing on the side slopes of the road.

Assume suitable rates of payment for each item.

Solution

Figure 1.8 presents the given data insofar as the longitudinal profile of the ground, and formation line are concerned – the Figure itself being self-explanatory. It should be noted that in contrast to the plotting of a cross-section to a natural scale (horizontal scale = vertical scale) in order to directly obtain the cross-sectional area by the counting of squares, here the two scales are chosen differently to allow a better representation of the ups and downs of the longitudinal profiles. In this particular example the vertical scale is chosen such as 2 cm represents 1 metre of the ground, while horizontal 1 cm represents 25 m of the ground.

Figure 1.8(a) : Determination of Formation Levels; and hence Depth of Cutting and Height of Embankment at Chainage Points (Example 1.3)

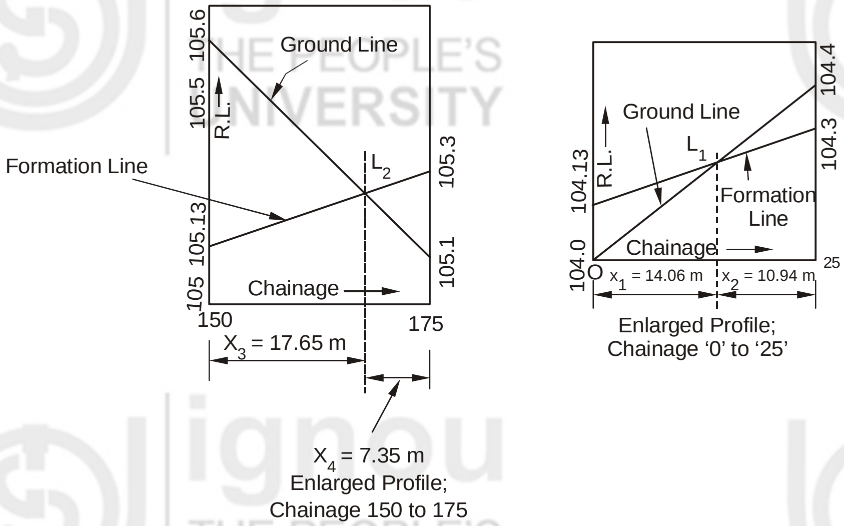


Figure 1.8(b) : Determination of Intersection of Formation and Ground Lines

After the ground profile is drawn, comes the turn of drawing the formation line as per the proposed grade/grades over the various stretches of the alignment. In this particular example it has been arranged to let the line pass through the given obligatory point as shown in the Figure 1.8. RLs of the longitudinal formation line at various chainage points can then be read off from the graph or can be calculated as per the gradient of the line – the latter being a more accurate procedure.

Knowing, by now, the RLs of the ground and the corresponding formation line, one can calculate the required depth of cutting or filling (as the case may be) at various chainage points, and enter the figures appropriately as shown in the Figure. As is observed by inspection, the present formation line intersects the ground profile at two points (L_1 and L_2) – it necessitates determining the chainages of these intersection points (where, obviously, there will neither be cutting nor filling involved) to allow computing earthwork between the intersection point and the adjacent chainage points, respectively, for better accuracy of estimation work. Figure 1.8 also depicts graphical constructions (to enlarged scale) to determine the chainages (RDs, i.e. reduced distances in the terminology of surveying and levelling) of these points, L_1 and L_2 – 14.06 m (0 + 14.06), and 167.65 m (150 + 17.65), respectively. For the sake of still higher accuracy (which, generally, may not be required at all in actual field conditions), however, one can arrive at these figures by calculations as well. Assuming the two triangles (to the right and left of point L_1 in Figure 1.8 – enlarged profiles, to be similar, one can write :

$$\frac{0.13}{x_1} = \frac{0.1}{x_2}, \text{ where } x_1 + x_2 = 25$$

or $$x_2 = \frac{0.1}{0.13} x_1 \text{ ; or } 25 - x_1 = \frac{0.1}{0.13} x_1$$

or $$0.13 \times 25 - 0.13\, x_1 = 0.1\, x_1$$

or $$x_1 = \frac{0.13 \times 25}{0.23} = 14.13 \text{ m } (\approx 14.06 \text{ m})$$

$\therefore \quad x_2 = 25 - 14.13 = 10.87$ m (≈ 10.94 m)

Similarly, with reference to other point, L_2, one can write :

$$\frac{0.47}{x_3} = \frac{0.2}{x_4}, \text{ where } x_3 + x_4 = 25$$

It gives, $x_3 = 17.53$ m (≈ 17.65 m) and $x_4 = 7.47$ m (≈ 7.35 m)

(Moreover, Figure 1.8 shows representative cross-sections – one in cutting and other in filling.)

Armed with the necessary data, one can next proceed to estimate the quantity of earthwork (cutting and embankment, respectively) involved in this road construction as detailed in Table 1.1 – in this Table, it is important to point out, two more chainage points (i.e. RDs), namely, 14.06 m and 167.65 m, that have been added for obvious reasons. [Each h_m is the mean of two values of h, and is entered against the end of the particular stretch.]

Table 1.1 : Calculation of Quantity of Earthwork (Bill of Quantities) – Example 1.3

b = 12.0 m; Side slope in filling, z = 2.5; Side slope in cutting, z = 2.0;

Chainage or Reduced Distance (RD)	Difference of GL and Formation		Mean Value of		Central Area ($b \times h_m$)	Two Side Triangle Areas (zh_m)	Total Cross - sectional Area ($b \times h_m + zh^2_m$)	Distance between Adjacent Chainage Points (l)	Quantity of Earthwork between Two Chainage Points, ($b \times h_m + zh_m^2$)	
	Depth, i.e., Cutting (h)	Height i.e., Filling (h)	Cutting (h_m)	Filling (h_m)					In Cutting	In Filling
(m)	(m)	(m)	(m)	(m)	(m^2)	(m^2)	(m^2)	(m)	(m^2)	(m^2)
0	–	0.13	–	–	–	–	–	–	–	–
14.06	0	0 }	–	0.065	(+) 0.78	(+) 0.010	(+) 0.790	14.06	–	11.10
25	0.10	–	0.05	–	(– 0.60)	(–) 0.005	(–) 0.605	10.94	6.61	–
50	0.09	–	0.095	–	(– 1.14)	(–) 0.018	(–) 1.158	25.00	28.95	–
75	0.17	–	0.13	–	(– 1.56)	(–) 0.033	(–) 1.593	25.00	39.82	–
100	0.30	–	0.235	–	(– 2.82)	(–) 0.110	(–) 2.93	25.00	73.25	–
125	0.84	–	0.57	–	(– 6.84)	(–) 0.649	(–) 7.489	25.00	187.22	–
150	0.47	–	0.655	–	(–7.86)	(–) 0.858	(–) 8.718	25.00	217.95	–
167.65	0	0	0.235	–	(– 2.82)	(–) 0.110	(–) 2.93	17.65	51.71	–
175	–	0.20	–	0.10	(+ 1.2)	(+) 0.025	(+)1.225	7.35	–	9.00
200	–	0.76	–	0.48	(+ 5.76)	(+) 0.576	(+) 6.336	25.00	–	158.40
225	–	0.63	–	0.695	(+ 8.34)	(+) 1.207	(+) 9.547	25.00	–	238.67
250	–	1.11	–	0.87	(+ 10.44)	(+) 1.892	(+)12.332	25.00	–	308.30
275	–	1.28	–	1.195	(+ 14.34)	(+) 3.570	(+)17.91	25.00	–	447.75
300	–	1.16	–	1.22	(+ 14.64)	(+) 3.721	(+)18.361	25.00	–	459.02
325	–	1.43	–	1.295	(+ 15.54)	(+) 4.192	(+)19.732	25.00	–	493.30
350	–	1.01	–	1.22	(+ 14.64)	(+) 3.71	(+)18.35	25.00	–	458.75
								Total	605.51	2584.29

{+indicates quantity in filling, – indicates quantity in cutting}

Assuming suitable rates for earthwork in cutting and filling, say, Rs. A and Rs. B per m³, respectively, one can calculate the cost of total earthwork, as shown below :

Abstract of Estimated Cost of Earthwork for Road

Item No.	Particulars	Quantity	Unit	Rate (Rs.)	Per	Amount (Rs.)
1	Earthwork in Cutting	605.51	m^3	A	m^3	(605.51) A
2	Earthwork in Filling	2584.29	m^3	B	m^3	(2584.29) B
						Total = [6.05.51 A + 2584.29 B]
						= C (say)
						Add 3% of contingencies $\left(= \frac{3}{100} \times C\right)$ = D (say)
						Add 2% of Work-charged Establishment $\left(= \frac{2}{100} \times C\right)$ = E (say)
						Grand Total = (C + D + E)

Cost of Turfing of Side Slopes of the Road

Table 1.2 gives the necessary calculations for calculating the area to be turfed :

Table 1.2 : Calculations for Turfing of Side Slopes

[For filling, $\sqrt{z_1^2 + 1} = \sqrt{(2.5)^2 + 1} = 2.692$, for cutting, $\sqrt{z_2^2 + 1} = \sqrt{(2)^2 + 1} = 2.236$]

RD (m)	*Mean Depth or Height, h_m (m)	One Sloped Breadth of Side Slope, $h \times \sqrt{(z_2 + 1)}$, (m)	*Length, l (m)	Area of both Side Slopes, $2l\left[h_m \sqrt{(z_2 + 1)}\right]$ (m^2)
0	–	–	–	–
14.06	(+) 0.065	0.065 × 2.692 = 0.174	14.06	4.89
25	(–) 0.05	0.05 × 2.236 = 0.111	10.94	2.42
50	(–) 0.095	0.212	25.00	10.60
75	(–) 0.13	0.290	25.00	14.50
100	(–) 0.235	0.525	25.00	26.25
125	(–) 0.57	1.274	25.00	63.70
150	(–) 0.655	1.464	25.00	73.2
167.65	(–) 0.235	0.525	17.65	18.53
175	(+) 0.10	0.269	7.35	3.95
200	(+) 0.48	1.292	25.00	64.6
225	(+) 0.695	1.870	25.00	93.5
250	(+) 0.87	2.342	25.00	117.1
275	(+) 1.195	3.216	25.00	160.8
300	(+) 1.22	3.284	25.00	164.2
325	(+) 1.295	3.486	25.00	174.3
350	(+) 1.22	3.284	25.00	164.2

Total = 1156.74 m^2

* [Values taken from Table 1.1.]

