UNIT 1 ESTIMATION OF EARTHWORK

Structure

1.1 Introduction

Objectives

1.2 Estimation of Earthwork in Road and Railway Track

1.2.1 Calculating Cross-sectional Areas of Road Formations

1.2.2 Computing Volumetric Quantities of Earthwork along a Road Alignment

1.3 Estimation of Earthwork in Canals

1.4 Specifications of Earthwork in Roads, Rail Roads and Canals

1.5 Computation of Earthwork in Building Foundation Trenches

1.6 Summary

1.7 Answers to SAQs

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

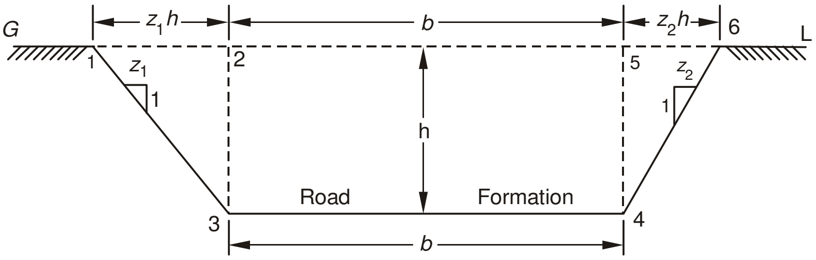
The basics of any computational methodology that may be adopted in the mensurational procedure, vis-à-vis, road/rail consist of calculating the average cross-sectional areas of filling/cutting, from point to point, along the given alignment, and then multiplying by the distances between any two consecutive 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)

$= (b \times h) + \frac{1}{2}\ (z_1h)h + \frac{1}{2}\ (z_2h)h$

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

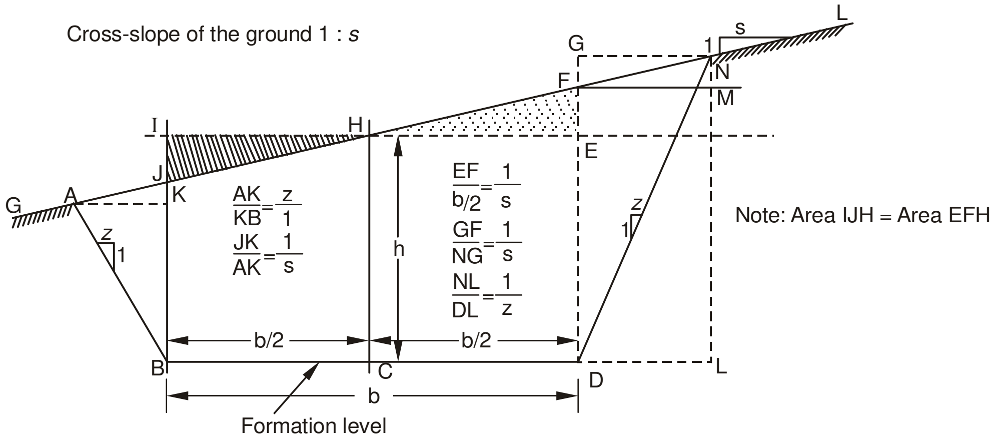
Figure 1.1 : Simple Section of a Real Formation in Cutting (When Inverted it Depicts Formation in Filling)

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.

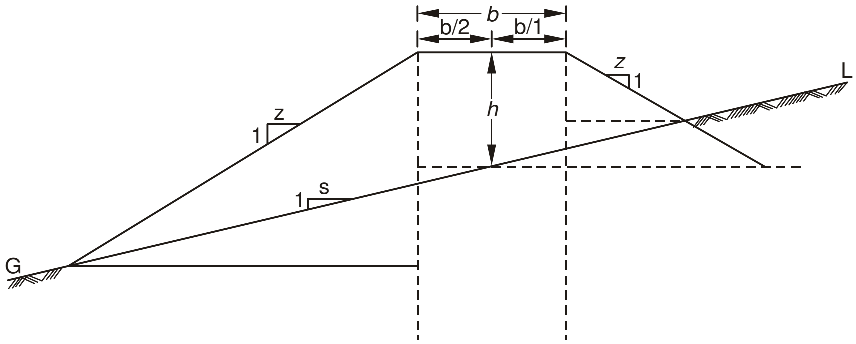


Figure 1.3 : Cross-section of Road Formation in Filling (in Embankment) in a Hilly Terrain with Marked Cross-slope of the Ground

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

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

∴ 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 $CDH = \frac{1}{2} \times b_2 \times HD$

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

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

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

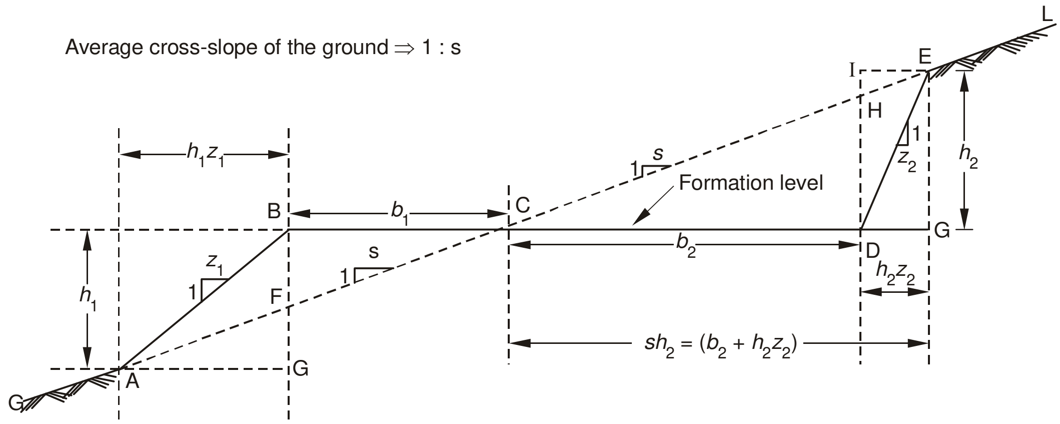


Figure 1.4 : Cross-section of a Road Formation in Cutting-cum-filling (i.e. Cutting-cum-Embankment) in a Hilly Terrain

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).

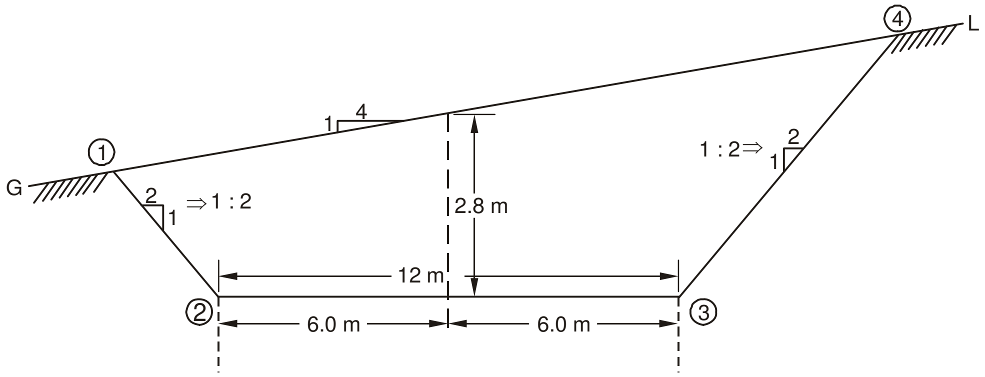


Figure 1.5 : Given Cross-section of a Road Entirely in Cutting (Example 1.1)

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 :

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

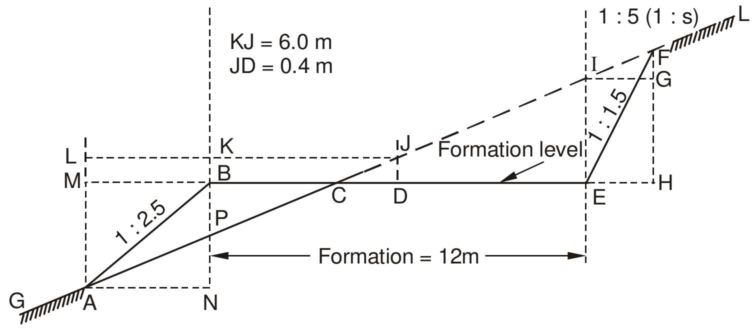
$$= \frac{2}{8 \times 4\,(4+2)}(2 \times 4 \times 2.8 - 12)^2 + 12 \times 2.8 + \frac{2}{8 \times 4\,(4-2)}(2 \times 4 \times 2.8 + 12)^2$$

$$= 1.126 + 33.6 + 36.98$$

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

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

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

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

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

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

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

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

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

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

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.

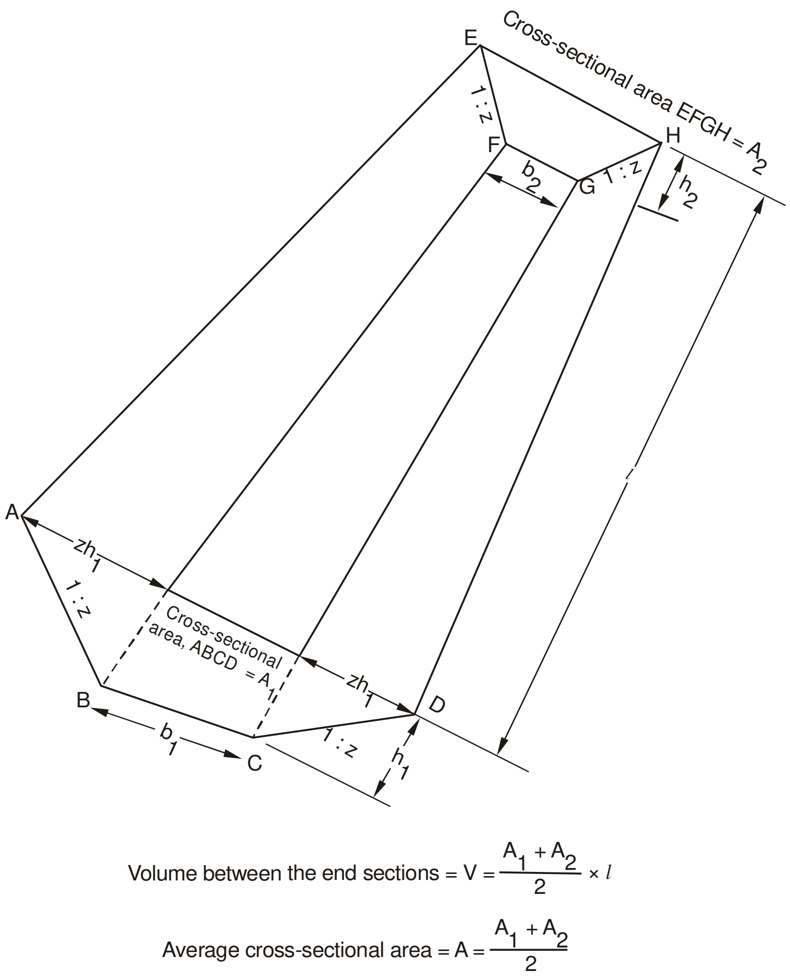


Figure 1.7 : Isometric View of a Road, Fully in Cutting, with End-section '*l*' Metres Apart

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, 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)

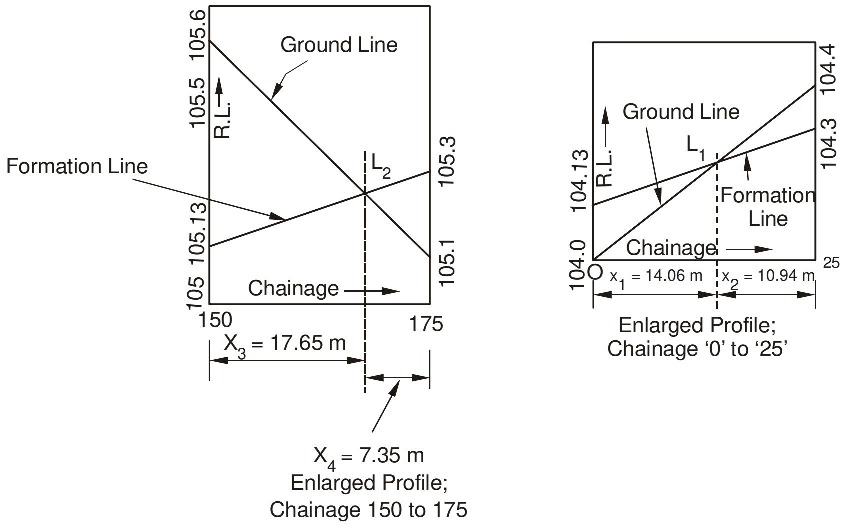


Figure 1.8(b) : Determination of Intersection of Formation and Ground Lines

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, ($b \times h_m + zh^2_m$)	
	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).

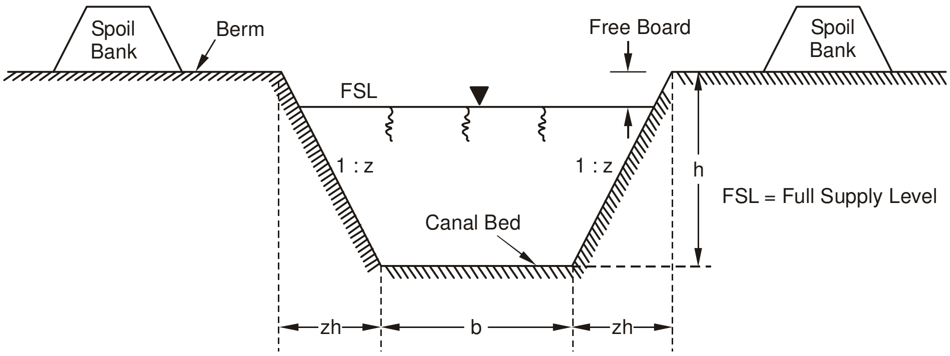


Figure 1.9 : Spoil Banks Along the Flanks of a Canal in Cutting

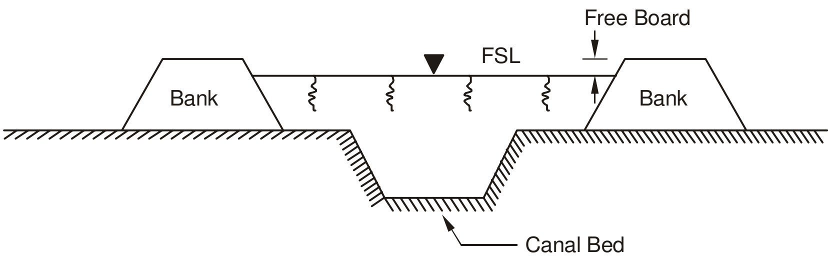
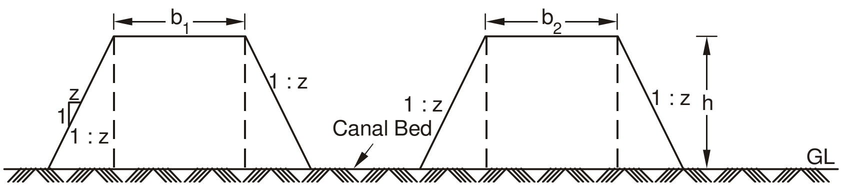
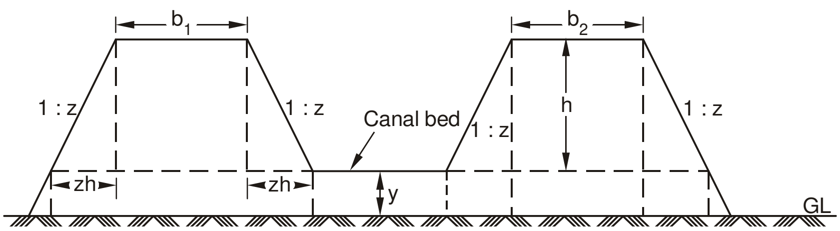


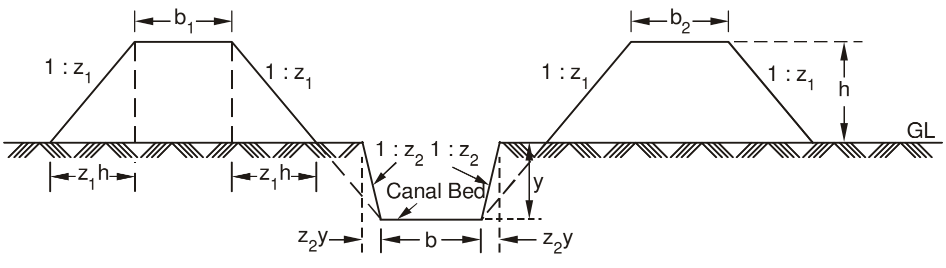
Figure 1.10 : Canal in Partial Cutting in a Plain Area – Spoil Banks Functioning as Water Retaining Banks



(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,

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

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

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),

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

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

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

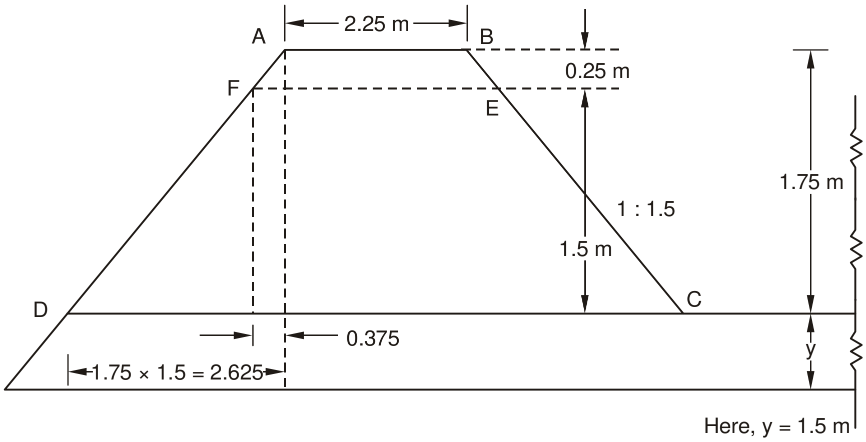


Figure 1.13 : Calculation of Cross-sectional Area of Canal (Filling) at Chainage '0' (Example 1.4)

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,

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

$= 2\ [3.127 + 2.898]$

$= 12.05\ \text{m}^2$

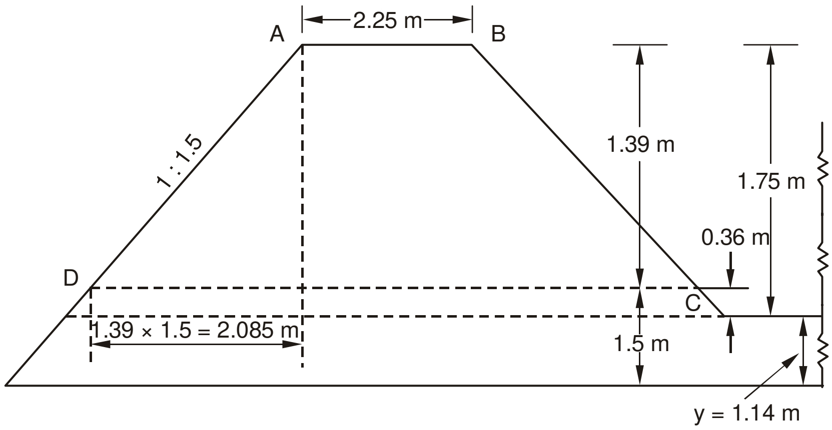


Figure 1.14 : Area Calculations of Chainage '300 m' (Example 1.4)

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

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

$= 12.468 + 18.691 + 25.365$

$= 56.524\ \text{m}^2$

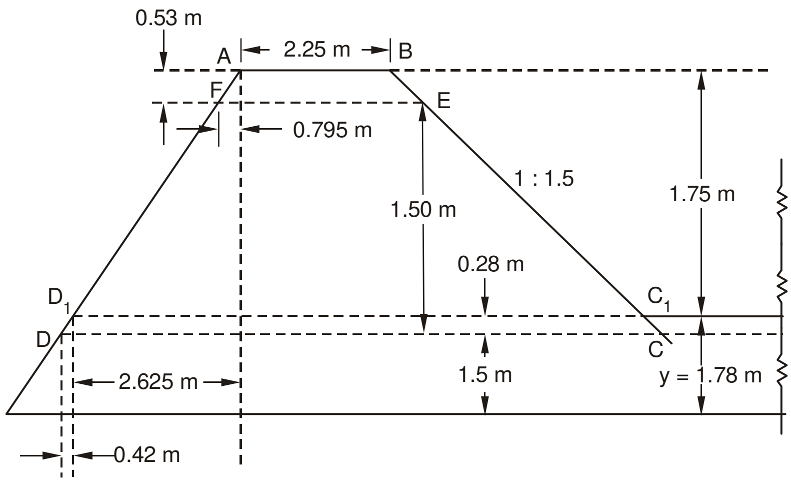


Figure 1.15 : Area Calculations at Chainage '600 m' (Example 1.4)

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)

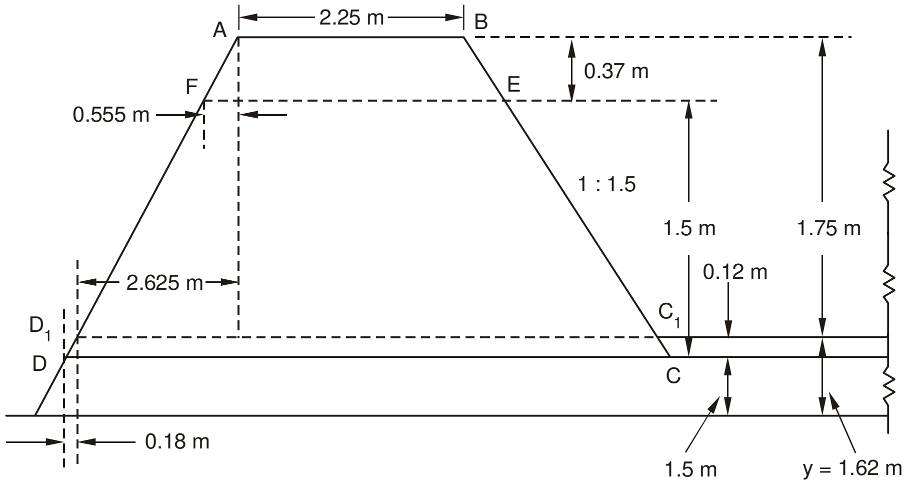


Figure 1.16 : Area Calculations at Chainage '900 m' (Example 1.4)

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

$= 12.468 + 17.035 + 23.085$

$= 52.588 \text{ m}^2$

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,

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

$= 2\,[3.622 + 3.888]$

$= 2 \times 7.510$

$= 15.020 \text{ m}^2$

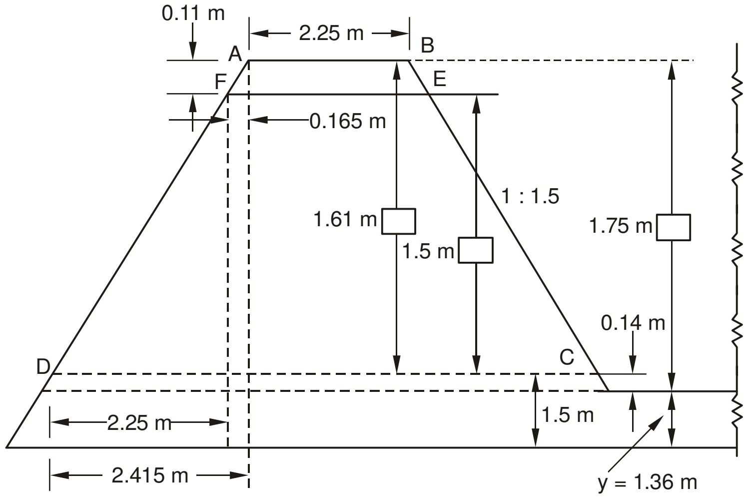


Figure 1.17 : Area Calculations at Chainage '1200 m' (Example 1.4)

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)

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

$= 12.468 + 13.953 + 18.525$

$= 44.946 \text{ m}^2$

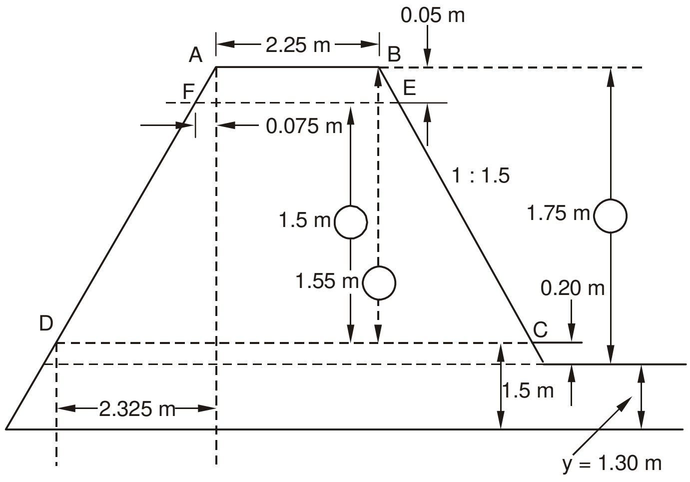


Figure 1.18 : Area Calculations at Chainage '1500 m' (Example 1.4)

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)

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

$= 12.468 + 16.236 + 21.945$

$= 50.649 \text{ m}^2$

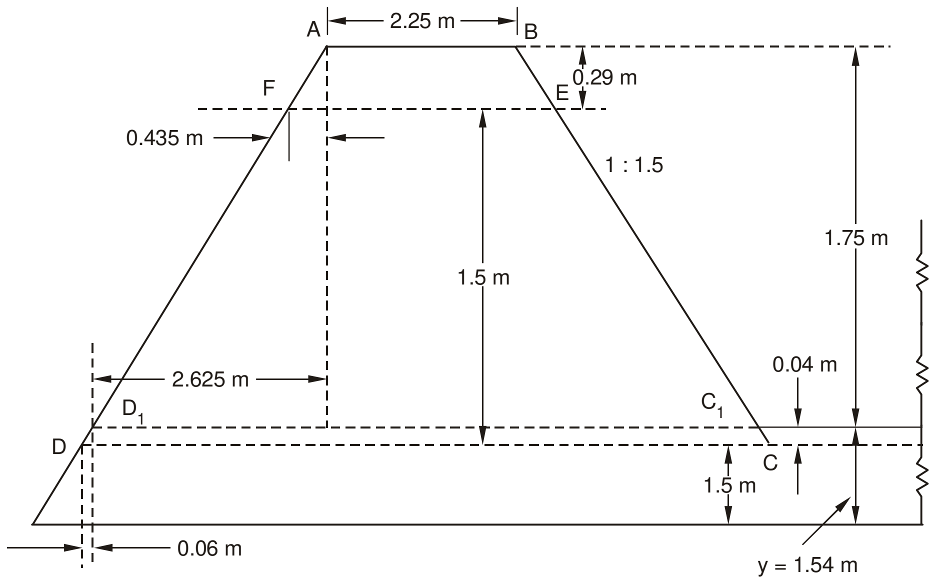


Figure 1.19 : Area Calculations at Chainage '1800 m' (Example 1.4)

Area ABCD (top to 1.5 m above GL),

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

$= 17.06 + 0.782$

$= 17.84 \text{ m}^2$

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) – (3rd 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

$= \text{Length } (L) \times \text{Breadth } (B) \times \text{Height } (H) \text{ / or Depth } (D)$

$= 6.50 \times 1.0 \times 1.40 = 9.1 \text{ m}^3$

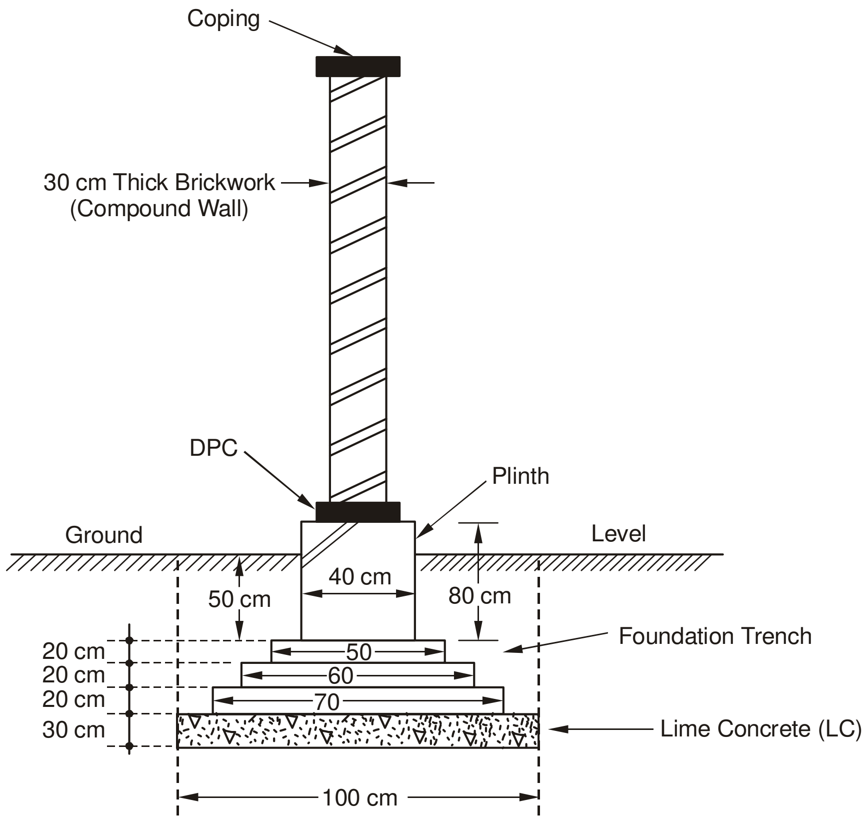


Figure 1.20 : Section of a Straight Compound Wall in a Brickwork

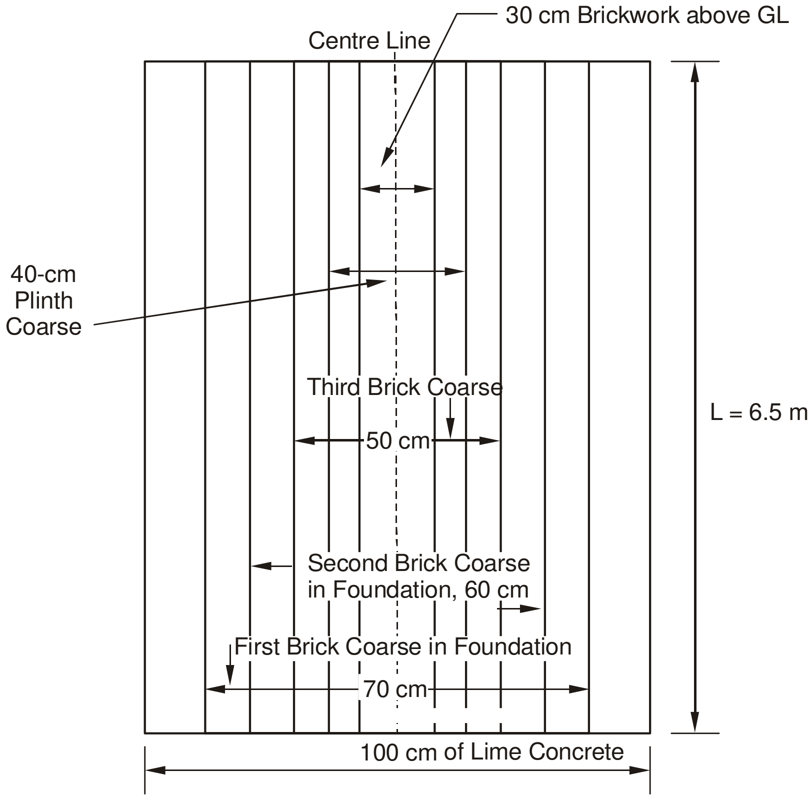


Figure 1.21 : Plan of the Foundation Trench for a Straight Compound Wall (Figure 1.20)

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***.

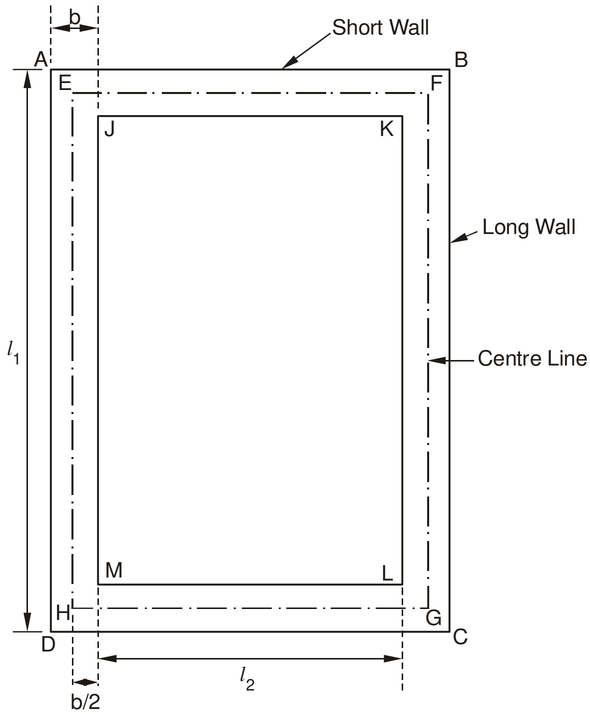


Figure 1.22 : Centre-line, Long and Short Wall, Method of Computing Earthwork

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

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

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

$$= 2\,(\text{FG} + \text{EF})$$

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

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

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.

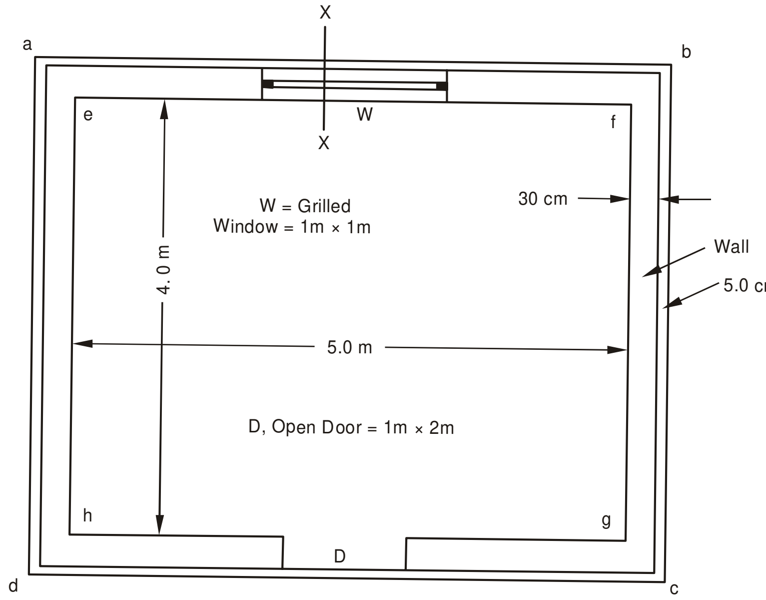


Figure 1.23(a) : Plane Above Plinth Level (at Window Level)

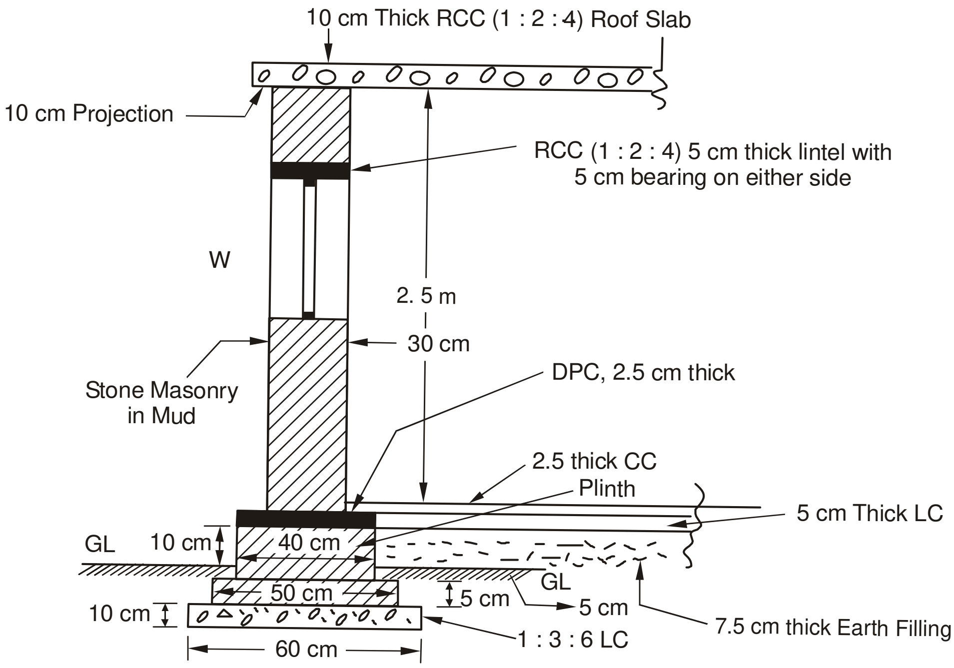
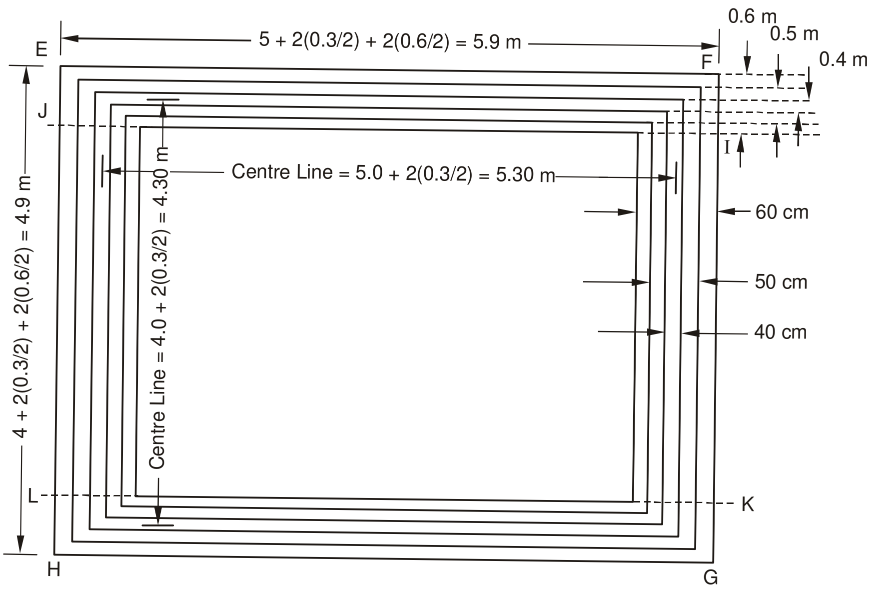