Abstract of Estimated Cost of Turfing of Side Slopes

Item No.	Particulars	Quantity	Unit	Rate (Rs.)	Per	Amount (Rs.)
1	Turfing on both side slopes : for cutting and filling	1156.74	m^2	100/– (say)	m^2	1,15,674/–
						Total = 1,15,674/–
						Add 3% as Contingencies = 3470.22
						Add 2% as Workcharged Establishment = 2313.48
						Grand Total = 121458/– (say)

In elaborate (standard) road cross-sections there is provision made for incorporating side drains (to take care of rainwater, or even oozing in hilly areas) – both in cutting as well as filling; in the latter case the drains are positioned on the natural ground beyond the embankments. Earthwork involved in these constructions can easily be computed as per details furnished in the cross-sectional data, etc.

Earthwork estimation in railroad work, and in canals is no different from the procedure outlined above, and can be done easily once the data is given.

1.3 ESTIMATION OF EARTHWORK IN CANALS

A canal along a given terrain can either be in full cutting, full filling (embankment), or in part cutting and filling – similar to the situation that can prevail for a roadway. The basic method of earthwork computation, as mentioned earlier, remains the same as outlined for a given road work.

In all earthworks (road and canal), an experienced engineer aims at achieving on economical depth of cutting (known as balancing depth) such that the quantity of earth cutting practically equals the quantity in embankment at a given location or over a stretch of alignment – this balance can be achieved by a judicious adjustment of alignment, and grade of the bed of the structure which is a difficult task when there are practical constraints to be faced. In practice, the quantity of excavation can exceed the quantity required for embankment – and, the extra (surplus) quantity of earth is used to form *spoil banks* (Figure 1.9). It is, however, obvious that when the excavated earth is less than that required for filling, one has to obtain the balance quantity from the borrow pits [regular-shaped pits dug on *the temporary acquired land*]. In case spoil banks are provided in the design of a canal section (due to particular practical reason(s), the canal is also said to be in balancing depth of cutting if the excavated earth is sufficient to form the required spoil banks. When the canal is in partial cutting (Figure 1.10) in a plain area (in a hilly area the section can be comprising a cutting in the hill slope and a fill on the down hill side – like that of a road section), the banks on the ground look like spoil banks.

A canal section in full embankment can have its bed at ground level, or above the ground land (Figure 1.11), or could be, as a general case, in part cutting and part filling. These situations arise depending upon the relative levels of the ground and the bed of the canal. Near aqueducts (or other cross drainage works) high embankments are necessitated to be constructed – in such cases core walls in the centre of banks are provided both as an antiseepage measures as well as a structural reinforcement (to be estimated separately as per the design approved for the purpose).

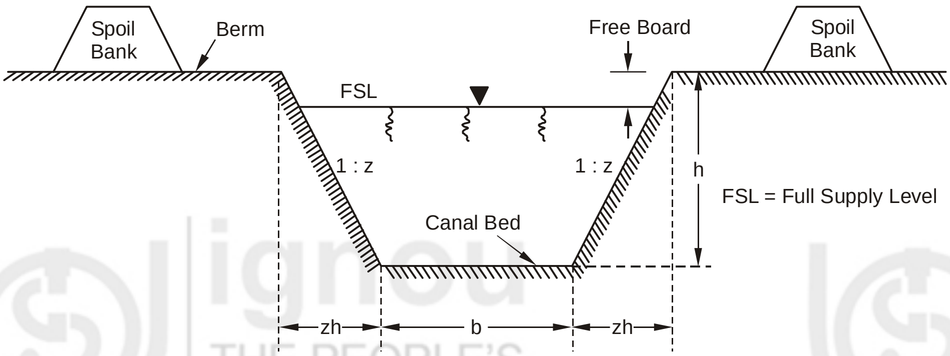


Figure 1.9 : Spoil Banks Along the Flanks of a Canal in Cutting

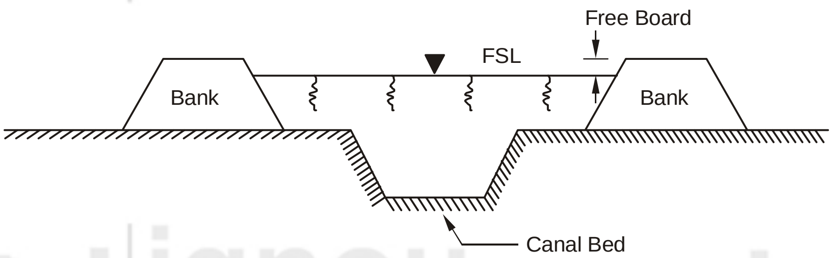
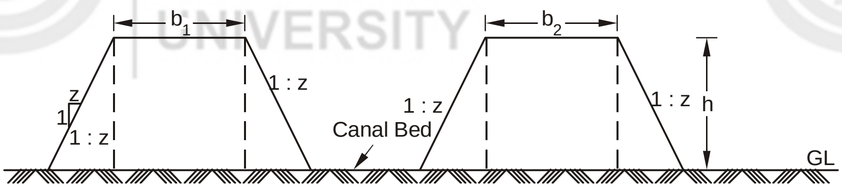
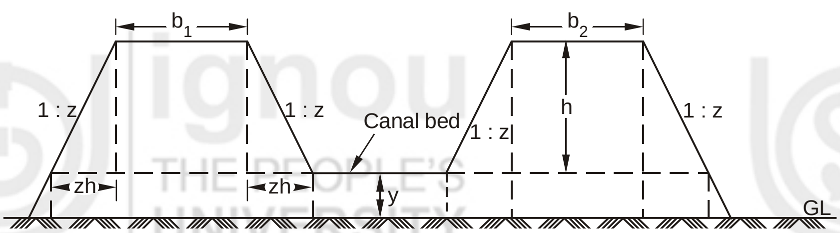


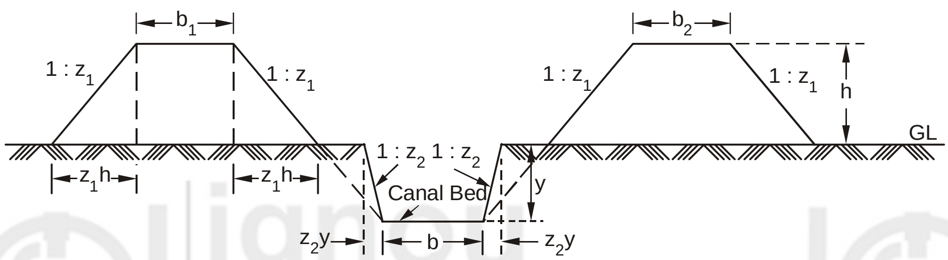
Figure 1.10 : Canal in Partial Cutting in a Plain Area – Spoil Banks Functioning as Water Retaining Banks



(a) Canal Bed at Ground Level (GL)



(b) Bed of Canal above Ground Level (GL) – Full Embankment



(c) Canal (in Plain Area) – Partly in Cutting and Partly in Filling

Figure 1.11 : Canal Bed at Ground Level, Above GL or Below GL

With reference to Figure 1.11(a), when the canal bed is at ground level (GL), the quantity of earthwork (*V*) between two adjacent chainage points (distance, *l*, apart) can be computed as,

$$V = \left[(b_1 \times b_2)\ h + 4 \left(\frac{1}{2} \times zh \times h \right) \right] l$$

or, $$V = [(b_1 \times b_2)\ h + 2z\ h^2]\, l \qquad \ldots (1.7)$$

Similarly, when the canal section is totally in cutting (Figure 1.9), the required quantity, is calculated as

$$V = \left[b \times h + 2 \left(\frac{1}{2}\ zh \times h \right) \right] l$$

or, $$V = [b \times h + z h^2]\ l \qquad \ldots (1.8)$$

For a canal section totally above the GL, we can write for the total filling (Figure 1.11(b)),

$$V = \left[(b_1 + b_2)\ h + 4 \left(\frac{1}{2}\ zh \times h \right) + 2 \left(\frac{1}{2}\ zy \times y \right) + by + \left(b_1 + 2zh + b_2 + 2zh \right) y \right] l$$

$$= [(b_1 + b_2)\ h + 2z \times h^2 + z\,y^2 + by + b_1\,y + 2\ zhy + b_2\,y + 2\,zhy]\ l$$

$$= [(b_1 + b_2)\ h + zh^2 + (zh^2 + 2zhy + zy^2) + (b_1 + b_2 + b + 2\ zh)\ y]\ l$$

or, $$V = [(b_1 + b_2)\ h + zh^2 + z\ (h + y)^2 + (b_1 + b_2 + 2zh + b)\ y]\ l \qquad \ldots (1.9)$$

For a more general case, canal section partly in cutting and partly in filling, as in Figure 1.11(c), one can write :

Volume in cutting,

$$V_C = (by + z_2\ y^2)\ l \qquad \ldots (1.10)$$

and, Volume in filling,

$$V_F = \left[(b_1 + b_2)\ h + 4 \left(\frac{1}{2}\ z_1\ h \times h \right) \right] l$$

$$= [(b_1 + b_2)\ h + 2z_1\ h^2]\ l \qquad \ldots (1.11)$$

It is obvious that while tabulating the results, for a given length of work, the columns of tabulation framework will be provided according to the formula used for the computational purposes.

Example 1.4

With reference to the construction of a distributory (branch of a canal), whose proposed bed slope is 1 in 5000, following survey data was made available for a portion of the work :

Chainage (m)	Ground Level (m)	Proposed Bed Level (m)
0	98.50	100.00
300	98.80	–
600	98.10	–
900	98.20	–
1200	98.40	–
1500	98.40	–
1800	98.10	–

The bed width is to be maintained at 4.5 m with the section being fully in banking. The top width of the side banks is to be kept as 2.25 m, with the side slopes at 1 : 1.5. The full supply depth of water is 1.25 m with a free-board of 0.5 m.

Borrow pits are to be dug on both sides of the distributory leaving a clear distance of 5 m from the toe of the bank, limiting the depth of borrow pits to 30 cm, with width that may exceed 1.5 m. As the lift (to be paid to the contractor) of earthwork increases with the height of the embankment, it is required to workout the quantity of earthwork (filling) in stages of 1.5 m from the GL.

Prepare a bill of quantities, and an abstract of cost of earthwork – rate for each item depends on the required specifications (detailed in contract documents).

Solution

The proposed bed levels and the height of filling from the GL to the bed (at each chainage) are calculated as follows :

Chainage (m)	Ground Level (m)	Proposed Bed Level (Bed Slope = 1 : 5000) (m)	Filling upto Bed Level, *y* (m)
0	98.50	100.00	100 – 98.50 = 1.50
300	98.80	99.94	1.14
600	98.10	99.88	1.78
900	98.20	99.82	1.62
1200	98.40	99.76	1.36
1500	98.40	99.70	1.30
1800	98.10	99.64	1.54

[**Note :** For every 300 m longitudinal distance there is a fall of 0.06 m in the bed level (at the given slope of 1: 5000).]

Figure 1.12 presents the canal cross-section (which is totally in filling) with essential details. Herein *head lead*, distance from the centre-line of a borrow pit to the centre-line of the adjacent bank, is indicated which is a function of y (which in turn varies from chainage to chainage as shown in the above table) – this head lead is to be paid for as a carriage over which the earth is to be carried along the horizontal distance.

Figure 1.12 : Canal Section (with Borrow Pits) – Example 1.4

Using Eq. (1.9), without the multiplier "*l*", one can calculate the sectional areas (filling) at various chainages.

Full Sectional Area (in Filling) at Chainage "o", A_0 (Figure 1.12)

$$= [(2 \times 2.25)\,1.75 + 1.5\,(1.75)^2 + 1.5\,(1.75 + 1.5)^2$$

$$+ (2 \times 2.25 + 2 \times 1.5 \times 1.75 + 4.5) \times 1.5]$$

$$= [(7.875 + 4.593 + 15.843 + (14.25) \times 1.5]$$

$$= 12.468 + 15.843 + 21.375$$

$$= 49.686 \text{ m}^2$$

Area ABCD (i.e. upto line DC –1.5 m above GL – from top line AB) – for full canal cross-section (Figure 1.13),

$$= 2\left[2.25 \times 1.75 + 2 + \left(\frac{1}{2} \times 2.625 \times 1.75\right)\right]$$

$$= 2\,[3.937 + 4.593]$$

$$= 17.06 \text{ m}^2$$

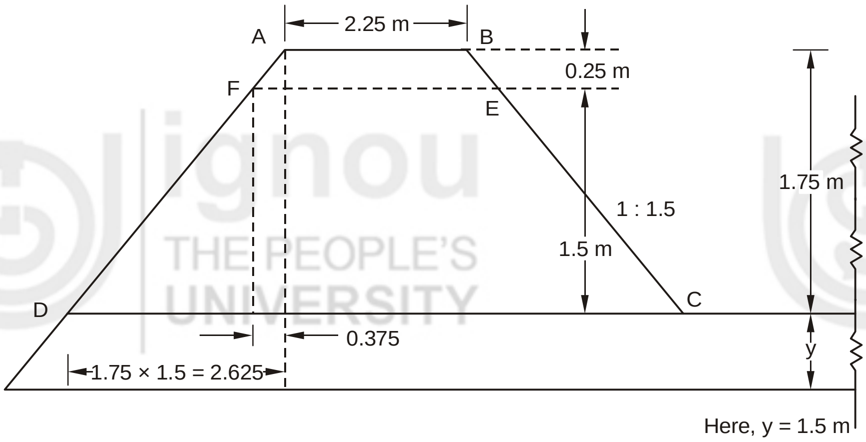


Figure 1.13 : Calculation of Cross-sectional Area of Canal (Filling) at Chainage '0' (Example 1.4)

Similarly, area ABEF (i.e. from top to 3 m above GL (Figure 1.13),

$$= 2\left[2.25 \times 0.25 + 2 + \left(\frac{1}{2} \times 0.375 \times 0.25\right)\right]$$

$$= 2\,[0.562 + 0.093]$$

$$= 1.31 \text{ m}^2$$

Full Sectional Area (Filling) at Chainage "300 m", A_{300} (Figure 1.14)

$$= 12.468 + 1.5\,(1.75 + 1.14)^2 + (14.25)\,1.14$$

$$= 12.468 + 12.528 + 16.245$$

$$= 41.241 \text{ m}^2$$

Area ABCD (top to 1.5 m above GL) – Figure 1.14,

$$= 2\left[2.25 \times 1.39 + 2\left(\frac{1}{2} \times 2.085 \times 1.39\right)\right]$$

$= 2\,[3.127 + 2.898]$

$= 12.05\ m^2$

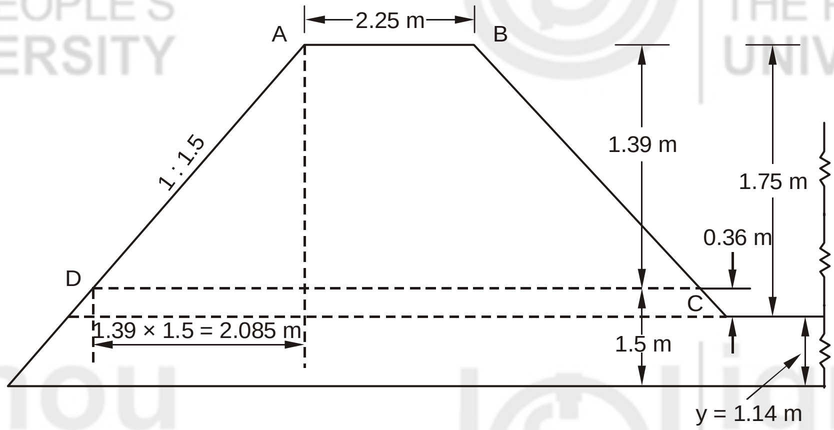


Figure 1.14 : Area Calculations of Chainage '300 m' (Example 1.4)

Full Sectional Area at Chainage '600 m', A_{600} (Figure 1.15)

$$= 12.468 + 1.5\,(1.75 + 1.78)^2 + (14.25) \times 1.78$$

$$= 12.468 + 18.691 + 25.365$$

$$= 56.524\ m^2$$

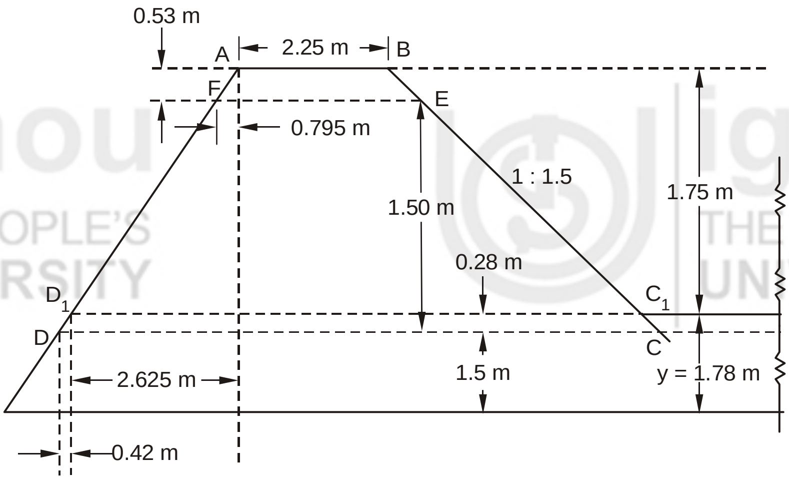


Figure 1.15 : Area Calculations at Chainage '600 m' (Example 1.4)

Area ABCD (from AB upto 1.5 m above GL)

= Area $AB\,C_1\,D_1$ + (Area $D_1\,C_1\,CD$ + Area under canal bed)

$$= 2\left[2.25 \times 1.75 + 2\left(\frac{1}{2} \times 2.625 \times 1.75\right)\right]$$

$$+ \frac{1}{2}\left\{\left[2 \times 2.625 + 2.25 + \frac{4.5}{2}\right]\right.$$

$$\left. + 2\left[2 \times 2.625 + 2.25 + \frac{4.5}{2} + 0.42\right]\right\} \times 0.28$$

$$= 2\,[3.937 + 4.593]$$

$$+ [5.25 + 2.25 + 2.25 + 5.25 + 2.25 + 2.25 + 0.42] \times 0.28$$

$= 17.06 + 5.577$

$= 22.637 \text{ m}^2$

Area ABEF (AB to 3 m above GL)

$$= 2\left\{\frac{1}{2}[2.25 + (0.795 + 2.25 + 0.795)] \times 0.53\right\}$$

$= [6.09] \times 0.53$

$= 3.227 \text{ m}^2$

Full Sectional Area at Chainage '900 m', A_{900} (Figure 1.16)

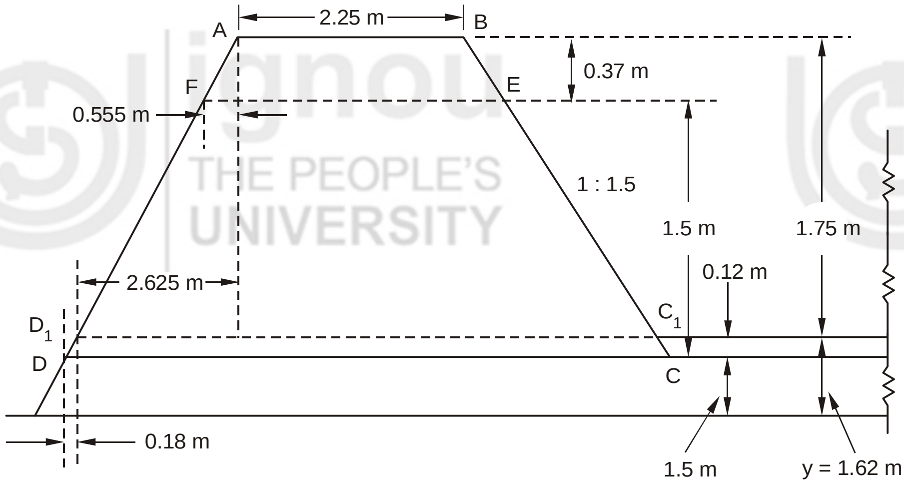


Figure 1.16 : Area Calculations at Chainage '900 m' (Example 1.4)

$= 12.468 + 1.5\,(1.75 + 1.62)^2 + (14.25) \times 1.62$

$= 12.468 + 17.035 + 23.085$

$= 52.588 \text{ m}^2$

Area ABCD (from AB upto 1.5 m above GL)

$$= 17.06 + \frac{1}{2}[19.5 + 2\,(9.75 + 0.18)] \times 0.12$$

$= 17.06 + (2.361)$

$= 19.421 \text{ m}^2$

Area ABEF (AB to 3 m above GL)

$$= 2 \times \frac{1}{2}[2.25 + (0.555 + 2.25 + 0.555)] \times 0.37$$

$= [5.61] \times 0.37$

$= 2.075 \text{ m}^2$

Full Sectional Area at Chainage '1200 m', A_{1200} (Figure 1.17)