Figure 1.23(b) : Section at X-X



(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
$= (2 \times 5.3) + (2 \times 4.3) = 19.20$ 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			Quantity (m^3)
			L (m)	B (m)	H (or D) (m)	
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	2	5.9	0.60	0.2	1.42
	(b) Short Wall	2	3.7	0.60	0.2	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)

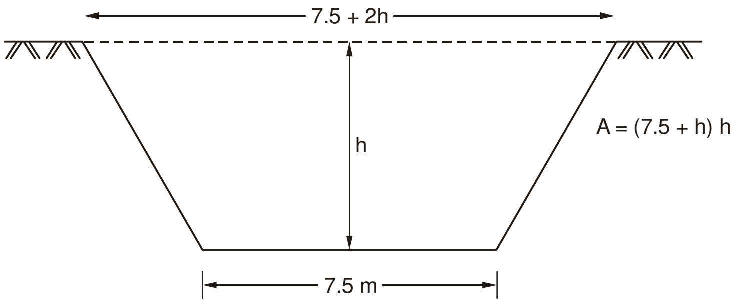


Figure 1.24

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)	Distanc e 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.

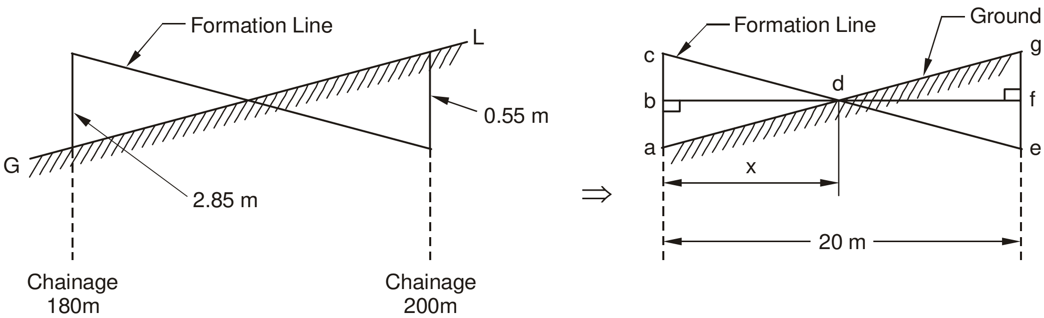


Figure 1.25

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

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 $6.182\,x = 103.64$

$\therefore \quad x = 16.76$ 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 = $1500 \times 10 \times (1.8 + 1.1)$

$$= 43500 \text{ kg} = 43.50 \text{ tonne}$$

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

(d) 2582.0 m^3

UNIT 2 ESTIMATION OF CONCRETE WORK

Structure

2.1 Introduction

Objectives

2.2 Quantification of Lime Concrete (LC) in Buildings

2.3 Quantification of Cement Concrete (CC) in Buildings

2.4 Rate Analysis of Plain Concrete Work

2.5 General Specifications of Cement Concrete Work in Buildings

2.5.1 Concreting under Water

2.5.2 General Considerations Regarding Formwork for Concreting above Plinth Level in Buildings

2.5.3 Measurement of Concrete Works

2.6 Activities

2.7 Summary

2.8 Answers to SAQs

2.1 INTRODUCTION

Concrete is an important building material of a modern structure. Primarily, two types of concrete – lime concrete and cement concrete – are in great use. Lime concrete goes into the first foundation course of a building or in foundations as a base for pavings of different types; and, also sometimes in terraces, floors, etc. So far as cement concrete (plain or reinforced) is concerned, it is used more widely in floors; in damp proof course (DPC); lintels over doors, windows; and other openings in a wall; chhajas (shades over doors/windows), roof slab, and shelves, etc.

Concrete is composed of aggregate and other building material – lime, sand, cement, surkhi as the case may be. In lime concrete (ordinary), the aggregate shall consist of either brick ballast, broken stone as shingle – each complying with the specifications laid down with regard to its quality. Fine lime concrete is used in filling up the haunches over jack arched roofing.

Concreting is also done in under-water ambience, say, for bridge foundations (in the absence of coffer dams), and other foundations.

In every building estimation work (quantity surveying), after estimating earthwork in excavation, lime concreting is the first item that is quantified – it covers the full width of the foundation trench, and its height is a fraction of the full excavated height. Thus, the computation of the quantities of lime concrete (LC) in foundations is quite easy and direct.

Insofar as cement concrete (CC) items are concerned sectional elevations and elevations of buildings contain the requisite information about the relevant measurements, and, therefore, need a careful study by the estimator.

Objectives

After studying this unit, you should be able to

- acquaint yourself with basic specifications about lime concreting, as well as cement concreting,

- discuss the general considerations about the requirements of the formworks associated with concreting, and
- explain the basic considerations governing the quantification of building concrete work of a given specification.

2.2 QUANTIFICATION OF LIME CONCRETE (LC) IN BUILDINGS

A focused study of cross-section/(s) of a given building along with its plan is the first step in comprehending the dimensions (length, breadth, and depth) of this item of work; and, then the cubical (or plan area) contents can easily be quantified.

Referring to Example 1.5 (Figure 1.23(b)), we find LC laid as a first course in the foundation of the room, and also as a 5 cm thick layer over the earth filling under the floor of the shed; and following calculations to estimate LC in foundations can be made:

(a) By Centre Line Method

Item No	Particulars	No	Measurements			Quantity (m^3)
			L (m)	B (m)	D (m)	
3	LC, 1:3:6, in foundation	1	19.2	0.60	0.10	1.15

(b) By L- and S-wall Method

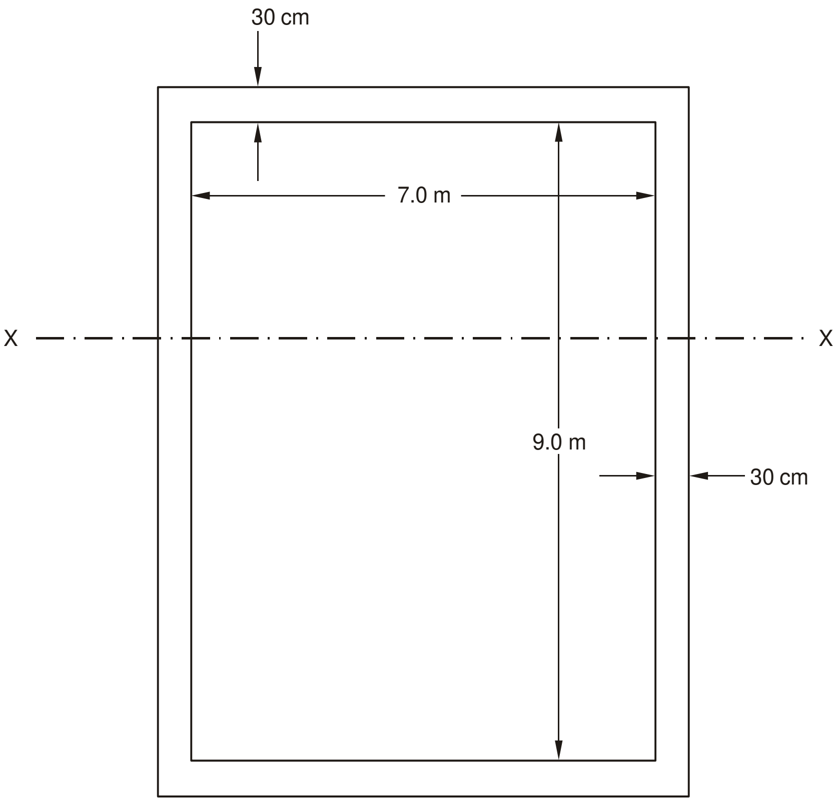
Item No	Particulars	No	Measurements			Quantity (m^3)
			L (m)	B (m)	D (m)	
3	(a) Long walls	2	5.9	0.60	0.10	0.71
	(b) Short walls	2	3.7	0.60	0.10	0.44
Total						1.15 m^3

Length of long walls and of short walls shall remain same for the excavation of trenches : but for higher courses of work the lengths shall keep decreasing according to the width of each course. This change in length shall be explained at the appropriate stage of the discussion.

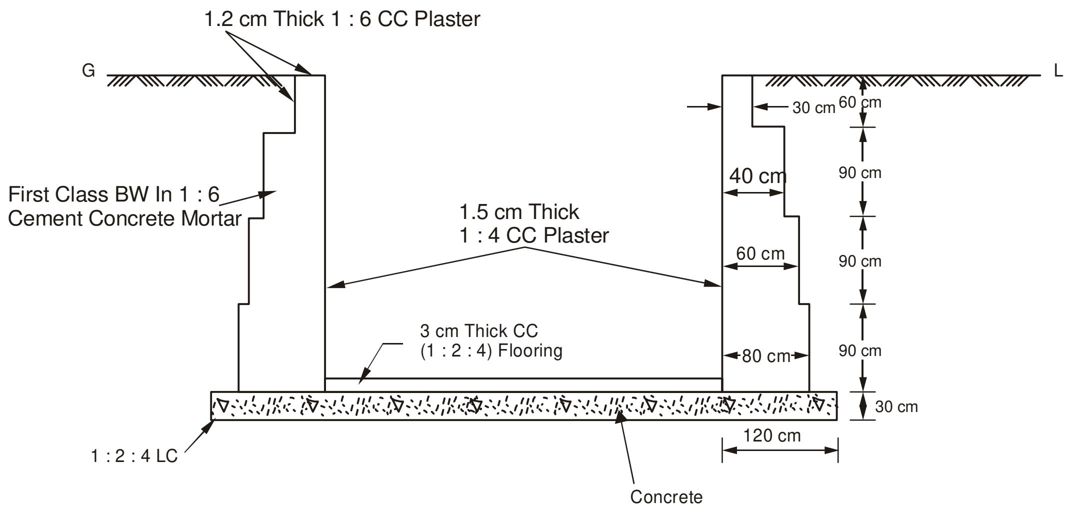
It is very obvious that the two approaches in the computational procedure (as shown above) lead to the same result. However, the centre-line method may not be applicable to compound plans – with different trench widths, etc.

Example 2.1

Figure 2.1 gives the plan and section of a water tank which lies entirely below the GL. Make a bill of quantity of LC (1 : 2 : 4) that is laid in its foundation.



(a) Plan at Ground Level



(b) Section X-X

Figure 2.1 : Underground Masonry Water Tank (Example 2.1)

Solution

It is easy to discern that lime concrete covers the whole length and breath of the full excavation, up to a thickness of 0.30 m. These dimensions – length and breadth – are worked out as follows:

Length = Internal dimension of tank + 2 (0.80) + 2 (1.20 – 0.80)

= 9.00 + 1.60 + 0.80

= 11.40 m

Breadth = 7.0 + 1.6 + 0.8

= 9.4 m

∴ Quantity of LC (1 : 2 : 4)

$= 11.40 \times 9.4 \times 0.30$

$= 32.15 \text{ m}^3$

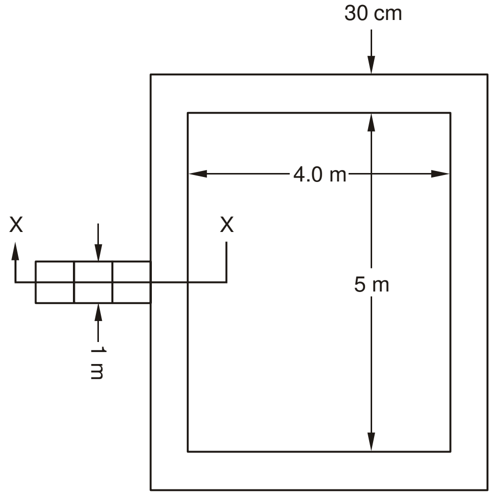
Earthwork in excavation can directly be computed as equal to

$11.40 \times 9.40 \times [0.60 + 3(0.90) + 0.30]$

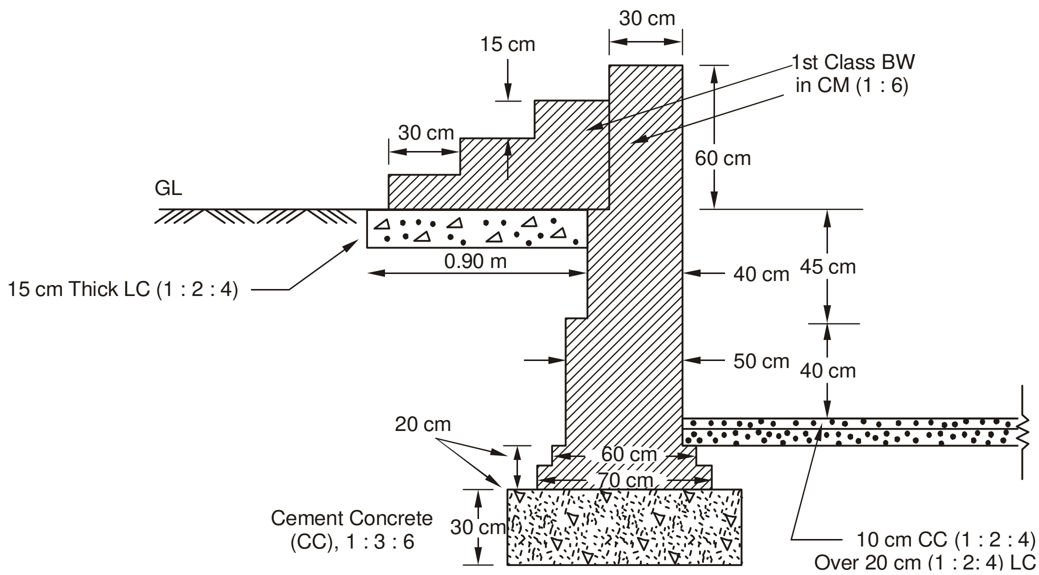
which works out to be 385.78 m^3. $\frac{1}{12}$th (i.e. $\frac{30}{300}$) of this quantity works out as 32.15 m^3 , which is the quantity of LC involved.

Example 2.2

A masonry water tank, partially underground, is shown in Figure 2.2. Calculate the quantity of LC (1 : 2 : 4) used up in this structure.



(a) Plan of Water Tank as Seen from Above



(b) Section at X-X

Figure 2.2 : Masonry Water Tank (Example 2.2)

Solution

Here, as per given drawings, lime concrete of same specifications (i.e. a mix of 1 : 2 : 4) has been laid at two locations – under the CC flooring of the tank, and under the steps that lead from the ground level to the top of the tank that stands 60 cm above the GL. The bill of quantities can be tabulated as shown below :

Details (or Description)	Measurements			Contents or Quantity (m^3)	Total
	L(m)	B(m)	D(m)		
Lime concrete (1 : 2 : 4)					
(a) Under floor	5.0	4.0	0.20	4.0	
(b) Under steps	0.90	1.20*	0.15	0.16	4.16 m^3

* = width of steps + sum of offsets (on both sides)

= 1.0 m + (0.10 m + 0.10 m)

= 1.20 m

(*This offset is the difference of thickness of tank masonry wall between top two courses,as is clear from the Figure*).

2.2.1 General Specifications of Lime Concrete (LC) Work in Buildings

Line concreting in order to be full of desired strength, finish and workmanship has to conform to some standards formulated on the basis of experience and experiments.

If the aggregate, used, is brick ballast, it shall be soaked by profusely sprinkling with water for at least *three* hours before the layer of *surkhi* and lime is added. The materials shall be measured and mixed on a specially put up platform – and this mixture shall be free of earth, dirt, or any other foreign matter. Measuring is done by stacking the ballast etc., in rectangular layer with trapezoidal cross section – to facilitate its stability and thus ease in measuring up the dimensions.

For achieving satisfactory mixing, the materials shall be turned over, at least, three times while in dry condition; and then again thrice when wet (i.e., mixing with water). Wetting should be only enough to render it wet but not sloppy. The mixture shall be laid immediately after it is ready for use – however, it should not be thrown down into the intended position from a height. It should be laid in layers not exceeding 15 cm in thickness; and should be thoroughly consolidated (with no further addition of water) with rammer of specified weight.

Consolidation is not taken as complete until a film of pure mortar covers the surface and completely hides the aggregate, and until a stick dropped endways from a height rebounds with a ringing sound.

For a speedy and good work, mixing and ramming shall go on continuously when once started. No concrete shall be laid later than two hours before the work is stopped for the day.

A lower layer shall in each case be swept (or washed) clean prior to laying the next layer. Whenever, joints in a layer are unavoidable, the end of each layer (in one plane) shall be sloped at an angle of 30^o. Vertical joints (i.e., two joints – one in each layer) must be at least 60 cm apart horizontally.

After completion, lime concrete shall be kept wet for a period of not less than 10 days. No brickwork (or any masonry) shall be laid on this lime concrete for at least 7 days after laying (to the desired height) is complete.