$= 12.468 + 14.508 + 19.38$

$= 46.356 \text{ m}^2$

Area ABCD (top to 1.5 m above GL) – Figure 1.17,

$$= 2\left[(2.25 \times 1.61) + 2\left(\frac{1}{2} \times 2.415 \times 1.61\right)\right]$$

$= 2\,[3.622 + 3.888]$

$= 2 \times 7.510$

$= 15.020 \text{ m}^2$

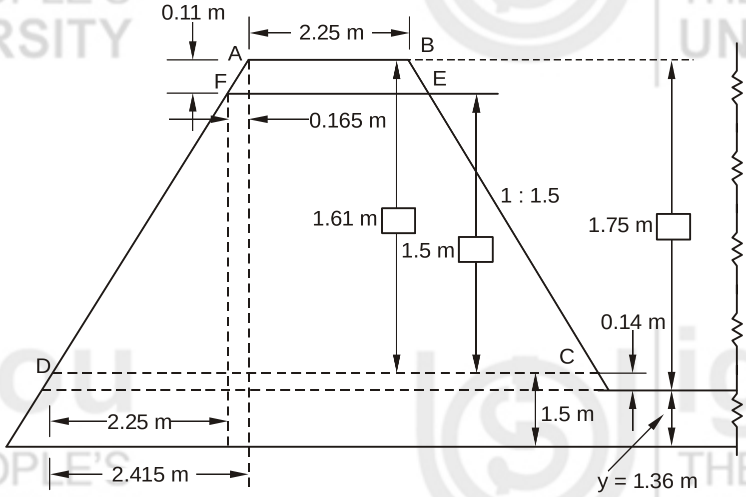


Figure 1.17 : Area Calculations at Chainage '1200 m' (Example 1.4)

Area ABEF (top to 3.00 m above GL)

$$= 2 \times \frac{1}{2} [(2.25) + (2 \times 0.165 + 2.25)] \times 0.11$$

$$= [2.25 + 0.742] \times 0.11$$

$$= 0.329 \text{ m}^2$$

Full Sectional Area at Chainage '1580 m', A_{1500} (Figure 1.18)

$$= 12.468 + 1.5 (1.75 + 1.30)^2 + (14.25) \times 1.3$$

$$= 12.468 + 13.953 + 18.525$$

$$= 44.946 \text{ m}^2$$

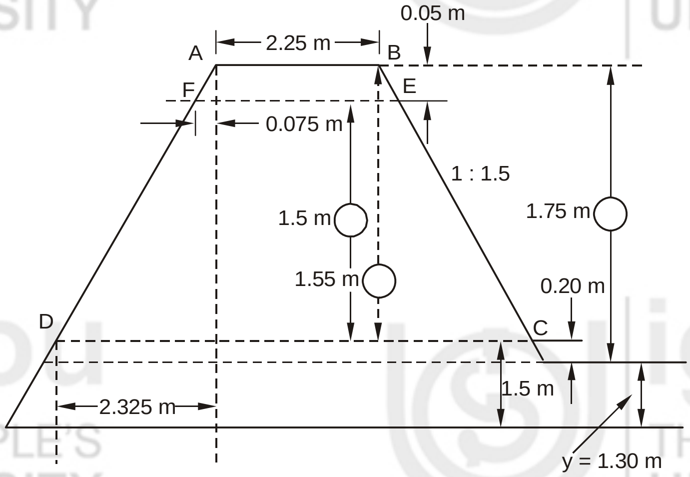


Figure 1.18 : Area Calculations at Chainage '1500 m' (Example 1.4)

Area ABCD (top to 1.5 m above GL) – Figure 1.18

$$= 2 \left[2.25 \times 1.55 + 2 \left(\frac{1}{2} \times 2.325 \times 1.55 \right) \right]$$

$$= 2 \times [3.487 + 3.603]$$

$$= 14.18 \text{ m}^2$$

Area ABEF (top to 3 m above G. L.)

$$= 2\left[\frac{1}{2}\left\{(2.25) + (2 \times 0.075 + 2.25)\right\} \times 0.05\right]$$

$$= 0.232 \text{ m}^2$$

Full Sectional Area at Chainage "1800 m", A_{1800} (Figure 1.19)

$$= 12.468 + 1.5\,(1.75 + 1.54)^2 + (14.25) \times 1.54$$

$$= 12.468 + 16.236 + 21.945$$

$$= 50.649 \text{ m}^2$$

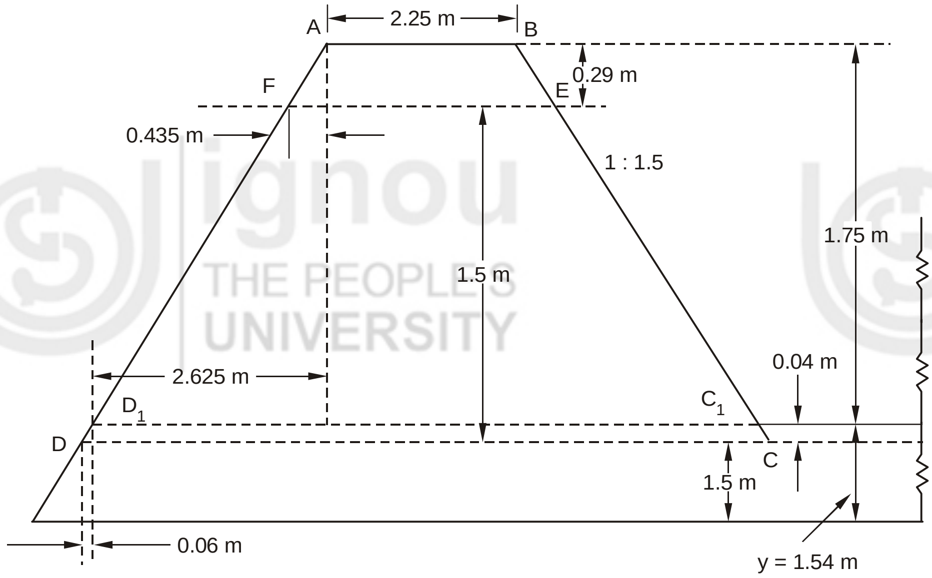


Figure 1.19 : Area Calculations at Chainage '1800 m' (Example 1.4)

Area ABCD (top to 1.5 m above GL),

$$= 17.06 + \frac{1}{2}[(19.5) + 2(9.75 + 0.06)] \times 0.04$$

$$= 17.06 + 0.782$$

$$= 17.84 \text{ m}^2$$

Area ABEF (top to 3.00 m above G.L.)

$$= 2 \times \frac{1}{2}\left[2.25 + (0.435 + 2.25 + 0.435)\right] \times 0.29$$

$$= \left[2.25 + 3.12\right] \times 0.29$$

$$= 1.557 \text{ m}^2$$

Following tables present the computational procedure to compute the work in *stages* of 1.5 m from the ground level (using the information worked out till now) :

Quantity of Earthwork upto 1.5 m above Ground Level

Chainage (m)	Total Area Above GL (m²)	Total Area between Top of Bank to 1.5 m above GL (m²)	Col. (2) – Col. (3)	Mean Area (m²)	Length of Reach = Difference of Chainage (m)	Quantity of Earthwork = Col. (5) × Col. (6) (m³)
1	2	3	4	5	6	7
0	49.686	17.06	32.626	–	–	–
300	41.241	12.05	29.191	30.91	300	9,273
600	56.524	22.637	33.887	31.54	300	9,462
900	52.588	19.421	33.167	33.53	300	10,059

1200	46.356	15.020	31.336	32.25	300	9,675
1500	44.946	14.18	30.766	31.05	300	9,315
1800	50.649	17.842	32.807	31.79	300	9,537
						Total = 57,321 m^3

Quantity of Earthwork between 1.5 to 3 m above Ground Level

Chainage (m)	**Total Area between Top of Bank to 1.5 m above GL (m^2)**	**Total Area between Top of Bank to 3 m above GL (m^2)**	**Col. (2) – Col. (3)**	**Mean Area (m^2)**	**Length of Reach (m)**	**Quantity of Earthwork = Col. (5) × Col. (6) m^3**
1	2	3	4	5	6	7
0	17.06	1.31	15.75	–	–	–
300	12.05	0.00	12.05	13.9	300	4,170
600	22.637	3.227	19.41	15.73	300	4,719
900	19.421	2.075	17.346	18.38	300	5,514
1200	15.020	0.329	14.691	16.02	300	4,806
1500	14.18	0.232	13.948	14.32	300	4,296
1800	17.842	1.557	16.285	15.12	300	4,536
						Total = 28,041 m^3

Quantity of Earthwork between 3 m above GL to Top of Banks

Chainage (m)	**Total Area between Top of Bank to 3 m above GL (m^2)**	**Mean Area (m^2)**	**Length of Reach (m)**	**Quantity of Earthwork = Col. (5) × Col. (6) m^3**
1	2	3	4	5
0	1.31	–	–	–
300	0.00	0.66	300	198
600	3.227	1.61	300	483
900	2.075	2.65	300	795
1200	0.329	1.20	300	360
1500	0.232	0.28	300	84
1800	1.557	0.89	300	267
				Total = 2187 m^3

Borrow Pits

Borrow pits (as per the given design) are made (on both sides of the distributory as given in the problem) which are not to exceed 30 cm in depth. This, therefore, is treated as work of surface excavation, and is paid for in m^2.