Fine lime concrete shall be exactly like the ordinary lime concrete, except for : size of the aggregate, consolidation, and finish – the aggregate (brick ballast, shingle, or broken stone) shall be of about 2.00 cm ($\frac{3}{4}$ inch) gauge.

Consolidation of fine LC shall be carried out, after some preliminary ramming (beating the concrete with "thappies" – wooden/metallic plates, provided with handles) until the mortar is nearly set. When the beating is over, the mortar that has come on the top must be softened by the addition of water, and smoothened with a float or trowel to render the desired polish to the surface.

Lime concrete [like cement concrete (CC)] is paid for as per its specifications – proportion of mix, and finish (if any) to be brought out. Unit of measurement is cubic metre – dimensions should be noted to the nearest cm.

It is to be understood that practical proportioning of LC ingredients shall be by volumetric measure. Generally, the internal size of boxes (used for the measurement of materials) shall be 35 × 25 × 40 cm. While measuring the aggregate, no shaking, ramming or heaping must be done. In machine mixing, it is done by pouring the measured quantity of aggregate and wet ground mortar for one batch in a drum mixer while it is in revolving mode. The consistency of concrete, in machine mixing, shall be such that the mortar does not tend to segregate from the course aggregate. Prior to suspending the day's work, the material in the drum shall be cleaned off by revolving the drum while sufficient quantity of water is fed each time.

Green work shall be protected against rain (or dust storm) by suitably covering it. After the concrete begins to harden up, curing has to be done – maintaining the concrete damp with moist gunny bags, or wet sand, or any other approved method at least for seven days.

It is the usual practice *not to* make deductions in contents for the following items :

(a) ends of dissimilar material that go into the work, such as, beam, posts, girders, etc. if their area measures up to 500 cm^2 in section,

(b) opening up to 100 cm^2,

(c) volumes taken up by pipes, conduits etc., not exceeding 100 cm^2 each in cross-sectional area, or as otherwise specified,

(d) small voids, each not exceeding 100 cm^2 in area.

2.3 QUANTIFICATION OF CEMENT CONCRETE (CC) IN BUILDINGS

Cement concrete is most commonly laid in floors, lintels (over doors and windows) etc. as discussed earlier; however, sometimes it is laid in foundations, say of water tanks, etc. for obvious reasons. Its quantification in volumetric measure is basically done in a manner similar to the estimation of LC. Figure 2.3 gives the plan and section of a mortar garage where CC is used in lintels, almirah shelves, roof slab, and in flooring. These items in CC are the most usual items found in buildings.

Example 2.3

Calculate cement concrete and lime concrete (in volumetric measure) used in the motor garage (Figure 2.3) with following specification regarding all the items of this work :

Foundation in 1 : 2 : 4 LC

1st class brickwork in 1 : 6 cement sand mortar is plinth and foundations

Depth of almirah = 23.0 cm

Bearing of lintels over the gate is 20 cm on either side

Bearing of lintels over windows and almirahs is 10 cm on either side

Slabs in almirah shall have width equal to the thickness of wall, and a bearing of 10 cm on either side.

The rate for the sheet iron gate includes fittings.

Window shutters shall have iron fittings included in the rates.

Soil may be taken as ordinary soil, and the excavation will be paid at the rate that includes lead up to 30 m, and lift up to 1.5 m.

1st class brickwork in L.M. (lime mortar in superstructure).

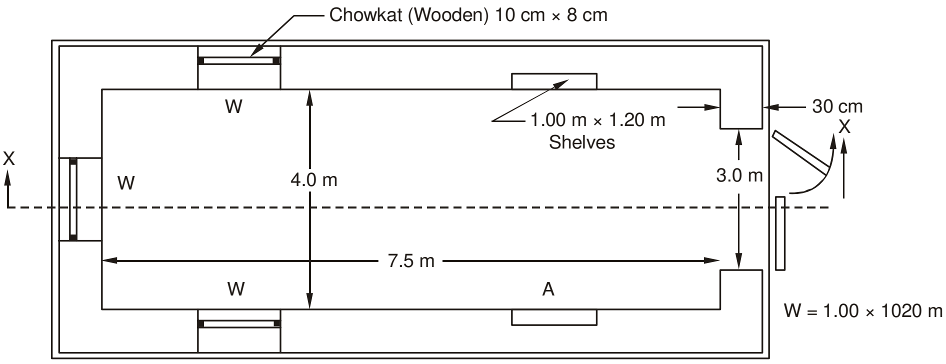
All RCC work is in 1 : 2 : 4 mix – shall be calculated in volumetric measure; its mild steel (in the absence of details) shall be taken as 1% of its cubic content. Its rate will include centering and shuttering.

LC in roof terracing (8 cm thick) shall be paid as per sq. m. measure

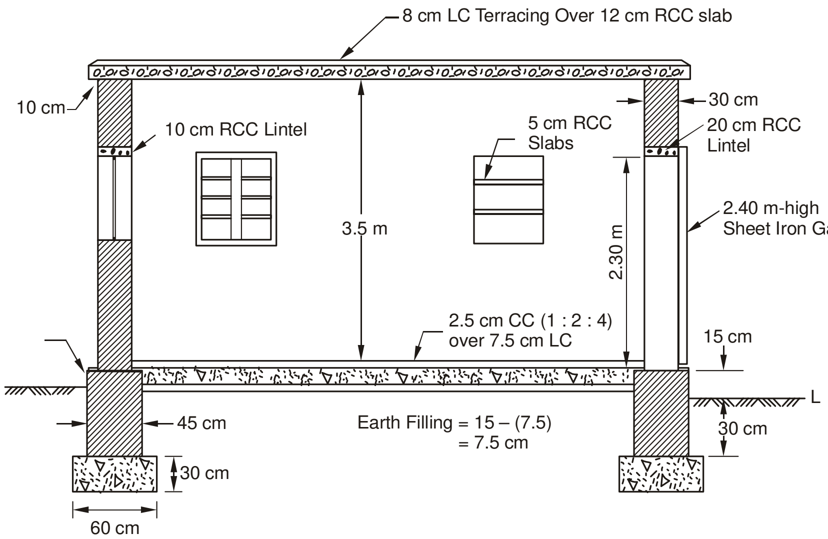
13 mm thick plaster in CM (1 : 6) inside and outside the garage

2.5 mm CC (1 : 2 : 4) floor over 7.5 cm LC together form one item of work, to be paid at the scheduled rate.

DPC shall be paid as per sq. m. measure.



(a) Plan at Window Level



(b) Section at X-X

Figure 2.3 : Motor Garrage (Example 2.3)

Solution

In this problem, LC is used in foundations and as roof terracing over the roof slab. In the case of terracing the quantity is to be measured in sq. m. as the specifications demand due to the rates having been determined for the composite item. Moreover, LC under CC in flooring forms a separate item.

As for CC work following items of this kind of work have to be quantified :

(a) DPC.

(b) RCC work which excludes the quantification of mild steel used in this item.

(c) CC flooring over LC.

(d) CC flooring – those portions that are laid over plinth projections.

The following table explains the required calculations as outlined above :

Details of Measurement : Bill of Quantities

Item No.	Details/Description of Items of Work	No	Dimensions L (m)	B (m)	H/D (m)	Contents/ Quantity	Total	Remarks
1.	LC in foundations (1 : 2 : 4)							It is obvious that the quantity of LC here = $\frac{1}{2}$ (quantity of earthwork in excavation) because of every dimension being same except the depth being half of the depth of total excavation. So, if one has either of the quantity, the other can immediately be written down
	Long walls	2	8.4*	0.60	0.30	3.024		
	Short walls * [7.5 + 0.3 + 0.6 = 8.4 *m* & 4 + 0.3 – 0.6 = 3.7 *m*]	2	3.7*	0.60	0.30	1.332	4.36 m^3	
2	*2 cm thick DPC as per specifications* Over long walls	2	8.25 *	0.45	–	7.425		As the breadth (0.45 m) of each item here is same, hence the net length (2 × 8.25 + 2 × 3.85 – 1 × 3) × 0.45 also leads to the same result.
	Over short walls	2	3.85 *	0.45	–	3.465	10.89 m^2	
	Deduct door	1	3.0	0.45	–	1.35 m^2	(–) 1.35 m^2	
	Net DPC	–	–	–	–	–	9.54 m^2	
	*[7.5 + 0.30 + 0.45 = 8.25 and 4.0 + 0.3 – 0.45 = 3.85 m]							

3	RCC (1 : 2 : 4) work excluding mild steel, but including cost of centering and shuttering							
	Roof slab	1	8.3*	4.8*	0.12	4.78		
	Lintels over the gate	1	3.4	0.3	0.2	0.20		
	Lintels over windows, and almirahs	5	1.2*	0.3	0.1	0.18		
	Almirah shelves	2 × 2	1.2*	0.3	0.05	0.07	5.23 m^3	
	*[7.5 + 0.6 + 0.2 = 8.3 m; 4.0 + 0.6 + 0.2 = 4.8 m; and, 1.0 + 2 (0.10) = 1.2 m]							
4	8.0 cm thick LC in roof terracing over the roof slab	1	8.3	4.8	–	39.84	39.84 m^2	
5	2.5 cm CC (1 : 2 : 4) flooring over and including 7.5 cm LC	1	7.35*	3.85*	–	28.30	28.30 m^2	
	*[7.5 – (0.45 – 0.30) = 7.35 m; and, 4.0 – (0.15) = 3.85]							
6	2.5 cm CC (1 : 2 : 4) in flooring over the plinth projections							
	Long walls	1	7.5	0.15•	0.025	0.028 m^3		
	Short walls	1	4.7*	0.075••	0.025	0.008 m^3		
	Sill of gate	1	3.0	0.45	0.025	0.033 m^3	0.07 m^3	

* 4.7 m is the length of one full short wall, plus the portions of short wall on which sheet iron gate is filted – 3.85 + [(4.0 – 3.0) – 0.15] = 4.7 m.

It may be noted that the portions of short wall of the right and left of the gate = 4.0 – 3.0 = 1.0 m.

* 0.15 m, obviously, when multiplied by 7.5 takes care of both long walls

** 0.15/2 = 0.075 m.

In general non-uniformities in a building plan say, different wall thicknesses etc. are encountered by a civil engineer in practice. However, these non-uniformities pose no problems in the computation of quantities if one is careful to account for these variations in specifications. It could best be explained by a concrete example as shown later on.

2.4 RATE ANALYSIS OF PLAIN CONCRETE WORK

The procedure of calculating the rate of an item of work (at which payment to the contractor is to be made) takes into account the following costs :

(a) cost at site of quantities of various materials used.

(b) cost of labourers – mazdoors, and *mistri*.

(c) hire of tools and plants used in the work.

(d) supervision charges (personnel employed for the supervision of the work) – also known as overhead charges – and contractor's profit, etc.

This process of arriving at the appropriate rate for the item is known as the *analysis of rate* or simply as *rate analysis*. Usually a profit of 10% (unless otherwise specified under special circumstances) for the contractor is allowed on all the items arranged by him (i.e., if some controlled items like, tar, steel, cement, etc. are supplied by the government, no profit falls due to the contractor).

Rate analysis bases our assessment of the overall cost on the economical use of materials, effort (labour), and processes, vis-a-vis, completing a given item of work. Sometimes, items, in addition to those covered by the contract bond, are needed to be done in the course of a project (small or big); and then rate analysis helps to work out the appropriate cost. And, it is obvious that rate analysis is the tool used to revise the schedule of rates (Departmental list of rates) from time to time due to increase in the cost of materials and labour as well as due to change in the work technology – increasing use of mechanization and automation.

Labour costs are basically (in addition to increase in wages) dependent on the *output of the labour* – progress of work (out turn) per day for various types of labour. Similarly, mechanized work costs are based on the output of various types of tools plants used in a given construction work. Generally, to the sum of material and labour costs is added 1.5% of this sum for those items of work that require addition/use of water in any way. Considering one unit (say, 1.0 m^3) of work :

Let the cost of materials for a given *unit* of work (say 1.0 m^3) = a

Cost of labour = b

Cost of tools and plants = c

$\therefore$ Total of material and labour costs $= a + (b + c)$

Add 1.5% towards charges for adding water (if any) $= \frac{1.5}{100}[a+(b+c)]$

Add 10% contractor's profit $= \frac{10}{100}[a+(b+c)]$

Grand Total Cost **$= 1.115\,[a + (b + c)]$**

which is the rate per **unit** of the particular item, namely, 1.115 $[a + (b + c)]$

Knowing the well established standards regarding the required quantities of various materials, vis-à-vis, a given item of work, and the number of labour of various categories involved, one can directly determine the appropriate rates. A few examples about the materials and labour, etc. are given as under :

(a) **10 m^3 of Kankar Lime Concrete in Roof Terracing** (with 2.5 cm gauge brick ballast including raking a shallow drain on the edge if so desired).

Required Materials

Brick ballast	10 m^3
Kankar lime	4.5 m^3
Bael frint	7.0 kg
Gur	12.0 kg

Labour

Mistri	0.5 No
Mason	1.5 No
Beldar	14.5 No
Mazdoor	22 No
Bhisti (waterman)	2 No
Blacksmith	0.5 No
Tools and plants, Sundries, etc.	Provided on lump sum (LS) basis

(b) **10 m^3 Line Concrete for Foundation and Under Floors** (with 4 cm gauge brick ballast and kankar lime)

Required Materials

Brick ballast	10 m^3
Kankar lime	3.3 m^3

Labour

Mistri	0.5 No
Mason	1.0 No
Beldar	11.0 No
Mazdoor	11.0 No
Bhisti	2.0 No
Blacksmith	0.5 No
Tools and plants, Sundries, etc.	Provided on lump sum (LS) basis.

(c) **10 m^3 of Line Concrete in Roof Terracing** (with 2.5 cm gauge brick ballast, white lime and surkhi in 100 : 18 : 36 proportion)

Materials

Brick ballast	10 m^3
White lime (slaked)	1.8 m^3
Bael fruit	7.0 kg
Gur	12 kg
Surkhi	3.6 m^3

Labour

(Same as for Item (a) above)

(d) **10 m^3 of Lime Concrete for Foundations and Under Floors** (with 4 cm gauge brick ballast, white lime, and surkhi in 100 : 16 : 32 proportion)

Materials

Brick ballast	10 m^3
White lime (slaked)	1.6 m^3
Surkhi	3.2 m^3

Labour

[Same as for Item (b) above]

(e) **10 m^3 of Cement Concrete in Foundations and Under Floors** (with 4 cm gauge with brick ballast, fine local sand – of fineness modulus = 1.25 in 12 : 6 : 1 proportion)

Materials

Brick ballast	10.0 m^3
Fine local sand (of 1.25 fineness modulus)	5.0 m^3
Cement (0.84 m^3)	24 bags

[**Note :** *Add 2.5 % as wastage on cement and sand – in the form of additional cost of these two items*.]

Labour

Mistri	0.5 No
Mason	1.0 No
Beldar	11.0 No
Mazdoor	11.0 No
Bhisti	2.0 No
Blacksmith	0.5 No
Tools and plants, Sundries, and hire for mixer, lubricants, etc.	Add on lump sum basis

(f) **10 m^3 of Cement Concrete in Foundations and Under Floors** (with 4 cm gauge with brick ballast, fine local sand – of FM = 1.25 in 10 : 5 : 1 proportion)

Materials

Brick ballast	10.0 m^3
Fine local sand of 1.25 F.M.	5.0 m^3
Cement	2.5 bags

[**Note :** *Add 2/5 % – as above – wastage on cement and sand*.]

Labour

[Same as for item (e) above]

(g) **10 m^3 of Cement Concrete** (with 4 cm gauge stone ballast, coarse sand, and cement in 4 : 2 : 1 proportion)

Materials

Stone ballast	8.8 m^3
Coarse sand	4.4 m^3
Cement (2.2m^3)	66 bags

[**Note :** *Add 2.5 % wastage on cement and sands*.]

Labour

Mistri	0.35 No
Mason	2.0 No
Beldar	14.5 No
Mazdoor	14.5 No
Bhisti	7.0 No
Blacksmith	0.35 No
Tools and plants, Sundries, and hire for concrete mixer, lubricants etc.	Add on lump sum basis

(h) **10 m^3 of Cement Concrete** (with 4 cm gauge stone ballast, coarse sand, and cement in 6 : 3 : 1 proportion)

Materials

Stone ballast	9.0 m^3
Coarse sand	4.5 m^3
Cement (1.5 m^3)	45 bags

[**Note :** *Add 2.5 % wastage on cement and sand*.]

Labour

[Same as for item (g) above].

2.5 GENERAL SPECIFICATIONS OF CEMENT CONCRETE WORK IN BUILDING

All concreting, especially cement concrete work, is a specialized task in respect of bringing out quality: finish, strength, and leak-proof performance.

Cement Concrete

Cement concrete work can be categorized (for separate measurements to be billed separately as per varying rates of payment because of differing specifications) as follows :

(a) Plain concrete work

(b) Reinforced concrete work

(c) Pre-stressed concrete work

(d) Pre-cast concrete work – plain or reinforced

(e) Cast-in-situ concrete work – plain or reinforced.

Unit of measurement is cubic metre if no qualifying statement is made in its detailed specifications.

Reinforcement in an RCC work, if not accounted for in the composite rate analysis, is measured as a separate item. Similarly, formwork (a necessary item in an RCC work) is measured separately.

Description of a cement concrete work should include the type of finishing of the surface that is desired. Special finishes shall be paid separately in m^2 measure.

Special concrete, such as cooled (for dams) heated, cellular, heat resisting has to be fully and in detail described; and is measured as a separate item.

Damp proof course (*DPC*), while, stating its thickness, is measured in m^2. Its rate shall include formwork and fair finish to edges which includes levelling and full preparation of the brick or stone masonry on which it is to be laid.

Only sufficient water, and no more, shall be used to give the slump test specified for the work. Consistency shall be frequently tested by carrying out slump tests. For this test, concrete is filled into a metallic conical mould open at both ends, and conforming to the frustum of a cone of specified dimensions. The mould shall be placed on a horizontal metal sheet, and the concrete (that is prepared) filled into it in, say, 10 cm layers. Each layer is lightly prodded by a bar. Its top layer is struck off level with the top of the mould, which then shall be withdrawn by means of the handles provided on it, by a gentle, steady upwards pull. Later the pile of concrete, that is left, will settle as much as is determined by it, consistency – this amount of settlement in height is known as *slump*.