It is usual, unless otherwise stated, to assume the cross-sectional area of a borrow pit (that falls on either side of the earthwork) to be equal to half the cross-sectional area of the distributory at a given chainage. Therefore, we have :

Chainage (m)	**Sectional Area (m^2) of a Borrow Pit = (Total Cross-sectional Area of Distributory) / 2**	**Width of Borrow Pit, $x = \frac{\text{Col. (2)}}{\text{Depth of Pit}}$** (m)	**Average Width of Pit** (m)	**Total Surface Area of Pits = Col. (4) ×length** (m^2)
1	2	3	4	5
0	$\frac{49.684}{2} = 24.84$	$\frac{24.84}{0.3} = 82.8$	Average of values in Col. (3) $\frac{569.93}{7} = 81.42$	$2 \times 81.42 \times 1800$ $= 293112$
300	$\frac{41.241}{2} = 20.62$	68.73		
600	$\frac{56.524}{2} = 28.26$	94.2		
900	$\frac{52.588}{2} = 26.29$	87.63		
1200	$\frac{46.356}{2} = 23.18$	77.27		
1500	$\frac{44.946}{2} = 22.47$	74.90		
1800	$\frac{50.649}{2} = 25.32$	84.4		

By now, all the required quantities stand calculated, and the following bill of quantities is made for working out the cost of each item of work and of the total work :

Bill of Quantities of Various Items (Example 1.4)

Item No.	**Particulars**	**Measurements**				**Quantity**	**Remarks**
		No.	**L (m)**	**B (m)**	**H (m)**		
1	Earthwork in borrow pits (here, surface excavation) not exceeding 30 cm in depth (but its width may exceed 1.5 m). Disposal of this excavated material shall be done as per given horizontal distance and upto given maximum lift.	–	–	–		293112 m^2	Here, obviously measurement columns are not to be entered into
					Total	293112 m^2	
2	Earthwork in filling (banking) – to be excavated in layers not exceeding 20 cm depth, breaking clods, watering, rolling as per specifications, and dressing up, with a lead upto 50 m and lift upto 1.5 m (1st stage).	–	–	–		57321	
					Total	57321 m^3	
3	As in Item (2) above, with lift from 1.5 m to 3 m (2nd stage).	–	–	–		28041 m^3	
					Total	28041 m^3	

4	As in Item (2) above, with lift from 3 m to top of the bank (i.e. upto 3.53 m above GL) – (3^{rd} stage).	–	–	–		2187 m^3	
					Total	2187 m^3	

Knowing the rates for different items of work, as per applicable *Schedule of Rates, Abstract of Estimated Cost of Works of* Example 1.4 can be tabulated according to the following Proforma.

Abstract of Estimated Cost of Works of Example 1.4

Item No.	Particulars	Quantity	Unit	Rate	Per	Amount
				Total		
				Add 3% for Contingencies		
				Add 2% for Workcharged Establishment		
				Grand Total (say, to be rounded off)		

[**Note :** It is to be noted that, unlike in road/rail work, canals incorporate falls along their alignment. Therefore, at those chainages, where a fall is positioned, that particular cross-section is to be considered twice – once with the cross-section at the chainage previous to it, and secondly with the one at the following chainage – to compute the earthwork.]

1.4 SPECIFICATIONS OF EARTHWORK IN ROADS, RAIL ROADS, AND CANALS

Fundamentally important principles ever and always govern the earthwork (as any other civil engineering work) wherever it is undertaken with a view to achieve a quality in its workmanship, and its durability. Therefore, these principles (general specifications) are universally applicable. However, in addition to these requirements, sometimes more and finer aspects (in detailed specifications) are covered under special clauses to cater to the excellence of work – hence, it can happen that seemingly these specifications may differ from agency to agency or place to place; but the basic primise being quality and durability.

1.4.1 General Specifications Regarding Earthwork in Road, Rail and Canal

Cutting

All work in cutting (excavation) shall be classified as outlined below :

Rock Cutting (*Blasting Not Resorted to*)

This work shall comprise all rock cutting, which may not be removed by blasting because of the proximity of buildings (or for any other reason), by means of chisels or wedges. However, blasting is resorted to for the removal of rock in masses where blasting is permissible.

Cutting Soft Rock

Soft rock shall include all that material that is rock, but does not need blasting; and it can be removed with the help of *picks, jumper, shovels, and kasis.*

Cutting Hard Soil

This includes, besides hard soil, all kinds of disintegrated rock, shale, indurated (hardened) clay mixed with boulders (not needing blasting), and can be removed by means of picks.

Earth Cutting

This type of work includes all cutting in earth that is capable of being ploughed, no matter whether picks or *phowrahs* are used in the excavation work. Mud, a mixture of soil and water – in a state of fluid–like material or weak solid state – is paid for separately.

In excavation, special care shall be taken ensuring that start and progress of work proceed in a manner that the excavations drain themselves – in order to avoid delays caused by water (oozings or rain water) being trapped.

All the materials obtained (by cuttings/excavations), if suitable for pitching, ballast, or any other purpose, shall be the property of the government. It shall be stacked suitably as per authorized directions, for which the contractor shall be paid extra for the labour involved in stacking, and for the excess lead if any.

For the purposes of determining leads, all distances shall be measured along the shortest practical route which may not necessarily be the actual route taken. Distance of 0.5 km or more shall be taken as 1.0 km, and a distance of less than 0.5 km shall be ignored (with relaxation in this rule under special circumstances). Earth, etc. shall be stacked by leveling the materials in layers.

Any finds such as relics, coins, fossils, etc. shall belong to the government.

Trenches and foundation pits, if necessary, shall be fenced, surrounded with appropriate caution signs, and marked with red lights at night to avert accidents. Excavations shall not be carried out upto a depth that goes below the foundation level of adjacent buildings/structure unless, under authorized directions, underpinning, or shoring, etc. is done (liable to be paid for the contractor).

All cuttings (including for building foundations) shall be measured carefully to the precise dimensions detailed on the drawing. In the case of the bed (bottom) of the cutting having been taken down deeper than necessary by overright or neglect of the contractor, the scooped out hollow has to be filled with hard stuff to achieve *true* depth and shall be rammed at the contractor's expense. No payment shall be made for this cutting that has been made in excess of the designed profile.

No claim for inequalities in the original ground shall be entertained (including for building foundations) unless the same have been measured before the commencement of work.

Excavation that does not require dressing of sides and bottom and going upto (reduction to) exact levels are classified as *rough excavation*. An example of this kind of excavation is best presented while excavating earth from borrow pits (to be used elsewhere).

As is well understood, cuttings as per design vis-à-vis a given work, shall be done from top to bottom – in no case shall under-cutting or under-mining be allowed to be indulged in. The sides of all excavations shall be dressed up or trimmed, and the bed (bottom) shall be levelled (or graded if required) as per the intended design.

In the case of hard rock, that requires blasting to be resorted to, the cutting depth (for the sake of measurement) shall be measured upto the actual levels if it was an unavoidable outcome of the operation.

Excavation over an area (*in soft or hard soil*) shall consist of excavation for basements, water tanks, septic tanks, etc.; excavation in foundation trenches that are more than 1.5 m in width or/and 10 m^2 in plan; and also those excavations that are more than 1.5 m in breadth (width) or/and 10 m^2 in plan and exceeding 30 cm in depth. If these items of earthwork in cutting in firm soils, the sides of the trench shall be cut vertical upto a depth of 2 m from the bottom. In case of greater depth, it is important to widen the trench by providing steps of 50 cm on either side after every 2 m from the bottom, or allow side slopes of 1 : 4. For soft, loose or slushy soils either the width of the steps shall be increased suitably or sides given appropriate slope or the soil is shored up. The bed of the excavation (after the designed profile is achieved) shall be consolidated by watering and ramming. Soft/defective areas/spots shall be dug out and filled with levelling concrete.

All excavated earth, it is to be ensured, shall not be dumped within 1 m of the edges of trenches, and shall be disposed off as per the agreement between the contractor and the executing agency.

If different rates of payment are to be paid to the contractor according to the different classes of earth to be excavated, it is customary not to execute any work except, at first, the work to be paid at the lowest rate till the whole quantity at this rate has been billed – however, exceptions can be made by the authorized officer according to difficult/hard field conditions. The same procedure shall be followed for each succeeding higher rates as per varying classification.

The rate of payment for excavation/cutting must include lead and lift, as well as dressing the bed and sides of the cutting. Spoil from a given cutting shall be carried into the adjoining embankment (if any) upto the usual lead distance.

Filling

Before any earthwork (including cutting) is commenced, the entire area (falling under the designed profile) shall be cleared of shrubs, grass, etc. and trees and saplings; and the rubbish shall be removed upto distance falling beyond the boundary of the area under clearance. The roots of the trees shall be extracted from upto a minimum of 60 cm below the ground level or a minimum of 30 cm below the formation level, whichever is lower – all the hollows shall be filled up with earth, levelled and rammed. In case Archaeological monuments fall within the area (or adjacent to it), necessary fencing around these be provided as a measure of protection.

Masonry pillars shall be erected at appropriate points in the area to delineate the earthwork area, as well as serve as benchmarks. Necessary earthwork profiles shall be set up with the help of bamboo posts, pegs and strings – or "*burjis*" shall be erected to indicate the required formation levels. All this arrangement shall be maintained during the execution of the work.

Ground levels shall be taken at adequately close intervals to also incorporate local pits, mounds, and undulations.

Earth from cutting (if of required quality) shall be directly used for filling, and no claim for double handling of earth shall be accepted. *Filling shall be done in regular horizontal layers – each layer not to exceed 20 cm in height.* All this earth has to be free from grass, rubbish, roots; and lumps and clods exceeding 8 cm in any dimension have to be broken down. Each layer that is laid shall be consolidated by ramming (and for certain works water is to be used in this process). The surface of the finished filling work (embankment) shall be neatly dressed. Finished formation levels shall be built upto higher than the designed levels (say, by an allowance of 10% of the total depth of filling) to allow future settlement for ordinary consolidated fills. This allowance could be reduced to only 5% for fills consolidated by heavy mechanical machinery. However, for works consolidated by heavy mechanical machinery with *optimum moisture content* being maintained, no such settlement allowance shall be made.

Rates for making payments shall cover cost of lead upto, say, 300 m; and a lift of 1.5 m from the borrow pits. It is usual to use borrow pits for measuring the quantity (m^3) of earthwork used in filling; and no measurements of finished work are used for payments. That is why *sakhis* (i.e. *dead man/tell tale/matams*) – earth pillars are left out to help take accurate measurements of earthwork dug out for the intended embankment – these are removed after measurements are made; and the spoil is used up in the embankment. It is understood that any excess quantity (i.e. greater than given by the profile of the embankment) shall be excluded from the borrow pit-based quantity.

In exceptional cases, where the basis of measurement has been agreed upon to be based on the actual embankment profile, all measurements shall only be taken after the bank has fully settled.

Wherever feasible, in case of high banks, continuous longitudinal earth bunds (of appropriate dimensions) shall be made on the outer edges of the top of the bank, and also cross bunds (at designed intervals) to impound rain water (if any) in order to expedite the consolidation of the embankment – it will entail extra payment of the contractor, at ordinary earthwork rates.

Lead for purposes of payment shall be measured from the centre line of bank at right angles to itself. In situations where borrow pits may not be situated opposite to embankments (where their spoil is intended to go in), lead shall be measured from the centre of gravity of the fill to the centre of gravity of the borrow pits.

Filling in approaches to bridges, in the backing of abutments and in spandrils and haunches, shall proceed evenly with the masonry.