Fine and coarse aggregates shall be measured loose or placed (thrown) in the measuring box and struck off. The measured quantity of cement shall be placed on the top of the measured quantity of fine aggregate, and the whole is mixed dry, three times or more to bring it to a uniform colour. Next the measured quantity of coarse aggregate shall be added to the mixture and the whole mixed dry once. Later, the required quantity of water (measured volumetrically or weighed for each batch) shall be added gently (with a rose) and, the process of turning over goes on until the whole mass of this mixture has been turned wet three times or more till a homogeneous mixture of the required consistency is obtained. Hand mixing shall only be done on a smooth platform.

Concrete shall be handled, from the mixing platform to the final placement point, as quickly as possible in the ways that prevent the segregation (separation) or loss of its ingredients. It is placed in the forms as nearly as possible in its final position to avoid re-handling. It shall in no circumstance be dropped, short or tipped from a height greater than 30 cm. It shall be deposited such that to maintain, until the completion of the particular unit of work, a plastic surface approximately horizontal. After concrete is deposited, it shall be rodded, tamped or worked to ensure no hollow places are left in its mass – now-a-days electrically working vibrators are much in use which should be used as per specified instructions. Such tamping or working shall be completed within half an hour of adding water to the cement. Any voids, hollows left in the mass contribute, later on, to undesirable seepage through it – a very annoying feature of roof slabs. Water proof compounds that are added to the mix way fail to give results if bigger voids are there to exist.

Laitance (a milky accumulation of fine particles forming on the surface of freshly laid concrete when the concrete is too wet or is vibrated or tamped too much) shall be prevented on horizontal layers when stopping day's work. If it occurs, it shall be removed (i.e. removing any "creaming" or excess water) as soon as concrete is laid and compacted. Where laitance has formed and hardened, it shall be removed before recommencing work, by chipping gently so as not to disturb the concrete that has already partially set.

Re-tempering of concrete or mortar that has set partially – i.e. remixing with/without additional cement, aggregate or water – is absolutely unacceptable. Moreover, never shall concrete, that has partially hardened, be deposited in the work.

The top surface, if it stands exposed (but not under any wear), shall be smoothed with a wood float. A steel trowel is not to be allowed. Any excess water (or cream) that has formed on the surface shall first be removed. Dry cement, or a dry mixture of element and sand, shall not be sprinkled on the surface with the intentions of absorbing such excess moisture.

Concrete shall be cured after laying by being covered with gunny bags, sand or saw dust which shall be maintained wet constantly for 15 days. Shuttering shall not be removed before the specified period regarding different structural parts.

Special case needs to be devoted on the storage of cement (as also for lime, and surkhi). All cement shall be stored in a weather proof shed whose floor has to be damp proof in nature, and at least 30 cm above the natural ground surface. Cement shall not be stored in contact with walls. *To reduce deterioration by aeration, cement should be stored in bulk wherever feasible. When stored in bags, these shall be placed horizontally in contiguous lines and layers.*

No cement that has been stacked throughout a monsoon or for more than six months shall be used for reinforced concrete until samples have been tested against laid down properties/quantities.

Cement Concrete Floor Finishes over Structural Concrete in Buildings

By far the most common type of flooring in most residential and non-residential buildings in India, in urban areas, is of cement concrete topping. While used in conjunction with structural slab, the design and laying of such floor finishes pose some problems that arise fundamentally out of lack of adequate bond between the base and the topping layer – it occurs when the topping is laid after the base has hardened up. Lack of the desired bond causes the wearing surface to sound hollow while being tapped leading to cracking and disintegration of the finish. Moreover, variations in composition between the base of the floor and the topping result in different rates of shrinkage which contributes to the warping or curling of the topping. If there is, under load or impact, deflection of the base, further loss of adhesion results. It has to be stressed that the damage is progressive in nature. These floor finishes may be ordinary concrete floor finish, or granolithic (comprising cement and granite chips) finish.

Floors shall be smooth, dustless, and free from cracks. Where ordinary concrete (in heavy engineering workshops, say) is used for general finish, the track travelled by trolleys shall be surfaced with special concrete (granolithic) to reduce wear. At places where oils and flats are to pour on the floor, it should be given an acid resisting finish – these substances being acidic in nature. And, a well laid concrete floor shall be impermeable.

With a view to achieve durability of concrete, it is desirable to have :

(a) a hard tough aggregate,

(b) a low water – cement ratio compatible with workability,

(c) a dense well compacted finish, and

(d) integral hardness and surface hardness.

A good concrete finish offers adequate resistance to wearing under all conditions of usage – in a non-industrial building, the traffic, which is entirely pedestrian, varies in intensity from heavy wear near doors, over corridors, etc., to almost negligible wear in bed rooms.

Concrete floor finishes may either be laid monolithic with the structural base while the base is still plastic, or may be subsequently laid on and bonded to it. Monolithic finish has certain disadvantages when used in conjunction with RCC slabs, such as :

- the finish is likely to be damaged or discolored due the subsequent construction operations,
- the finish may develop hair breadth cracks due to infinitesimal deflections that follow the removal of shuttering of the structural slab, and
- repair of the damaged monolithic topping may cause difficulties – there being a risk of either the slab being weakened while picking up the surface, or the level of floor being raised to accommodate the extra thickness required while repairing the surface with a fresh non-monolithic topping.

However, the advantages of monolithic topping also are there: its required thickness is less than in the case of bonded finish, thus economizing materials and structural load, and thus the cost.

Wherever the thickness of monolithic topping exceeds about 4 cm, it is advantageous to incorporate some light reinforcement when the floor passes over a supporting beam/wall. The thickness of granolithic concrete shall not be less than 1.25 cm – the actual thickness shall depend on the wear and abrasion that the surface is to undergo. In large number of domestic buildings, it shall be desirable to provide a monolithic finish of not less than 2.0 cm thickness. In the case of treads of stairs, corridors of offices, and places of high concentration of traffic, the thickness of the finishing may be increased to more than 3.0 cm.

Thickness of concrete in the case of flooring laid on hardened concrete (slab) shall depend on the conditions of roughness and cleanliness. When laid on set and hardened surface, the finished thickness shall not be less than about 4.0 cm; and this thickness can be up to 7.50 to 8.0 cm. Sometimes, it is necessary to lay a damp proof membrane – bitumen or asphalt – on the hardened concrete before this finished floor is laid; in such situations concrete finished should stand at least 5.0 cm thick.

In low cost residential buildings, ordinary concrete may be sufficient under normal circumstances. Whenever the thickness of finish exceeds 7.0 to 8.0 cm the flooring shall be laid in two layers – the top layer being laid on while the bottom layer is still plastic, i.e. within 45 minutes to 2 hours of its laying depending on the setting properties of cement used and the atmospheric conditions prevailing. The bottom layer in this case should be ordinary concrete; and the finishing layer shall be either of the two specifications, depending on the wearing qualities that are desired.

As in all cases of concrete (*lime or cement*) *aggregates shall consist of sand and crushed stone, and shall be clean and free from crushes, dust or adherent coatings*. Obviously, aggregates take the wear and abrasion imposed on the floor.

These shall be sufficiently tough and hard. Hard fine grained granite, basalt, limestone, quartzite, etc., are particularly suitable as *coarse aggregate. All aggregates shall be clean, free from dust, and preferably angular in shape – however*, round shaped material too is in use where it is available naturally in sub-Himalayan areas (like in Kashmir, and Himachal, etc.). Deleterious materials like *mica, iron pyrites, coal or laminated flaky or elgonated particles are unacceptable.*

For granolithic finish the usual mix consists of 1 part of cement (by volume) to 2.5 parts of mixed aggregate, or 1 part of cement to 1 part of sand and two parts of coarse aggregate. For ordinary concrete finish, the usual proportion of the mix (by volume) shall be one part of cement to 3.5 parts of mixed aggregate, or 1 part of cement to 1.5 parts of fine aggregate and
3 parts of coarse aggregate. The consistency of the mixed concrete shall give a slump of about 1.50 cm. The moisture content present in the aggregate should be allowed for while determining the quantity of water to be added while mixing the mass.

The most desirable degree of adhesion between the base and the finish in monolithic construction is obtained laying the finish as soon as the base has stiffened up sufficiently to allow walking on it. In non-monolithic finish, if the finish is to laid until the hardening of the base has advanced far, a thorough preparation of the base is necessary. The surface of this sub-floor concrete shall be brushed with a stiff broom just before it hardens, to remove all laitance and loose aggregates and to roughen, the surface to improve the bond. Whenever this is not quite possible, the hardened concrete shall be roughened by chipping or by some other suitable treatment. Suitable, detergents can be used to wash off superficial oil, etc.

Screed battens carefully levelled and placed on mortar pads shall be fixed at a proper height to suit the thickness of the floor, while preparing to lay the floor. Mixed concrete is spread on the base floor or levelled with a screeding board and well compacted by floating and tamping. Flooring shall be laid in panels not exceeding 2.4 × 2.4 m. When laid on a hardened base the joints shall be left to correspond to the joints in the base.

When laying on a hardened base, alternate bays should be laid, and the intermediate bays should be filled in after a few days – allowing the bays laid first to harden up and the screening boards to be removed before the remaining bays are laid, thus preventing the adjacent bays to bond and also permitting some shrinkage to take place before a continuous surface is formed. It shall be aimed to achieve clean vertical butt joints extending through the depth of the finish.

All floated and levelled surface shall then be trowelled. Only just sufficient trowelling is to be done to render a level surface, immediately after laying. However, further trowelling shall be done when the mix has stiffened to the point where a solid well compacted surface could be obtained without bringing up the slurry. Dusting the surface with neat cement to facilitate later trowelling shall not be allowed, nor shall cement slurry be applied to the surface. Power driven floating and trowelling is now available for use in construction industry.

As in the case of other concrete surfaces, curing of the floor is the most important element of construction process. The floor shall be kept damp by ponding water or by spreading a layer of wet sand (or saw dust), or wet gunny bags for a minimum period of 7 days. Membrane curing – using plastic sheets (or other membrance) – can be used advantageously. Membrane curing is specially useful in the case of floor finishes on first and higher floors when laid monolithically with the slab. These membranes may be covered with a layer of earth to prevent further construction operations from damaging the surface.

Granolithic-finish surface could be ground for a better look. The flooring shall be kept wet during the process. All the matter ground off shall be removed by washing, mopping and flushing. After the first grinding, air holes, pits and other blemishes shall be filled with cement grout of a creamy consistency – the floor shall be kept moist for three days to allow the grout to harden. The surface is next ground again to obtain a fine polish.

A non-slip surface can be obtained by the addition of suitable abrasives. To prevent dusting (if at all it occurs) and to increase hardness of the surface, surface hardeners shall be used.

2.5.1 Concreting Under Water

Construction of foundations under water is always a delicate operation whether done under surface waters – rivers, lakes, or seas – or under the conditions of sub-soil flow. Experience and modern equipment are two important requisites for such a work. First of all, whenever possible, it is preferred to execute the work in dry conditions – may be it is possible at times to pump out water from the interior of an enclosure that is raised to protect the work (sheet piles or a cofferdam). There are situations where the level of water (static or running around the enclosure) can be lowered by positioning pumps some distance away from the excavation. In sub-soil flow situations, the wet ground can be chilled (or solidified) by chemical processes; or, finally, water can be driven out by the aid of compressed air as in the case of a caisson. These measures aim at enabling the foundations to be placed in dry solid below the level of surrounding water. However, there are cases where, for technical (or economical) reasons, it is not feasible to apply any of these procedures – and, it becomes necessary to concrete under water (even running water). There have been cases in India where packed concrete (lime/cement) – in gunny bags – have been manually thrown into the foundation trenches of bridge piers (while having gone under running water due to say, flash floods, etc.) with excellent results. There are many examples in foreign countries also (met with commonly in Switzerland) where in the construction of harbours, concrete is filled in jute bags, lowered into water, and placed at the proper place by a diver. Jute protects the concrete from being washed away, and as it is slightly processes when the bags are in position, the mortar squeezes through so that the bags are bonded to each other to form a mass without any voids. In the case of emergencies, this process is sometimes the only method to seal a breach, say in a dam.

The total cost of a structure (whose foundations are laid under water) is bound to escalate due to the extra expenditure involved in underwater concreting. Every exercise in quantity surveying must include the costs borne on this account.

Because of the operations being carried out under these conditions that cannot be properly controlled – such as washing off, segregation, etc. – it is of prime importance to use concrete of a *very good quality*. In general, a cement content of 350 kg per m^3, and even 400 kg m^3, is chosen for the bottom-most foundation layers. The grading of aggregates should be excellent and *rounded aggregates*, *rather than crushed aggregates*, *which mix very easily*, *should always be preferred.* Plastic and even highly plastic concrete should flow easily and should entrain the least possible amount of air, because air later rises to the surface of the overlying water causing water bubbles that carry away cement with it.

Placing of cement under water, to be most efficient, must conform to some essential guidelines, such as :

(a) Necessarily avoid segregation and washing away of concrete. Allow it to fall freely in water, but at the same time it should form a continuous mass with only the exterior surface remaining in contact with water.

(b) Try keeping water perfectly still – therefore, the formation of an enclosure around the work is necessary.

(c) Maintain the enclosure almost completely water tight along its height, especially along its junction with the foundation in the case of cofferdams. Thus, it becomes indispensable, in general, to press divers into service.

(d) Organize the work such that concreting is carried out rapidly without any interruption whatsoever.

Conditions of still water environment and water tightness should be ensured expressly during the setting and first hardening of concrete.

The surface of concrete, being placed under water, for obvious reasons is not plain and regular. Sometimes its levelling may be attempted by means of slight vibration. If concreting is done in many layers, it should be distributed in a way that the last (i.e., the nearest to the surface) layer has a normal thickness. It is no advantage providing a last layer of 15 to 20 cm (6 to 8 inch) thickness – this will be quickly washed off and will, consequently, be necessarily of a bad quality.

Regarding setting and hardening, any concrete placed under water behaves in the same way as concrete placed in open air, *since the cement is a hydraulic binder*. Unless the quantity of water demands special cement, it is adequate to use ordinary Portland type cement. In order to estimate the time of settings and of hardening of cement, one must not forget the fact that the temperature of water should also be taken into consideration. Delay in the removal of formwork rarely matters; but, the degree of hardening has to be known before proceeding with pumping, and before the foundation is allowed to bear pressure and surcharge. It is obvious that so long as concrete remains under water there is no need for any treatment and protection after concreting is done.

2.5.2 General Considerations Regarding Formwork for Concreting above Plinth Level in Buildings

Formwork, in general, comprises all temporary or permanent *forms* (or *moulds*) that are needed for forming the concrete used in *cast-in-situ* items, together with all temporary set-up required for their support and rigidity.

All formwork has to be a rigid construction true to shape and dimensions as required. The work shall be as strong as is sufficient to withstand dead and live loads and those arising out of ramming and vibrations of concrete and other loads inherent in this construction work – during and after casting of concrete.

Formwork is rendered sufficiently rigid by the required number of ties and braces. Screw jacks or hard wood wedges are used to make up for any settlement in the formwork either before or during the placement of concrete.

It has to be appreciated that the assembling (construction) of forms shall allow its removal (dismantling) in sections in the desired sequence without damaging the surface of concrete and disturbing other sections of the total formwork used for a unit of work – column, roof, slab, etc. This aspect stresses the requirement that all formwork shall be easy to strip after set up in place (i.e., connecting various elements). It is very important to take care that no part is, keyed into the concrete. Before, reinforcement bars (as per design) are placed in position, formwork must be inspected properly.

Materials that are used in a formwork include timber, plywood, and steel. Timber that is used shall be easily workable with nails, i.e. it would not cause splitting, and it should not be too heavy to handle. Yet, this timber shall be stiff, and strong enough not to undergo undue deflection while under due loading. It shall be stable, and also not liable to warp while it stands exposed to sun and rain, and subject to wetting during concreting. It shall not get damaged easily (either inside or superficially) under normal conditions of erection, fixing steel or pouring concrete.

Props that are used for centring shall be timber posts, *ballies*, steel etc. Use of temporary brick masonry pillars (in mud mortar) is also resorted to. Ballies, in no circumstance, shall have a diameter less than 100 mm measured at mid length, and 80 mm at the thin end. The maximum permissible spacing shall be 120 cm centre to centre. It is to be seen to that these ballies rest squarely on *wooden sole plates* of 40 mm thickness, having a minimum bearing area of 0.1 m^2 – laid either on ground or on 40 × 40 cm brick masonry pillars in mud mortar (of a height not exceeding 40 cm). As a further buttress, double wedges shall be provided between the sole plates and the wooden props – this arrangement allows easy tightening and *easing* of shuttering that does not jar or disturb the concrete. In case brick masonry pillars are used (instead of props), wooden sole plates shall be provided at the top of pillars, and double wedges inserted between the sole plate and the bottom of shuttering.

For a building of too or more storeys (floors), the weight of concrete, centring and shuttering of any upper floor being cast shall be appropriately supported onto the floor immediately below the one being cast. It is preferable to position the props of the upper floor just above the ones used in the lower floor. It is important to provide planks at the top ends of props in order to achieve as even a distribution of load as possible.

No formwork (and concreting) shall be done till the concrete of lower floor has set for at least 14 days. The details of formwork outlined above are applicable for spans of 4.5 m and a height up to 3.5 m. Whenever these limits exceed, it is necessary to appropriately design a formwork for self weight, weight of fresh concrete, weight of reinforcement, and live loads expected to operate during the construction activity (workmen and equipment, etc.). Action of wind, dumping of concrete and movement of construction equipment induce lateral forces : and, the formwork should be sturdy enough (as a result of proper design) to prevent any lateral failure – suitable horizontal and diagonal bracings are, therefore, a necessary part of the whole framework. While concreting is in progress, at least one expert carpenter shall be readily available at the site for immediate remedial measures that may be necessary at any time.

All the shuttering shall have smooth and even surface; and its joints shall not permit leakage of cement grout. Timber should be well seasoned, with no loose knots, projecting nails, splits, etc., so that the concrete surface does not suffer any unwanted defacement. Shuttering pieces (timber) shall not be so dry as to absorb water from the newly laid concrete; it should not swell or bulge. Also, it should not be that much green (or wet) as to lead to its shrinkage after erection – thus, only those species of timber that satisfies these requirements to a large degree shall be allowed to be used.

Accurate sawing and planning of shuttering timber on the sides and the surface to remain in contact of concrete is necessary for a good quality – work to emerge. When metal forms are in use, all bolts and nuts shall be counter sunk. In timber form, where use of nails in necessary, a minimum number of nails shall be used and these shall be left projecting to facilitate easy withdrawal.

Surfaces of timber shuttering, intended to remain in contact with the concrete, must be made sufficiently wet, and coated with yellow soap solution, raw linseed oil, etc., or suitable materials (like polythene, etc.) be placed over it to prevent adhesive of concrete to the formwork.

Formwork shall be removed as gently as possible – to avoid any damage to the concrete. In a slab-and-beam construction, sides of beam shall be stripped first, and then undersides of slab and lastly the underside of the beam. Following Table summarises the least period for which a shuttering should remain in position, vis-à-vis, and various items of RCC work – wherever possible, the formwork should be left in place for a longer times as it helps in the effort to cure the concrete.

Least Period for Formwork to Remain in Position

S. No.	Description of the Item	Period for which Formwork Shall Remain in Position
1.	Sides of walls, columns, beams and foundations	48 hours
2.	Undersides of slabs (up to 4.5 m span)	7 days
3.	Undersides of slabs (with more than 4.5 m span), and of beams, and arches (up to 6.0 m span)	14 days
4.	Undersides of beams and arches (with more than 6.0 m span and up to 9.0 m span)	21 days
5.	Undersides of beams and arches with more than 9.0 m span	28 days

Unless otherwise specified, formwork is measured separately – its rate analysis includes the cost of labour and cost of materials and its use many times over. The usual unit of measurement is m^2, i.e. the area covered by shuttering.

2.5.3 Measurement of Concrete Works

As per IS : 1200 (part II) – 1974, lime concrete and mud concrete shall be measured in m^3 with each item fully described (i.e., specified).

Concrete in columns shall be measured from top of the column base to the underside of the first floor slab, and subsequently from top to the floor slab to the underside of the floor above. In the case of columns for flat slab, *flare* of columns shall be included with the column for measurement.

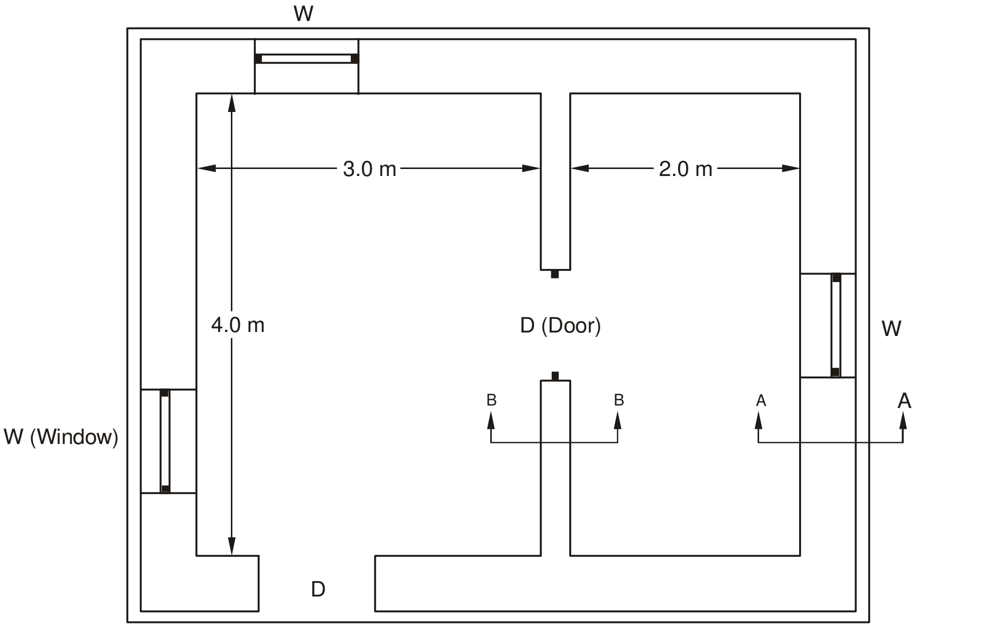
Beam shall be measured from face to face of columns and shall include haunches, if any, between columns and beams. The depth of beam shall be measured from bottom of slab to the bottom of the beam : but, in the case of inverted beam, it shall be measured from top of the slab to the top of the beam.

Dimensions shall be noted to the nearest cm in cement concrete in foundations, flooring, etc., while the thickness of slabs, beams, etc., is measured to the nearest 0.5 cm. As a general practice, no deductions in quantities are made for openings in concrete if their area is less than or equal to 0.1 m^2.

SAQ 1

(a) A hut, comprising two rooms, has been built for use of labour working on a project (Figure 2.4). Prepare a bill of quantities for all LC work, and CC items using both centre-line, and Long- and Short-wall methods.

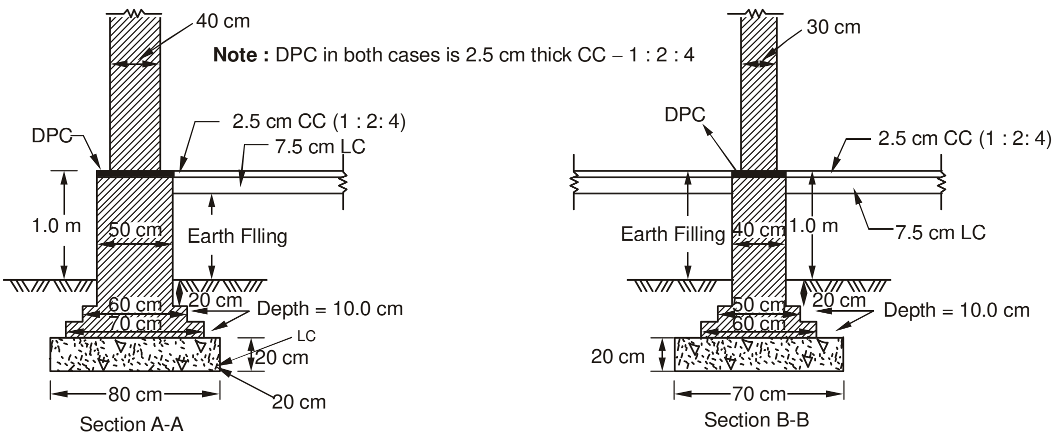
No roof slab estimation need to be done. DPC shall be calculated in m^3, as its rate here is based on its cubical contents.



Lintels (RCC 1 : 2 : 4) :
over D = 15 cm thick with
10.0 cm bearing on either side
W = 10.0 cm thick with
10.0 cm thick bearing
on either side

D = 1.0 × 2.1 m
W = 0.9 × 1.3 m

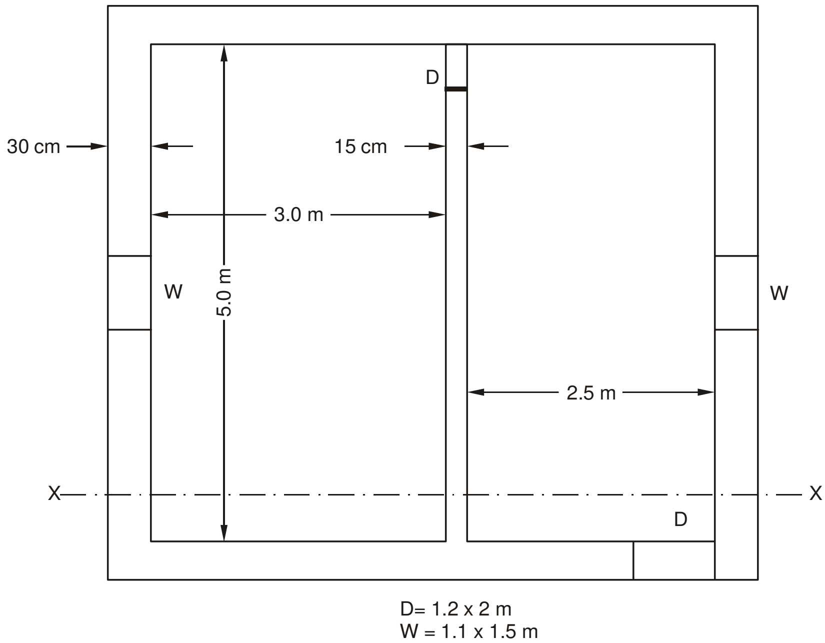
(a) Plan of the Hut – Clear Height of Rooms = 3.5 m



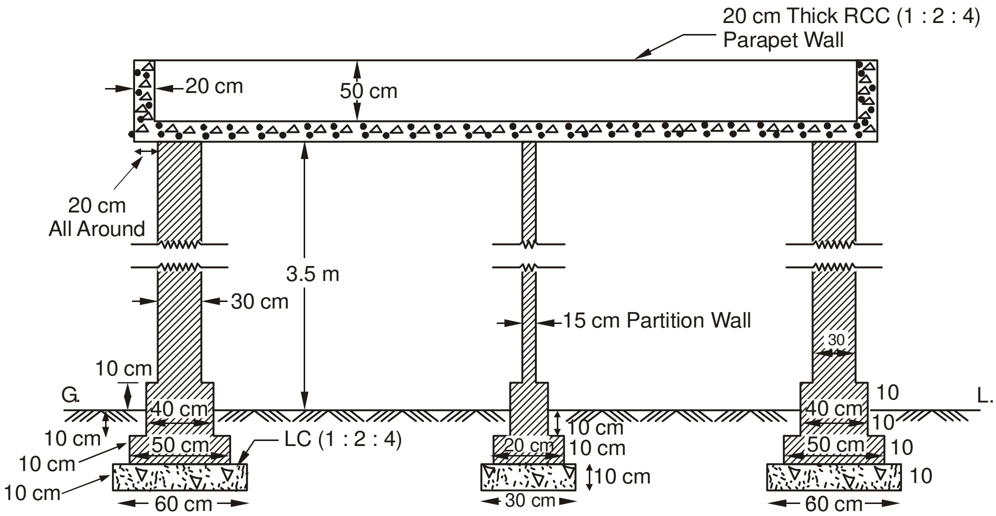
(b) Sections through Walls

Figure 2.4 : A Two Roomed Hut for Use of Labour

(b) A contractor could not complete a two-roomed structure (Figure 2.5) due to some dispute with the owner on the terms and condition of the contract.



(a) Plat at Window Level



(b) Section at X-X

Figure 2.5 : An Incomplete Two Roomed Structure – SAQ 1 (b)

The arbitrator ordered a fresh appraisal of the work done, till date, about the quantities done and specifications followed.

As an exercise you may quantify the lime concrete work done as well as the RCC work in the parrapet wall at the top of the roof slab.

SAQ 2

Write short notes on the following :

(a) Rate analysis of cement concrete work.

(b) General specifications of cement concrete work.

2.6 ACTIVITIES

Collect the relevant drawings (plans, and sections) of a simple building that is already constructed – either from municipal authorities or other agencies, and estimate the LC and CC items done in that work.

Compare your results, later on, with the quantities estimated in the data you have collected – for any miss outs you have gone into.

In Unit 3, study the Examples given and calculate, on your own, LC and CC items and compare the results with the quantities estimated there in – if these items are not computed there, you still do it as an exercise.

2.7 SUMMARY

Quantification of LC ands CC as used in a building is an easy procedure once the student is able to take out the required dimensions – length, breadth, and thickness (i.e. height).

For these items of work to come up satisfactorily, the relevant specifications have to be followed – in the quality of materials, proportioning, mixing, laying, and curing. Any relaxation in the supervision of these aspects affects the work badly.

For appropriate measurements, laid-down norms are being followed universally.

In the next unit, we will study the general specification of RCC work along with the estimation of brickwork in single storey buildings and stone masonry.

2.8 ANSWERS TO SAQs

SAQ 1

(a) Length of centre-line

For 40 cm-thick walls $= 2\left[3 + 0.3 + 2 + 2\left(\frac{1}{2} \times 0.4\right)\right]$

$+ 2\left[4 + 2\left(\frac{1}{2} \times 0.4\right)\right]$

$= 20.20$ m

For 30 cm-thick walls $= 4 + \frac{1}{2}(2 \times 0.4) - (0.8)$

$= 3.60$ m

(Here, 0.8 m is the trench width of the thicker wall – section A–A)

As already pointed out, long and short wall lengths and widths too keep changing as we go up, course by course, towards the ground level (GL).

Following Table presents the necessary measurements, and works out the required quantities :

Details of Measurement : Bill of Quantities

Item No.	Details/Description of Item of Work	No.	Dimensions L (m)	B (m)	H/D (m)	Contents / Quantity	Total	Remarks
1.	Lime Concrete in foundations							Once earthwork in excavation is calculated, LC in foundations can be directly written as (1/3)rd of that quantity, because the thickness of LC = 20 cm = 60/3, other dimensions remaining same.
	(a) By centre - line method							
	40-cm walls	1	20.20	0.8	0.2	3.232		
	30-cm walls	1	3.60	0.7	0.2	0.504	3.74 m^3	
	(b) By L-S wall method							
	(i) 40-cm walls							
	Long wall	2	6.5*	0.8	0.2	2.08		
	Short wall	2	3.6*	0.8	0.2	1.152		
	(ii) 30-cm wall	1	3.6**	0.7	0.2	0.504	3.74m^3	
	* [*3+0.3+2+0.4+0.8=6.5m; and 4+0.4-0.8 = 3.6 m*]							
	** [*4+0.4-0.8=3.6m - i.e, same as the length of 30-cm short walls*]							
2.	*2.5 cm thick DPC* (*1:2:4*)							
	(a) By centre line method							
	40-cm walls	1	20.20	0.50	0.025	0.253		
	30-cm walls	1	3.60	0.40	0.025	0.036	0.29 m^3	
	Deduct the door sills, for these are covered by the CC in flooring							
	40-cm wall	1	1.0	0.5	0.025	0.013		
	30-cm wall	1	1.0	0.4	0.025	0.01	(–) 0.02 m^3	
	Net DPC						0.27 m^3	
	(b) By L-S wall method							
	(i) 40-cm walls							
	Long walls	2	6.2*	0.5	0.025	0.155		
	Short walls	2	3.9*	0.5	0.025	0.098		
	(ii) 30-cm walls	1	3.9	0.4	0.025	0.039	0.29 m^3	
	Deduct for door sills as computed above						(–) 0.02 m^3	
	Net DPC						0.27 m^3	
	* [*3 + 0.3 + 2 + 0.4 + 0.5 = 6.2 m; & 4 + 0.4 – 0.5 = 3.9 m*]							
3.	*2.5 cm thick CC (1:2:4) flooring*							
	(i) 4 × 3m Room	1	3	4	0.025	0.30		
	(ii) 2 × 4m Rooms	1	4	2	0.025	0.20	0.50 m^3	
	Add door sills as calculated above (for deduction)						(+) 0.02 m^3	
	Gross CC in flooring						0.52 m^3	

Item No.	Details/Description of Item of Work	No.	Dimensions			Contents / Quantity	Total	Remarks
			L (m)	B (m)	H/D (m)			
4.	*Lintels*							
	(a) 15 cm thick RCC over doors							
	(i) on 40-cm wall	1	1.2	0.40	0.15	0.072		1.0 + 2 (0.1) =1.2 and 0.9 + 2 = 1.1
	(ii) on 30-cm wall	1	1.2	0.30	0.15	0.054		
	(b) 10 cm thick RCC over windows	3	1.1	0.4	0.10	0.132	0.26 m^3	

(b) Calculations and bills of quantities based on the data are summarized below :

Length of excavation in each long wall

= 3 + 0.15 + 2.5 + 0.3 + 0.6

= 6.55 m

Length of excavation in each short wall

= 5 + 0.3 – 0.6 = 4.7 m

LC (1 : 2 : 4) in Foundations

Item	No.	L (m)	B (m)	D (m)	Quantity (m^3)	Total
Long walls	2	6.55	0.6	0.1	0.786	
Short walls	2	4.70	0.6	0.1	0.564	
Partition wall	1	4.70	0.3	0.1	0.141	1.49 m^3

(Partition wall length is the same as for short walls)

Length of the parapet wall along the long wall side

= 3 + 0.15 + 2.5 + 2(0.3) + 2 (0.20)

= 6.65 m

This leaves the length of the parapet wall along the short wall side

= 5 + 0.3 + 0.3

= 5.6 m

20-cm Thick RCC (1 : 2 : 4) Parapet Walls (All Around)

Item	No.	L (m)	B (m)	D (m)	Quantity (m^3)	Total
Long - wall side	2	6.65	0.20	0.5	1.33	
Short - wall side	2	5.6	0.20	0.5	1.12	2.45 m^3

UNIT 3 ESTIMATION OF BRICKWORK IN SINGLE STOREY BUILDINGS; STONE MASONRY; GENERAL SPECIFICATIONS OF RCC WORK

Structure

3.1 Introduction

Objectives

3.2 Quantification of Brick Masonry : Dimensions of Masonry Work in Buildings

3.3 General Specifications for Brickwork – Walls and Arches

3.4 Classification of Ordinary Buildings : 1st Class, 2nd Class and 3rd Class

3.5 Case Study : Brick Masonry and Other Items in a Building

3.6 Estimation of Brick Masonry in Arches

3.7 Typical Rate Analysis of Brick Masonry

3.8 Stone Masonry

3.9 Summary

3.10 Answers to SAQs

3.1 INTRODUCTION

The oldest man-made building block is the unbaked brick – and, it is still in use inspite of the increasing use of cement concrete with or without reinforcement. Bricks and the mortar to be used (foundations, walls, and now almost obsolete practice of reinforced brickwork in roofs and stairs, etc.) shall be fully specified (described) while measuring up the work. If any bond is specified (English, Flemish, etc.) it shall be so stated.

General brickwork includes building in ends of beams, slabs, lintels, sills, trusses, joints etc.; building in hold fasts etc.; preparing tops of existing walls for further raising work to be carried out; leaving holes for pipes etc.; bedding wall plates, lintels, sills, corrugated sheets, etc. in or on walls if not paid for separately; etc. Footings (of foundations), plain copings (on compound or other exposed walls), etc. also fall in the general category of brickwork.

Brickwork is generally measured in m^3. However, one-brick-thick walls (and of lesser thickness) shall be measured in m^2 stating specifically the thickness of the item. For a fraction of half brick wall thickness, occurring in architectural embellishments shall be measured such as :

(a) up to ¼ brick – give actual measurements,

(b) more than ¼ brick – taken as a full half-brick thick.

Deductions in the quantity of brickwork shall be made for lintels, doors, windows, etc. But, no deductions on additions shall be made for the following features done in the work :

(a) a dissimilar material (say, beams, lintels, etc.) measuring up to 0.10 m^2 in section,

(b) cement concrete blocks used for fixing hold fasts and holding down bolts,

(c) wall plates, bed plates, bearing of slabs etc., where thickness does not exceed 10.00 cm, and the bearing does not extend over the full wall thickness, and

(d) iron fixtures, i.e. wall ties, pipes up to 30 cm dia, and hold fasts for doors and windows.

Pillars and columns are to be measured in m^3, and to be fully described – rectangular, polygonal; curved (in plan); or any special shape.