Earthwork Measurements : General Considerations

For every earthwork, length, breadth and depth shall be measured upto the nearest cm if measurements are taken by tape. In the case of measurements being taken by means of staff and level, the reading shall be noted correct to

5 mm depth of cutting, and height of filling also correct to 5 mm – the cubical measure (contents) shall be worked out to the nearest two places of decimal of a cubic metre.

For excavations in trenches (or from borrow pits), that lie in a fairly uniform ground, the measurement of cutting shall be made as usual. In borrow pits, *diagonal ridges, cross ridges*, or dead-man (positions fixed by the competent authority) shall be left for measurements after the completion of the work. Deductions for such ridges and deadmen are to be made appropriately to arrive at the correct quantities. However, no such deductions are made if these are meant to be removed later on for the use of this earth in the work profile itself.

When ordinary soil and hard rock are mixed in nature, the different kinds of rock shall be stacked separately to be measured up – the net quantity of each type shall be given by the measured loose quantity after applying appropriate loosening factor (when in stacked form compared to the unloosened volume).

In case the ground is not uniform, levels shall be taken before the start of excavation work, after due site clearance, as well as after the completion of work – and the quantity shall be worked out accordingly. For filling as well this principle will apply equally.

Lift shall be measured from the ground level. Excavation upto 1.5 m depth below the ground level and depositing the excavated material on the ground shall comprise this lift. However, extra lift shall be measured in units of 1.5 m or part thereof (unless otherwise specified). While the ground slopes in one direction, the inherent lift in the lead shall be accounted for wherever appropriate.

1.5 COMPUTATION OF EARTHWORK IN BUILDING FOUNDATION TRENCHES

Excavations of a foundation trench of a building, having walls of different thicknesses (widths), gives rise to trenches of different breadths, and sometimes even of different depths. Necessary drawings – plan and sections at appropriate locations – coupled with clear, lucid imagination, enable a civil engineer to estimate the various items of a building, including earthwork in an excavation of foundations. The very first step, in order to get introduced into these seemingly intricate mensurational procedures, is to comprehend the drawings of a straight compound wall (Figure 1.20) – the simplest case of a trench excavation. It is always useful for all, especially a beginner, to draw a trench plan as per the given section (as well as the given plan at plinth level, which is generally provided for use); and, here Figure 1.21 details out such a plan for the given compound wall which is, say, 6.5 m long – it also helps, as will be appreciated later on as one progresses through the following Unit, in computing the quantities of various other items of the structure. In this example, the trench is a straight cut into the ground (assuming the wall does not enclose any other side of the compound) which is uniformly 1.0 m in width – the dimension of the widest item laid underground, namely, lime concrete. An inspection of Figure 1.20 shows that the total depth of the excavated trench adds upto :

50 cm of plinth course (below the ground level) + (3 × 20) cm of the three courses of brickwork done in three steps + 30 cm of lime concrete (LC) = 140 m, a depth that is more than the usual depth of foundation for a brick wall because of local soil conditions.

Therefore, earthwork in excavation in foundation of the wall

= Length (*L*) × Breadth (*B*) × Height (*H*) / or Depth (*D*)

$= 6.50 \times 1.0 \times 1.40 = 9.1\ m^3$

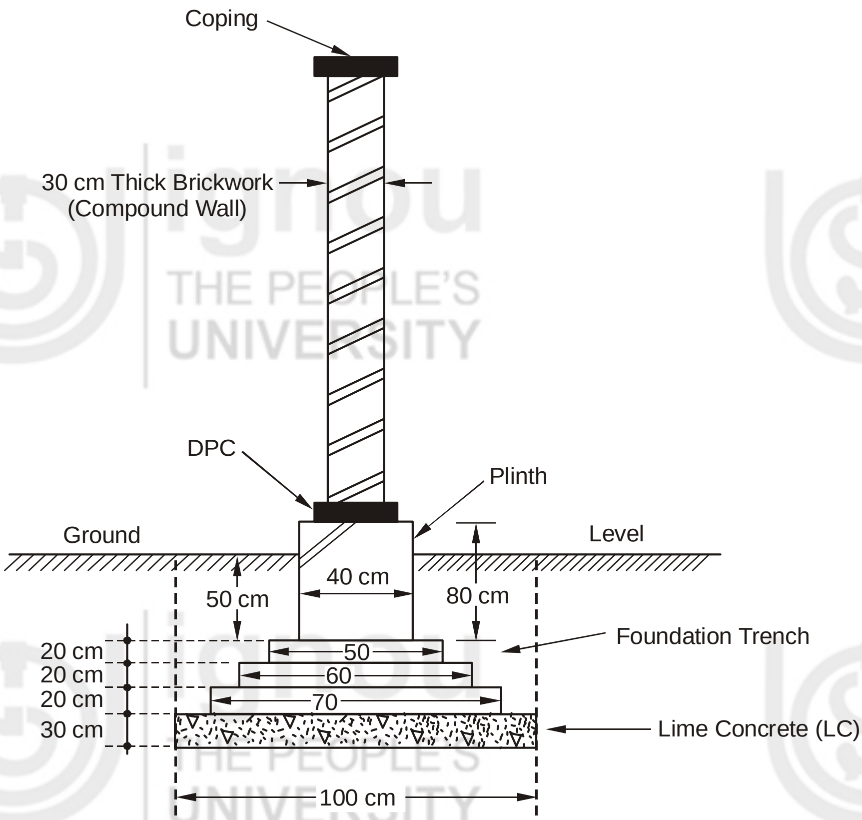


Figure 1.20 : Section of a Straight Compound Wall in a Brickwork

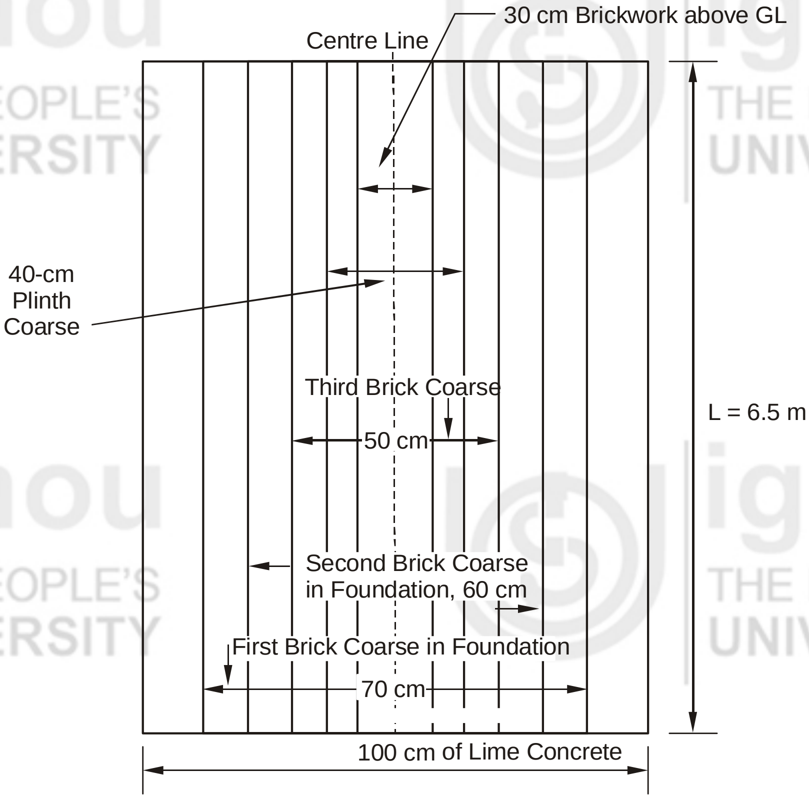


Figure 1.21 : Plan of the Foundation Trench for a Straight Compound Wall (Figure 1.20)

Considering a foundation trench for a wall enclosing a rectangular area as shown in Figure 1.22 – with uniform trench width and depth all around – one can discuss two methods of calculating earthwork in excavation, viz, ***Centre-line method***, and ***Long-wall and Short-wall method***.

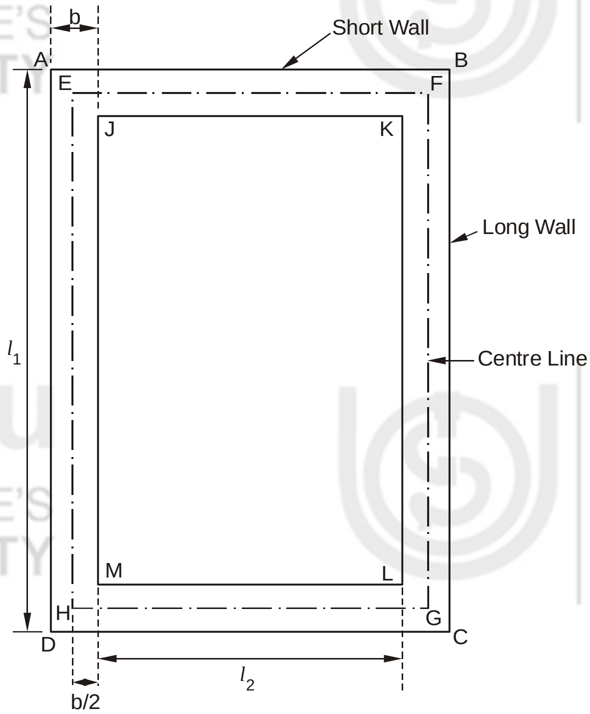


Figure 1.22 : Centre-line, Long and Short Wall, Method of Computing Earthwork

Centre-line Method

Dashed line EFGH (Figure 1.22) is the centre-line of the trench, dividing the width (b) of the trench into two equal halves. The total length of the centre-line

$$= EF + FG + GH + HE$$

$$= 2\,(EF) + 2\,(FG)$$

$$= 2\,(FG + EF)$$

$$= 2\left[\left(l_1 - 2 \times \frac{b}{2}\right) + \left(l_2 + 2 \times \frac{b}{2}\right)\right]$$

$$= 2\left(l_1 + l_2\right)$$

Taking the uniform depth of cutting all around as h, and width as b (as shown in this Figure), and total Volume of excavation $= [2\,(l_1 + l_2) \times b \times h]$. In cases where the width (b) of the trench is not uniform, even though the depth (h) is uniform, this method of Volume computation is not applicable.

Long-wall and Short-wall Method

In this Figure there are two long walls (BC and AD), and two short walls (JK and ML) whose widths are same (b), and depths same (h). Volume of excavation (V) can be worked out as given below :

Excavation in two long walls $= 2\,[l_1 \times b \times h]$

and, Excavation in two short walls $= 2\,[l_2 \times b \times h]$

$$\therefore \quad V = 2\,[l_1\, b\, h + l_2\, b\, h]$$

$$= [2\,(l_1 + l_2) \times b \times h],$$

which is the same as worked out by centre-line method.