All circular brickwork, above 6.0 m radius, shall be included in the general brickwork. But, all brickwork, circular in plan and radius not exceeding 6.0 m is measured separately, and shall include all cutting and waste, etc.

At certain places it is a practice to lay the damp proof courses of bricks too – laid on edge. All such work shall be measured in m^2, stating its thickness. Vertical and horizontal DPC shall be measured separately.

As a common classification, brick masonry (or even stone masonry) shall have following categories (to be paid for accordingly – as the height form GL increases, and labour to lift the brick too increases) :

(a) brickwork in foundations (footings, etc.),

(b) brickwork in plinth below GL and above GL, and

(c) brickwork in superstructure – work in each floor measured separately.

Scaffolding for ordinary works is not measured and paid for separately but is included in the rates for brickwork (BW).

Rounded or splayed sides of walls are considered as rectangular, and those very dimensions are employed for computing quantities. As for other, such items, dimensions shall be measured to the nearest 0.01 m (i.e. 0.1 cm) areas shall be worked up to the nearest 0.01 m^2; and the cubic contents shall be worked up to the nearest 0.01 m^3.

For bricks of nominal size (22.9 × 11.4 × 7.6 cm), the half-brick size is taken as 11.4 cm, for bricks of nominal size (25.4 × 12.7 × 7.6 cm), the half-brick size is 12.70 cm; and for model bricks of 20 × 10 × 10 cm, the half-brick size is 10.0 cm. Hence, for different brick sizes, wall thickness given in table below is taken into account :

Wall Size as Multiple of Brick Size	**Thickness of Brick Wall (cm)**	
	For Brick Size	
	20 × 10 × 10 cm	22.9 × 11.4 × 7.6 cm
One-brick wall	20.0	22.90
1½ - brick wall	30.0	34.30
2-brick wall	40.0	45.70
2½ - brick wall	50.0	57.10
3 - brick wall	60.0	68.60

Objectives

After studying this unit, you should be able to

- estimate the quantity of brickwork (BW) in the foundations of a building,
- estimate the quantity of BW in plinth, and superstructure,
- develop a full plan of a building, given its *line plan*,
- estimate the quantity of BW in arch work,
- describe the general specifications regarding RCC work, and
- explain the general specifications about stone masonry.

3.2 QUANTIFICATION OF BRICK MASONRY : DIMENSIONS OF MASONRY WORK IN BUILDINGS

In the procedure for the quantification of brickwork, two approaches – Centre-line, and Long- and Short-wall methods – are applicable. While in the case of centre-line approach (in straight forward cases), the total length dimension remains unchanged with the width and height of the masonry courses (in footings, plinth, and superstructure) varying according to the design as detailed in the given section of the wall; but the length dimensions (as well as width and height) in long- and short-wall method do register a change from course to course (Figure 3.1).

In fact there are no strict straight-jacket rules for arriving at (taking out) dimensions from the plan, elevation, and sectional drawings – experience and suitability (vis-à-vis, each drawing) always guide one dividing a plan into parts so that the dimensions are easily worked out for ultimately computing the quantities. Three procedures (for the sake of clear understanding of full basics of the mode of mensuration) however, are available concerning the quantification of foundation work – excavation, concreting and masonry – and superstructure in a given building as listed hereunder :

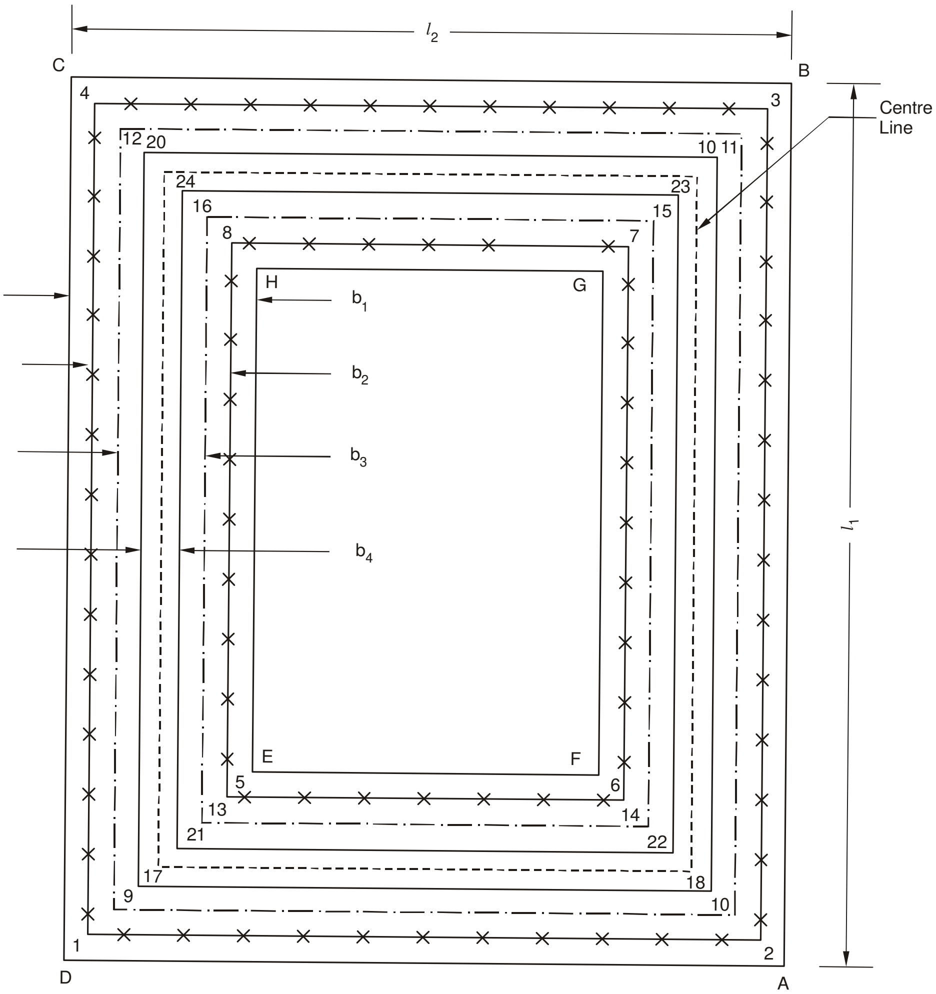
(a) out-to-out and in-to-in method (i.e., long- and short-wall method),

(b) crossing method, and

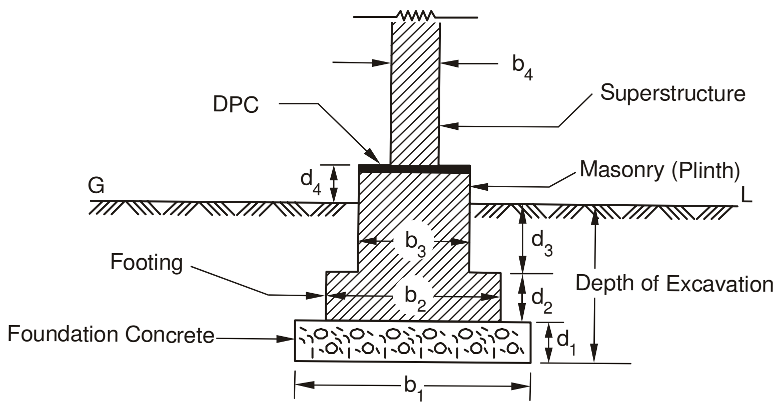
(c) centre-line method.

Out-to-out and in-to-in method is the most commonly adopted procedure. Here the length of long walls (say for excavation purposes) are reckoned from out to out – AB in Figure 3.1 – and, the length of short walls measured in between the long walls in-to-in – EF. These lengths shall, obviously, apply to foundation concreting also. The magnitude of these dimensions changes (in fact, decreases) for long walls, and increases for short walls at every change in the breadth (or, ray, thickness) of a course of brickwork :

AB will decrease to $\left(AB - 2 \times \frac{[b_1 - b_2]}{2} \right)$, i.e. for the first footing of the foundation masonry the length of long wall shall be (2 – 3). And, EF shall increase by the same amount, becoming $\left(EF + 2 \times \frac{[b_1 - b_2]}{2} \right)$, i.e. (5 – 6). Here, the width for excavation is b_1 and height (or thickness, vertically) is d_1; while for the first footing, width = b_2, and depth = d_2. Similarly, in the plinth course (or for next footing if it is there), long wall length shall be [(10) – (11)], and short-wall length shall be [(15) – (16)] – width being b_3, and depth = $(d_3 + d_4)$. And for the superstructure, long-wall will have a length [(18) – (19)], and short wall length will be [(23) – (24)] – width being = b_4, and height = height of the room from the top of DPC (of floor top) to the underside of roof slab (or whatever it is). Here it is important to point out that the width and depth of excavation shall be b_1 and $(d_1 + d_2 + d_3)$, respectively; while for foundation concrete the values will be b_1 and d_1, respectively.



(a) Trench Plan



(b) Section

Figure 3.1 : A Simple Rectangular Trench Plan of a Building and Section of Wall-cum-Foundation

It is obvious that with the decrease in the thickness of walls of a room, (i.e. proceeding up from the first footing towards the superstructure) the length of a long wall decreases, whereas the length of a short wall increases in accordance with the breadth (or, thickness as it is generally designated). At the plinth level, the length of long wall = the length of the room (wall to wall, i.e. inner dimension plus twice the wall thickness; and the length of short wall = width of the room (inner dimension). If the thickness of the walls is different, the dimensions are reckoned accordingly.

Example 3.1

A 20 cm brick wall (of a 4.8 × 3.30 m hut, having one door opening 1.5 × 2.5 m) has directly a beam built on a 30 cm thick plinth which goes 20 cm below ground level and remaining 50 cm above ground. Under this plinth there lie two footings – 40 cm, and 60 cm thick (i.e., wide), respectively, while their respective heights are 10 cm and 20 cm. The LC is 100 cm wide and 20 cm deep.

All this brickwork has been erected on LC 1.0 m thick (i.e., wide) and 20 cm deep.

Draw the cross-section of the wall and the foundation (to an enlarged scale) and also the trench plan, superimposed with the plan for footings, plinth and wall.

Calculate the following items of work by Long- and Short-wall method (as well as by centre line method) :

(a) Earthwork in excavation,

(b) LC in foundation,

(c) Brickwork in first two footings,

(d) Masonry in the plinth,

(e) Masonry in superstructure.

Take the height of the hut form the plinth = 3.5 m.

Solution

[**Note :** *The student shall draw the figures: section and plan as asked for and check the dimensions therewith as worked out in this solution*.]

The following Table presents the quantification of the required items by Long- and Short-wall procedure :

Quantification of Items

Sl. No.	Items	No.	Dimensions			Quantity	Remarks
			L (m)	B (m)	H/D (m)	(m^3)	
1.	Earthwork in excavation						
	(i) Long walls	2	6.0	1.0	0.70	8.4	
	(ii) Short walls	2	2.5	1.0	0.70	3.5	
					Total	**11.9 m^3**	

2.	LC in foundations		$11.9 \times \frac{0.20}{0.70}$			3.4 m^3	Length and width of LC is same as for Item (1) except its depth being 20 cm
3.	Masonry (BW) in two footings 1st footing						(i) Long wall shorter by 2 × 0.2 m each; and short walls lengthen by 2 × 0.2 m each for 1st of footing (ii) For second footings these adjustments are 2 × 0.1 m and 2 × 0.1 m, respectively, w. r. t. the first footing lengths.
	Long walls	2	5.60	0.60	0.20	1.34	
	Short walls	2	2.90	0.60	0.20	0.74	
	2nd footing						
	Long walls	2	5.40	0.40	0.1	0.43	
	Short walls	2	3.1	0.40	0.1	0.25	
		Total of Item (3)				**2.72 m^3**	
4.	Masonry (BW) in the plinth						Here, the adjustments are 2 × 0.05 m for the respective walls, w. r. t. the second footing
	Long walls	2	5.30	0.3	0.70	2.23	
	Short walls	2	3.2	0.3	0.70	1.34	
					Total	**3.57 m^3**	
5.	Masonry in superstructure (BW)						Here the adjustments for the lengths of respective walls are 2 × 0.05 m each w.r.t item (4)
	Long walls	2	5.2	0.20	3.5	7.28	
	Short walls	2	3.3	0.20	3.5	4.62	
			∴ Gross Total			11.90 m^3	
	Deduct Door Opening	1	1.5	0.20	2.5	(–) 0.75	
		Net for Item (5)				**11.15 m^3**	

In crossing method (basically nothing but long- and short-wall method itself, suitable for symmetrical cases), length and breadth of walls are directly taken from the plan, such as :

Length of any long wall (at *any level of the cross section*) = Inner length of the wall + 2 × (wall thickness).

Length of short wall = Inner length of the wall (i.e. inside to inside).

It is by now obvious that this method is suitable only while the offsets (of one footing w.r.t. to the adjacent one) are symmetrical, and the building is more or less regular. For any asymmetries detailed calculations from the plan dimensions are called for.

In centre line method, the plan of a building helps one to compute the total length of the centre line. This method is most suited to find the quantities of earthwork in excavation, masonry in walls, etc., when the plan is curved, rectangular, circular, etc.

In Example 3.1, one can see that the length of centre line
= 2 × [6.00 – 2 × 0.5 (i.e., width of the trench)] + 2 [4.5 – 2 × 0.5]

= 2 (5) + 2 (3.5) = 10 + 7

= 17.0 m

Hence, one can work out the required quantities also as follows :

(a) **Earthwork in Excavation**

Sl. No.	L (m)	B (m)	H (m)	Quantity (m^3)
1	17.0	1.0	0.7	11.9 m^3

(b) **LC in Foundation**

Sl. No.	L (m)	B (m)	H (m)	Quantity (m^3)
1	17.0	1.0	0.2	3.4 m^3

(or $11.9 \times \frac{0.20}{0.70} = 3.4$ – this mode of calculation being most common for reasons given earlier).

(c) **Masonry (BW) in Two Footings**

Sl. No.	L (m)	B (m)	H (m)	Quantity (m^3)
1st footing				
1	17.0	0.6	0.2	2.04 m^3
2nd footing				
1	17.0	0.4	0.1	0.68 m^3
			Total	**2.72 m^3**

(d) **Masonry (BW) in Plinth**

1	17.0	0.3	0.7	**3.57 m^3**

(e) **Masonry (BW) in Superstructure**

1	17.0	0.2	3.5	11.9 m^3
1	1.5	0.2	2.5	(–) 0.75 m^3
			Net for item (5)	**11.15 m^3**

In actuality, a full building plan is somewhat complicated in its juxtaposition – there being cross walls joining two parallel walls (say, either long to long, or short to short), or there being walls that are of different thicknesses, etc. – and, the application of centre line method shall not be done without applying a proper thought. While multiplying the length of a centre line by the thickness of the trench or a course, one actually, in this process, accounts for that portion of the centre line that joins it via a cross wall or so. Hence, appropriate deductions (according to the width, i.e. thickness of the course) have to be applied to the gross length of the walls for getting correct results with respect to the quantification of an item – these finer points shall be made clear in the following examples.

It may be pointed out that sometimes for a quick approximate estimation, in the case of a number of foundation masonry footings such as shown in Figure 3.1– or, a section with still more footing – the cubic quantity of masonry is taken as

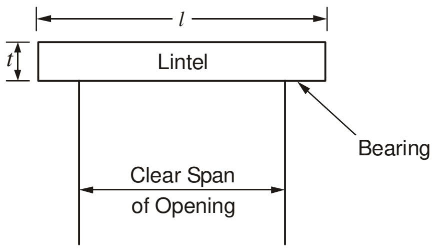
$$Q = \text{Appropriate mean length (i.e., the appropriate centre-line length)} \times \frac{(b_2 + b_3 + ... + b_n)}{(n-1)} \times [d_2 + d_3 + ... + d_n]$$

It may again be emphasized that this formula is only an approximation, and not meant to replace detailed calculations.

As mentioned elsewhere (later on) class of bricks, materials of mortar, and different heights of construction in a building, **are the factors that govern the estimation of brickwork under various groups (headings).** In general, scaffolding is included in the rates of payment, unless otherwise stated – unit of measurement being **m^3**. Brickwork in superstructure up to a height of 8.0 m, above the plinth level is taken under one item; and above 8.0 m height, the quantities for every 3.0 m height or its part are calculated under separate items. Rounded or splayed sides (as reiterated later on also for the sake of impressing the point) of walls are considered as rectangular, and extreme dimensions are taken for the purposes of computations.

Deductions Made in the Gross Contents

Deductions for openings (doors and windows and cup boards) are necessarily made in the gross cubic content of masonry to arrive at the appropriate quantity for which specified rates are given – commonly, deductions are made in superstructure masonry only.



Lintels over openings (doors, windows, cup boards) may consist of RCC, or RB work, or wood (as in earlier times), or simple bricks placed in transverse direction to the bricks of the wall – unit of quantification is m^3. These items are paid for separately, and are to be deducted from the gross quantity of masonry. In the absence of data about the bearing of lintel (on either side),
l (the length of the lintel) is calculated as :

$$l = \text{Clear Span} + 2t$$

where, the value of $2t$ should, at least, be taken as 12 cm. Thus, the cubic content of the lintel, Q, is given as :

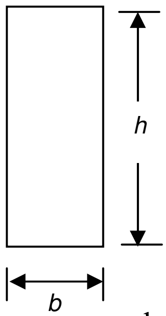
$$Q = l \times t \times \text{(Thickness of wall)}$$

Similarly, for rectangular openings (doors, windows, cup boards),

$$\text{Deduction} = b \times h \times \text{Wall thickness}$$

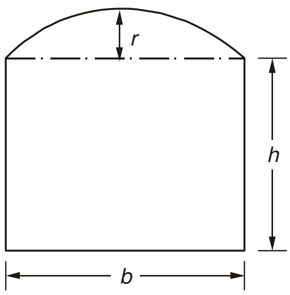
For doors and windows with small segmental arches (i.e. r is very small), the openings are considered as rectangular only :

$$\text{Deduction} = b \times h \times \text{Wall thickness}$$



In the case of segmental arch openings, with rise, r,

$$\text{Deduction} = (b \times h \times \text{Wall thickness}) + (\frac{2}{3} \times b \times r \times \text{Wall thickness})$$



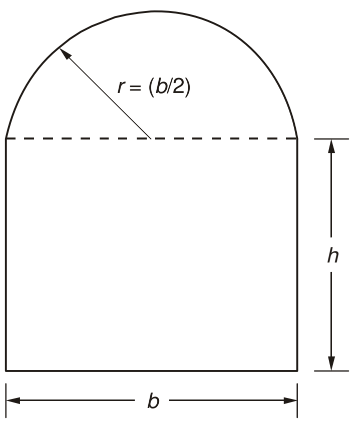
Segmental Arch

where, $\frac{2}{3} \times l \times r$ is an approximate estimation, but usefully adopted in practice.