In building plans where trench widths vary from trench to trench, use of long-wall and short-wall method for same width and depth items is used for easy and quick computations. It is obvious, as will be clear from solved examples given later on, that some other items of construction in foundation, or even above GL, are amenable to computations by either centre-line or long- and short-wall method – such as line concrete, brick work in foundation, DPC, superstructure.

Example 1.5

Calculate earthwork in excavation (in foundations), and filling under the floor and foundation trenches (i.e. refilling after the masonry has been done) for a Mazdoor Shed (Figure 1.23). Tabulate the results in the form of a bill of quantities.

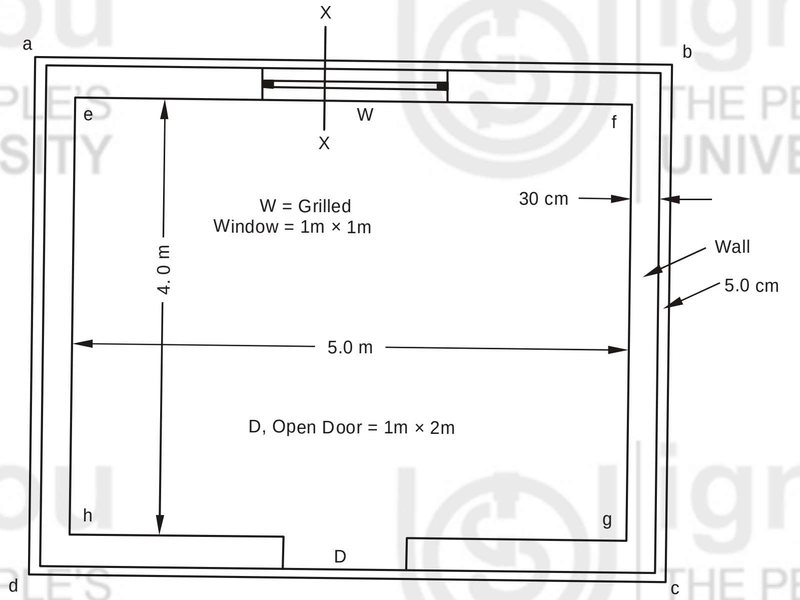


Figure 1.23(a) : Plane Above Plinth Level (at Window Level)

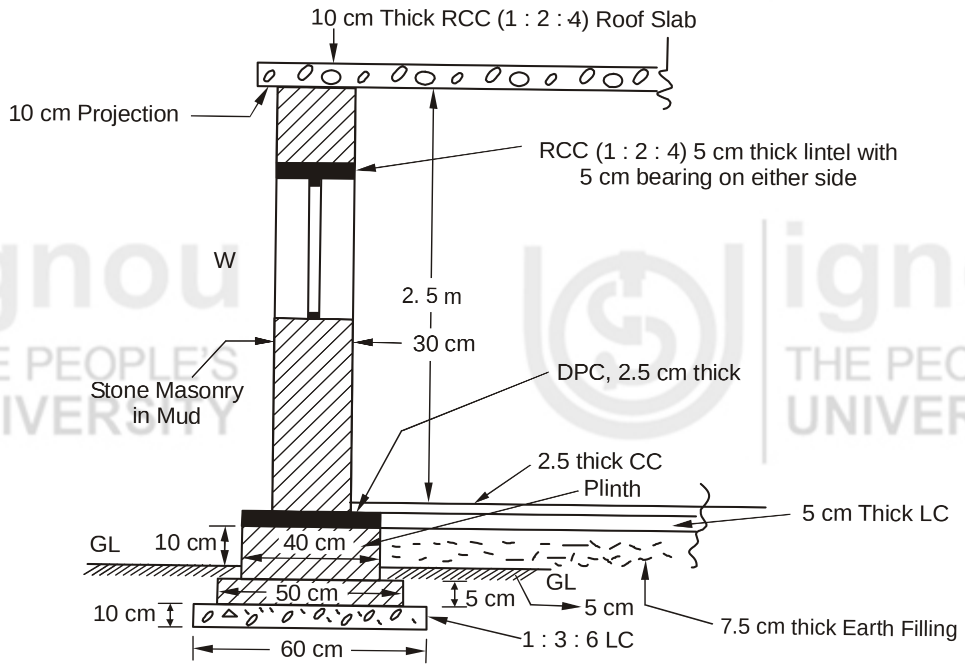
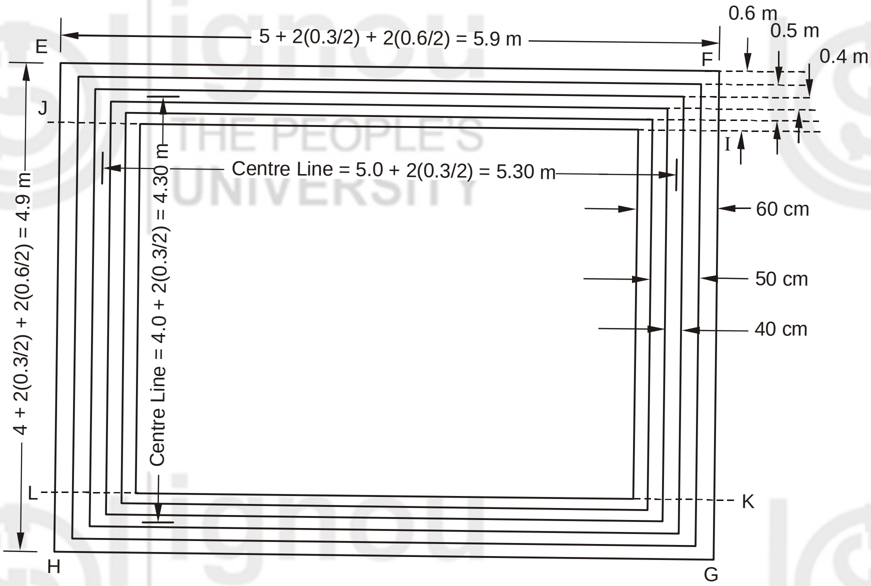


Figure 1.23(b) : Section at X-X



(c) Trench Plan

Figure 1.23 : Plan, Section and Trench Plan of a Shed for Mazdoors (Example 1.5)

Use centre-line and Long- and Short-wall methods for computations – i.e. solve by these two different modes of calculations.

Solution

Centre-line Method for Foundation Trenches

Referring to Figure 1.23(c), total length of the centre-line of trenches

$$= (2 \times 5.3) + (2 \times 4.3) = 19.20 \text{ m}$$

Depth of trenches = 5 cm + 5 cm + 10 cm = 20 cm = 0.20 m

Width of trenches = 60 cm = 0.60 m

Long- and Short-wall Method

There are two long walls and two short walls – Figure 1.23(a) – *ab* and *cd*; and *eh* and *fg*, respectively. Considering the corresponding trench plan (Figure 1.23(c)), their length can be worked as follows. Long walls namely, EFIJ and GHLK, each has a length that is the sum of the following elements :

(Internal length of the shed) + (Half the width of the wall on both sides) + (Half the width of the trench – i.e. width of L. C. course – on both sides)

$$= 5.0 + 2\left(\frac{0.3}{2}\right) + 2\left(\frac{0.6}{2}\right) = \mathbf{5 + 0.3 + 0.6} = 5.9 \text{ m}$$

It is important to point out that the addition of second term brings the length dimension to the centre line of the trench; and the addition of third term takes the trench length upto its full measure (EF).

Similarly, short walls (two in number, here – IK and JH) have each of a length of :

$$= 4 + 2\left(\frac{0.3}{2}\right) - 2\left(\frac{0.6}{2}\right) = \mathbf{4 + 0.3 - 0.6} = 3.7 \text{ m}$$

Depth and width of the trenches remain the same as for centre-line method.

Earthwork in filling under the floor is given to be 7.5 cm thick (Figure 1.23(b)). It is observed that this filling has following dimensions in plan :

Length = 5.0 – 2 (one offset between the width of plinth and width of wall)

$$= 5.0 \text{ m} - 2\left[\frac{1}{2}(40 \text{ cm} - 30 \text{ cm})\right]$$

$$= 5.0 - [0.40 - 0.30]$$

$$= 5.0 - 0.1$$

$$= 4.9 \text{ m}$$

and, Breadth = 4.0 – 0.1 = 3.9 m

With these dimensions in hand, one is ready to prepare a bill of quantities as follows :

Bill of Quantities – Earthwork (Example 1.5)

Item No.	Particulars	No.	Dimensions/Measurements L (m)	B (m)	H (or D) (m)	Quantity (m^3)
1	Earthwork in excavation (by centre line method)	1	19.2	0.60	0.2	2.30
	(By Long Wall and Short Wall) Earth work in excavation : (a) Long Wall (b) Short Wall	 2 2	 5.9 3.7	 0.60 0.60	 0.2 0.2	 1.42 0.88
						Total = 2.30 m^3
2	Earthwork in filling (a) Earthwork in filling under the floor	1	4.9	3.9	0.075	1.43
	(b) Earthwork in filling in foundations	Item (1) – [Item (3) + Item (4)] = x (say)				
						Total = 1.43 + x
3	Lime concrete (LC), 1 : 3 : 6, in foundations	Can be calculated as shown in Unit 2				
4	Stone masonry in mud, below ground level (i.e. in foundations)	Can be calculated as shown in Unit 3				

SAQ 1

(a) A road has been aligned along a given direction; the relevant survey data, and also the proposed formation levels are tabulated as under :

Distance (Chainage)	0 m	30 m	60 m	90 m	130 m	150 m	180 m
NSL (Natural Surface Level)	111.87 m	111.87 m	115.62 m	114.50 m	116.31 m	113.90 m	115.20 m
Proposed Formation Level	111.87 m	111.87 m	111.97 m	112.07 m	112.203 m	112.203 m	112.203 m

Take the proposed road cross-section as trapezoidal with side slopes of 1 : 1, and the formation width equal to 7.50 m.

Compute the earthwork in cutting/filling as the case may be.

(b) Reduced levels (RLs) of natural ground along the centre-line of a proposed road from chainage 0 to 200 m are given below. The formation level at the 40 m chainage is 102.75. The formation of road from chainage 0 to 80 m has a rising gradient of 1 in 40. The formation level has a falling slope of 1 in 100 from chainage 100 to 200 m.

The formation width of the road at top is 12.0 m and the side slopes of banking are 2 : 1.

Prepare a estimate of the earthwork in the road at the rate of Rs. 5 per m^3. Also, find the area of the side slopes, and the cost of turfing on the side slopes @ Rs. 100 per % m^2.

Also, work out the quantities of materials required for 1.5 km long road if

Metalled width of road = 10.0 m

Thickness of brick soling = 7.5 m

Chainage (m)	0	20	40	60	80	100	120	140	160	180	200
RL Ground (m)	101.50	100.90	101.50	102.0	102.85	101.65	101.95	100.70	101.25	99.90	100.60
Given RL of Formation			102.75								
Gradient	← Rising 1 in 40 →					← Falling 1 in 100 →					

Water Bound Wearing coat of stone metal = 12 cm loose which is to be consolidated to 8 cm thickness.

If the road is to be painted (Bitumen) two coats, find the materials required for the following specifications:

First coat painting = 12. 5 mm nominal size stone grit @ 1.5 m^3 per % m^2 of road surface; and Bitumen @ 1.8 kg/m^2.

Second coat painting = 10.00 mm nominal size stone grit @ 1.10 m^3 per % m^2 road surface; and Bitumen @ 1.1 kg/m^2.

Note : Calculate the EW if the last ground RL is 103.10 m.

(c) RLs of ground along the centre-line of a proposed road, from chainage 10 to chainage 20 are given as under :

Chainage	10	11	12	13	14	15	16	17	18	19	20
RL of Ground (m) (NSL)	105.0	105.6	105.44	105.90	105.42	104.3	105.0	104.1	104.62	104.0	103.3

Formation level at the 10^{th} chainage point is 107.0 m; and the road is in a downward gradient of 1 in 150, upto the chainage point 14, and then the gradient changes to 1 in 100 (downwards). Formation width of the road is 10 m, and side slopes of the banking are 2 : 1 (H : V). Take the length of each chain 30.0 m.

Prepare a estimate of the earthwork at the rate 70/– per % m^3.

Find also the cost of turfing the side slopes at the rate of 20/– per % m^2.

(d) A road in cutting has formation width of 4.0 m; side slope, s = 2; distance between two chainage points = 300 m; h_1 = 1.5 m; and h_2 = 1.1 m. Using the trapezoidal formula, compute the volume of earthwork in cutting.

1.6 SUMMARY

Earthwork is road/rail/canal – both as cutting and banking (filling) – is very often being encountered by a practicing civil engineer. Also, earthwork in the foundation trenches of buildings, as well as filling upto just below the floor level forms the very first item in the estimate of quantities. The whole process of computation demands mensurational skills and practice.

Every earthwork, as much as any other item of work, has to follow general/specific specifications to bring the work to the desired standards.

1.7 ANSWERS TO SAQs

SAQ 1

(a)

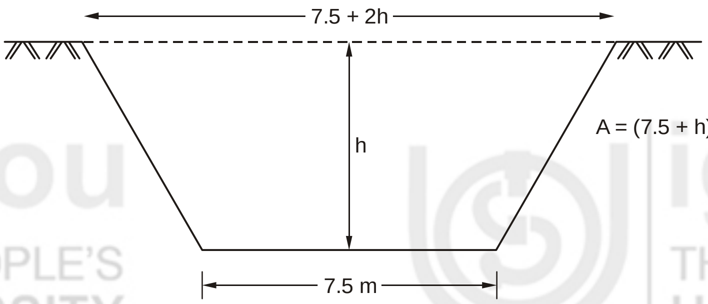


Figure 1.24

Chainage (m)	0	30	60	90	130	150	180
Filling (m)	–	–	–	–	–	–	–
Cutting (m)	–	–	3.65	2.43	4.107	1.697	2.997
Area (m^2)	–	–	40.70	24.13	47.67	15.64	31.50
Mean Area (m^2)between Chainage Points	–	20.35	32.42	35.90	31.66	23.57	–
Volume of EW in Cutting (m^3)	–	20.35 × 30 = 610.50	32.42 × 30 = 972.6	35.90 × 40 = 1436	31.66 × 20 = 633.20	23.57 × 30 = 707.10	–

Total E. W. in Cutting = **4359.40 m^3.**

(b) Given the formation gradients and the formation RL at chainage 40 m, we can compute and tabulate the other RLs of the formation.

Chainage (m)	0	20	40	60	80	100
Formation RL (m)	101.75	102.25	**102.75**	103.25	103.75	103.55
Chainage (m)	120	140	160	180	200	
Formation RL	103.35	103.15	102.95	102.75	102.55	

(m)							

Earthwork Computations

Formation width, $b = 12.0$ m; $1 : s \Rightarrow 1 : 2$, i.e., $s = 2$

Station (or Chainage) (m)	**Ht/Depth, *h* (m)**	**Mean, *h* (m)**	**Central Area, $b \times h$ (m^2)**	**Side Area, $s\,h^2$ (m^2)**	**Total Area, $A = b \times h + s\,h^2$ (m^2)**	**Distance between Two Areas, *l* (m)**	**Quantity, $A \times l$ (m^3)**	
							+	–
0	0.25	–	–	–	–	–	–	–
20	1.35	0.80	9.60	1.28	10.88	20	217.60	–
40	1.25	1.30	15.60	3.38	18.98	20	379.60	–
60	1.25	1.25	15.00	3.13	18.13	20	362.60	–
80	0.90	1.08	12.96	2.33	15.29	20	305.80	–
100	1.90	1.40	16.80	3.92	20.72	20	414.40	–
120	1.40	1.65	19.80	5.45	25.25	20	505.00	–
140	2.45	1.93	23.16	7.45	30.61	20	612.20	–
160	1.70	2.08	24.96	8.65	33.61	20	672.20	–
180	2.85	2.28	27.36	10.40	37.76	20	755.20	–
200	1.95	2.40	28.80	11.52	40.32	20	806.40	–
						Total	5031.00 m^3	NIL

If the last ground RL is 103.10 m then the depth of cutting at chainage 200 m is equal to 103.10 – 102.55, i.e. 0.55 m.

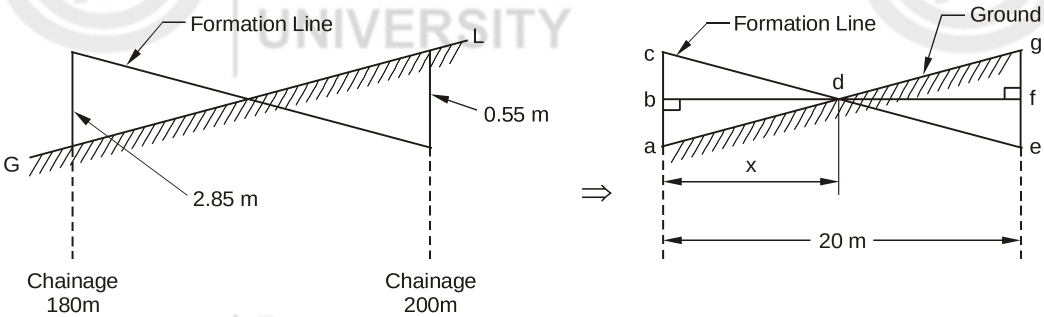


Figure 1.25

$$\frac{ac}{x} = \frac{eg}{20 - x}$$

or $$\frac{ac}{eg} = \frac{x}{20 - x}$$

$$\frac{2.85}{0.55} = \frac{x}{20 - x}$$

or $$5.182 = \frac{x}{20 - x}$$

or, $$103.64 - 5.182\,x = x$$

or $$6.182\,x = 103.64$$

∴ $x = 16.76$ m

Now, the calculations after chainage 180 m are given as shown below :

Chainage	h	Mean, h	$b \times h$	$s\,h^2$	A	l	Quantity	
							+	–
180	2.85	2.28	27.36	10.40	37.76	20	755.20	–
180 + 16.76 = 196.76	0	1.43	12 × 1.43 = 17.16	$2 \times (1.43)^2$ = 4.09	21.25	16.76	356.15	–
200	– 0.55	– 0.28	– [12 × (0.28)] = – 3.36	$-[2 \times (0.28)^2]$ = – 0.16	– (3.52)	3.24	–	11.40
						Total	~4581.0	11.40

Abstract of Cost of EW

Item	Particulars of Item	Quantity	Unit	Rate	Per	Amount
1	EW in embankment	5031	m^3	5	m^3	25,155/– = 25,000/– (say)
						Total = 25000/–
						Add 3% contingency = 750/–
						Add 3% workcharge establishment = 500/–
						Grand Total = 26,250/–

[**Note :** One can include cutting (11.40 m^3) and at an appropriate rate, calculate its cost as well.]

Calculations of Areas of Side Slopes for Turfing

Stn (m)	h (m)	Mean, h_m (m)	Sloping Length of the Side = h_m [$\sqrt{(s^2+1)}$], (m)	Length, l (m)	Area of Both Side Slopes = $2\,l \times h_m \sqrt{(s^2+1)}$, ($m^2$)
0	–	–	–	–	–
20	← As computed earlier →	← As computed earlier →	1.79	← As given earlier, i.e., 20.0 m →	71.60
40			2.91		116.40
60			2.80		112.00
80			2.41		96.40
100			3.13		125.20
120			3.69		147.60
140			4.32		172.80
160			4.65		186.00
180			5.10		204.00

200			5.37		214.8
					Total = 1446.80 m^2

Abstract of Estimated Cost of Turfing

Item No.	Particulars of Item	Quantity	Unit	Rate	Per	Amount
1	Turfing on both the side slopes of embankment	1446.8	m^2	100/–	% m^2	1446.8
						Total = 1446.8
						Add 3% contingency = 43.40
						Add 3% workcharge establishment = 28.94
						Grand Total = 1519/– (say)

Other Items of Road Work

(i) Quantity of brick soling

$$= (1.5 \times 1000) \times 10 \times 0.075 = 1125 \text{ m}^3$$

(ii) Quantity of stone ballast (WB wearing coat)

$$= (1.5 \times 1000) \times 10 \times 0.12 = 1800.00 \text{ m}^3$$

(iii) First coat painting : 12.5 mm nominal size stone grit

$$= 1500 \times 10 \times \frac{1.5}{100} = 225.0 \text{ m}^3$$

(iv) Second coat painting : 10.00 mm nominal size stone grit

$$= 1500 \times 10 \times \frac{1.1}{100} = 165.0 \text{ m}^3$$

(v) Quantity of Bitumen = 1500 × 10 × (1.8 + 1.1)

= 43500 kg = 43.50 tonne

(c) 3,574.5 m^2 of banking; and 648.9 m^2 of turfing.

(d) 2582.0 m^3