For a small semi-circular arch opening,

$$\text{Deductions} = [b \times h \times \text{Wall thickness}] + (\frac{3}{4} \times b \times r \times \text{Wall thickness})$$

where, $b = 2r$



Semi-circular Arch

Elliptical Arches are Considered as Semi-circular for Purposes of Deductions

However, large arches are dealt with on the basis of rigorous mathematical formulae.

As pointed out in the *general specifications*, partition walls (that are not load bearing) that may be 10 cm or 12 cm thick, are designated as $\frac{1}{2}$-brick walls (or brick on – edge walls). The quantities are calculated in m^2 or, sometimes in m^3, as per given rates of payment.

Mensuration as Applied to the Quantification of Masonry

Knowledge about deciphering drawings (plan, sections, and elevation – even side elevation sometimes) is the basic skill needed for an estimator. This calls for a clear concept (and imagination too) about the structure that is depicted: a prerequisite to reading a drawing, to enable taking length, breadth (width), thickness and heights accurately. Constant, and sustained practice goes a long way to render this seemingly difficult task very easy, because by this toil one develops an understanding about the various components of a structure.

Mensuration (and, a knowledge of trigonometry), comes handy, once the dimensions are read accurately, in computing the quantities. Commonly used mensuration formulae are given as under, for a ready reference, and brushing up one's knowledge :

(a) **Rectangle**

Area, A = Length × Breadth

Diagonal = $\sqrt{(\text{Lenght})^2 + (\text{Breadth})^2}$

(b) **Square**

$A = (\text{side})^2 = 0.6366 \times (\text{Area of circumscribing circle})$

$= 1.2732 \times (\text{Area of inscribed circle})$

Diagonal = $(\sqrt{2}) \times \text{Side}$

$= 1.4142 \times \text{Side}$

(c) **Triangle**

$$A = \frac{1}{2} \times \text{Base} \times \text{Altitude}$$

Also, $A = \sqrt{[s\,(s-a)\,(s-b)\,(s-c)]}$

$$= \frac{a \times b \times c}{4R}$$

$$= r \times s$$

where, a, b, c are sides of the triangle

$$s = \frac{1}{2}\,(a + b + c)$$

R = Radius of the circumscribed circle, and

r = Radius of the inscribed circle.

(d) **Circle**

$$A = \frac{\pi}{4}\ (\text{diameter})^2$$

$$= \pi\ (\text{radius})^2$$

$$= 0.07958\ (\text{circumference})^2$$

Side of an inscribed square = 0.707 α (diameter)

Side of a square that is equal to the circle in area = 0.8862 × Diameter.

(e) **Semi-circle**

Centre of gravity = $\frac{4r}{3\pi}$ from its diameter

Length of an arc = $\frac{\phi^o}{360} \times 2\pi r = \frac{\phi \times r}{57.3}$

$= 0.01745\ \phi \times r$

where, ϕ = Central angle of the arc (in degrees).

(f) **Sector of a Circle**

$$A = \frac{\phi^o}{360} \times \pi r^2 = \frac{1}{2} \times r \times (\text{Length of the arc})$$

where, ϕ = Angle substended by the arc at the centre (in degrees).

Short-cuts to Calculations of Some Related Items

By application of following rules, elaborate calculations can be replaced by easy and quick calculations.

(a) **Foundation Concrete (LC/CC)**

$$\text{Quantity} = \frac{\text{Quantity of earthwork in excavation}}{\text{Depth of foundation trench}} \times (\text{Thickness of foundation concrete})$$

This holds good only if the width (thickness) and depth of concrete is uniform throughout. For non-uniform dimensions, computation can be made by parts.

(b) **Inside White Washing (or Distempering of Walls and Ceiling)**

Its quantity (m^2) shall be the same as for inside plastering of walls and ceiling.

(c) **Outside Colour Washing**

Its quantity (m^2) shall be the same as for outside plastering or pointing.

(d) **Sand (or Cinder) Filling in Plinth**

Its quantity (m^3) =

$$\frac{\text{Quantity of earth filling in plinth}}{\text{Depth of earth filling}} \times \text{Required depth of sand filling}$$

3.3 GENERAL SPECIFICATIONS FOR BRICKWORK – WALLS AND ARCHES

Brickwork is designated as 1st, 2nd, or 3rd class brickwork according to the quality of the bricks and/or mortar used in the construction of this masonry. Thus, specifying the mortar (say, 1 : 4 cement, sand, etc.) with which the work is built, is an essential part of its designation.

Before any brickwork is begun to be constructed, *soaking* of bricks is the first step. This is of importance in the case of brickwork to be done in *cement mortar*, or composite lime mortar (other than C and D categories of lime mortar – eminently hydraulic lime is taken as class A category of lime; class C lime is known as fat lime, etc.). Bricks shall be adequately soaked in stacks, before use, and shall be profusely sprayed with clean water at regular intervals *for a period of not less than six hours*. However, in compliance with the strict old theoretical principles, they shall be immersed for 24 hours in a clean water body (tank, etc.). Bricks shall be placed in the tank or pit by hand, one at a time, and not thrown or tipped in. This procedure is meant to fill the pores of the brick so that it does not absorb the moisture of the mortar and thus allowing it to set properly and gain the intended strength. Tests have indicated that practically bricks absorb no further water after 15 minutes to one hour soaking in a pit. Bricks to be used with mud mortar, need not be soaked. It may be pointed out that *kacha* bricks built in mud mortar form very strong wall till it remain dry.

Bricks are laid generally in English bond with if frogs upwards if nothing else is specified. Half or cut bricks are not to be used except to complete the bond in a given course, *closers* is in such situations shall be done to the required size to be expressly used near the ends of a wall.

Wherever there is *exposed* brickwork, it is important to use only selected bricks as specified, because such parts of the work form the *face* of the work which demands a neat, decent look (*façade*).

Each brick shall be set with both bed and vertical joints filled with mortar, and bricks bedded in and set home (in position) by gentle tapping with the handle of the trowel or wooden mallet. Simple lipping with mortar at the edges shall not be permitted. All horizontal joints shall be parallel, and, unless otherwise specified, truly level. Vertical joints in alternate courses shall come directly over one another. All brickwork shall be taken up truly plumb and each brick mason (i.e., brick layer) shall be provided with a plumb bob and a straight edge.

A layer of mortar shall be spread over the full width covering a suitable length of the lower course. The inside face of a freshly laid brick shall be buttered with mortar before its adjacent brick is laid and pressed against it. On the completion of a course, all vertical joints shall be fully filled from the top with mortar. No portion of work shall be left (while building up) more than one meter below the rest of the work.

Thickness of joints shall not exceed 1.0 cm in a brickwork. All the face joints shall be raked to a minimum depth of 15 mm by the raking tool during the progress of work, when the mortar is still *green* – it helps provide a proper key for the plaster or pointing to be done. Where pointing/plastering is not required to be done, the joints shall be struck flush and finished at the time of laying. The face of brickwork must be cleaned on the very day the work is laid – also, all mortar droppings shall be removed promptly.

It is to be emphasized that for any face work, bricks shall be selected for trueness of edges, shape and colour – these shall not be chipped or stained during the progress of the work. Moreover, as is understood, bricks shall be laid as to give a perfectly straight and vertical face to the wall as to be always tested with a straight edge; and no chipping or rubbing of the faces will be permitted to remedy any bed laying. Bricks shall be cut or grooved where required for shaping jambs or fitting *chowkats*. Corners, where special bricks for the purpose are not available, shall be made with cut bricks, five being used per corner. Rates can include labour for this cutting of bricks and making of mitres, splays, etc., except grooving to receive *chowkats*.

Holdfasts and similar fixtures shall be built in with the surrounding brickwork in their correct positions in 1 : 3 cement mortars.

First Class BW

Only headers shall be left out to allow of a *putlog* (one of the short timbers that support the flooring of a scaffold) to be inserted, and not more than one brick shall be left out for each putlog. Under no circumstances shall putlog holes be made in, or immediately under, or next to the imposts or skewbacks of arches.

Brickwork laid in lime and/or cement mortar shall be protected during construction from the effects of the sun, rain, and frost, by appropriate covering if necessary, *and shall be kept moist for a period of* **ten days**. The work shall be, as per theoretical considerations, left flooded at the end of each day with 2.5 to 3.00 cam of water.

In buildings where specified (say, hospitals, etc.), cut or specially moulded bricks shall be used at all angles (formed by the junction of two walls) to give rounded corners. Similarly, wherever required, cut or moulded bricks shall be used in joints, arches and projecting corners in order to avoid the formation of sharp angles from the inside of such buildings.

Bed plates of 1 : 2 : 4 cement concrete (CC), or of stone shall be given under all beams and joists – for stones 1 : 3 cement mortar (CM) shall be used. Bed plates must be laid to the correct level (as per drawing/estimate) packing up, if needed, with tiles or split bricks.

In first class BW, the size of bricks shall be specified. These are made from good brick earth, free from saline deposits and shall be sand moulded. These shall be thoroughly burnt without being vitrified; shall be of good (reddish) colour, and be of regular and uniform shape and size, with sharp and square rises and parallel faces. First class bricks must be homogeneous in texture; *and must emit a clear ringing sound when struck*. These shall be free from flaws, cracks, chips, stones, nodules of lime or kankar and other blemishes. A first class brick shall not absorb more than 1/6th of its weight of water after being soaked for one hour, and shall show no signs of *efflorescence* on drying.

Second Class BW

Second class bricks shall be as well burnt as first class, or slightly over burnt, but not vitrified in any part and must give a clear ringing sound when struck. In second class bricks, slight irregularities in size, shape, or colour will be accepted, but in no case if these render the courses irregular or uneven when laid. Slight chips or flaws can be tolerated; but, must be free from lime or kankar nodules. They shall not absorb water more than 1/4th their weight after one hour's immersion.

Second class brickwork shall differ from first class only in that it shall be laid out with second class bricks. Specifications laid down for first class brickwork (as detailed above) shall apply *in toto*, except that the select bricks may not be used in face work. *However, no cut brickwork shall be executed with second class bricks.*

Third Class BW

Third class bricks need not be so fully burnt (*baked*) as first class or second class – however, they must be burnt to a reddish yellow colour *throughout*. Any defects in uniformity or shape can be accepted till these blemishes do not cause difficulty in obtaining uniform courses when laid.

Third class BW shall differ from first class brickwork, in that it shall be laid with third class bricks. Under-mentioned modifications are applicable to the specifications meant for first class brickwork :

(a) Brickwork laid in mud-mortar shall be protected during construction from rain or from uneven drying.

(b) Third class brickwork shall not be laid in 1 : 3 cement mortar.

(c) Joints in third class brickwork shall be 1.25 to 1.30 cm thick : but, in no case shall exceed 1.60 cm in thickness. The height of four courses as laid (with four joints) shall not exceed by more than 5.0 cm, the height of four bricks as piled dry one upon another.

(d) As the depth of courses is different from that in the case of first and second class brickwork, third class brickwork shall not be used where it has to bond with the brickwork of superior classes.

(e) No selection of bricks for face work shall be insisted upon.

(f) No cut brickwork shall be executed with third class bricks.

Bricks and Brick Tiles other than Classed Ones

Underburnt (or *pilla*) bricks shall not be used in the construction of brickwork except in sundried brickwork. Bricks that are so much overburnt as have gotten vitrified as distorted are known as *jhama* bricks, and are of no use for exact work. However, these are broken up for ballast provided the vitrified mass has not become porous or spongy in the process of being overburnt.

Sundried bricks shall be made from the same kind of clay that will produce good bricks on being properly burnt. These shall be sand moulded and shall be uniform in size and regular in shape. If after drying, a few bricks (picked up at random) from a batch break into more than two pieces on being dropped on an even ground from a height of about 1.30 to 1.50 m, the batch must be rejected as having beam moulded with too much sand. Batches of bricks in which cracks appear on drying shall be rejected as having been moulded with too little sand. Special care shall be taken that the earth used for making sun-dried bricks is free from *efflorescing* salts and from all traces of white ants. All sun-dried bricks shall be thoroughly dried before use; and have to be protected from rain – sun dried brick walls are given a facing of burnt bricks, or given a *mud-phaska* (mud + cut paddy grass leaves, i.e. straw) plaster (or even cement plaster). These walls stand very well till no moisture goes into this masonry. These are laid in mud mortar. Unless otherwise specified, two courses, underneath the roof (say, a pitched roof) battens, and the jambs of doors and windows (to a depth of 23 cm) shall be built in second class brickwork in mud. All roof beams shall also be carried on piers of second class BW in mud for the full height of the wall.

Brick tiles (burnt) are used in roofing (over, say, RCC slab) or even flooring.

Brick Ballast

Brick ballast shall be broken to the specified gauge, from first or second class bricks or their bats or from dense overburnt bricks. No under-burnt bricks or bats, nor *jhama* that has become spongy or porous in the process of burning, shall be broken up for ballast.

Brick ballast is used as a flooring base (over the filled earth up to plinth top) over which LC/CC etc. is laid to give the designed floor level and finish.

Ballast shall be free from surkhi, leaves, straw, earth, sand or any other foreign matter. To allow for loose stacking (before use, i.e., before spreading over earth between plinth walls, and ramming to adequate thickness), all stacks of ballast shall be paid as 30 cm for every 32.50 cm in height.

Half-brick Wall Masonry

The work shall be done in the same way as other brickwork, except that all the courses shall be laid with stretchers with staggered vertical joints. In special cases (like half brick walls for water tanks, and long-length half brick thick walls, etc.) sometimes reinforcement is provided to render the work structurally stronger. Generally, two lengths of 6 mm bars are provided at every third course. Reinforcement shall be clean from rust and loose flakes – using a wire brush is quite adequate. The reinforcement is placed quite straight on the mortar laid on the course under consideration. For full embedment of the reinforcement, first half the quantity of mortar is laid and then the rod is placed in position which is later covered with the remaining half the quantity of mortar. This arrangement makes the joint between the two courses stronger.

Such walls do serve as *partition walls* for WCs, baths, etc.

Length and height of this wall shall be measured correct to a cm. If it is to be paid per m^2 units, the area shall be calculated up to the line where the half-brick masonry wall is joined to the main wall of one brick or greater thickness – the measurements shall be taken for its clear length from the face of the thicker wall. Reinforcement may be paid separately.

Brickwork in Arches

Arches shall not be commenced until the abutments (supporting structure wall or joist) are built to their full width up to the level of the skew-backs. Arch work shall be carried up evenly from both abutments; and as soon as the arch is complete, the masonry is to be built up evenly on both sides to the height of the crown so as to load the haunches.

Before the building of an arch is begun, the abutments must be exactly at the same level and the skew-backs must be in place. Skew-backs shall be formed of bricks correctly shaped to radiate truly from the centre of curvature, and shall not be packed up with mortar or chips. Skew-backs are not to be measured as part of the arch.

Centering shall be strong enough to bear the weight of the arch without deflection. The surface of the centering shall be correctly struck to the curvature of the soffit of the arch. Cost of centering is generally included in the rate for arch work. Centering and shuttering shall also bear the live loads that are likely to come upon it during its construction. Shuttering shall be tightened with hard wood wedges or sand boxes to allow these to be eased without any jerks being transmitted to the arch. The sequence of easing the shuttering is to be planned before hand. Shuttering shall be struck (gradual lowering of the centres) within 48 hours of the completion of the arch but before 24 hours – this shall be done after the spandrel has been filled in and the arch is loaded. A common schedule of striking the centers that can be followed is outlined as under :

Sl. No.	Type of Arches	Striking Schedule
1	Single segmental arch	Centre shall be struck immediately after the arch is finished.
2	Series of segmental arches	Centre of each arch shall be struck as soon as the arch succeeding it is completed
3	Semi-circular, elliptical or pointed arches	Centres shall be struck as soon as the brickwork has reached two thirds of the height of such arches

Specifications for brickwork (as outlined earlier) shall also apply to the brickwork in arches. Arch work shall comprise masonry for both *gauged* as well as *plain* arches – in gauged arches, cut or moulded bricks shall be used; and, in plain arches uncut bricks are used. Defects in dressing of bricks shall not be covered up by any extravagant use of mortar, nor the use of chips, etc. shall be allowed.

The length of the arch shall be measured as the mean of the extrados and intrados of the arch correct to a cm. Generally, the thickness of the arch shall be measured in multiples of half brick. For arches exceeding 6.0 m in span, extra payment shall be made for additional cost of centering, strutting, bolting, wedging, easing, striking and its removal.

Corbelling, Copings, Cornices, Strings, etc.

All corbelling, brick copings, cornices, strings, eaves bricks, window sills, drip courses and chimney stacks shall consist of first class brickwork laid in lime and/or cement mortar as specified in the design. Vertical joints in each case shall not exceed 3.0 to 4.0 mm in thickness. Bricks when laid flat in such courses shall either be altogether without frogs or with frogs at one end so as not to show, either on top or from below, when the bricks are in position.

Corbelling, commonly, shall be effected by ¼-brick projections for ordinary work and 1/8 × brick projections where great strength is required. Corbelling shall be measured by the actual cubic contents, and shall be paid for at ordinary rates for the class of brickwork executed.

All the cornices shall be in accordance with the drawings, and accurately in line with straight and parallel faces. All exposed cornices shall be weathered and rendered on top in 1 : 3 cement mortar, and throated underneath.

Brick cornices, if intended to be pointed, shall be made with specially moulded bricks or bricks cut and rubbed so as to give mouldings true to drawings. The profile shall be checked constantly during construction with a sheet iron template. Cornices, if required to be palstered, shall have bricks that are roughly cut.

Cornices shall be measured and paid for by a linear rate.

For copings, unless otherwise specified, the top courses of all plinths, parapets, steps, etc. shall be built in brick on edge. Coping shall be measured by actual cubic contents.

String courses shall be made in bricks laid flat (or on edge) consisting of one or more courses as required. This work is paid for in cubic contents.

Eaves brick shall be laid flat with a projection of 7.5 cm with a chamfer on the upper edge. Eaves bricks are generally laid in 1 : 3 cement mortar – these are paid by a linear rate.

Window sills shall be made of bricks laid on edge on a tile creasing to keep the joints in line, and will extend to 7.50 cm beyond the opening on either side. The bricks shall project 7.5 cm from the outer face of the wall. Window sills are laid in 1 : 3 cement mortar. Sills shall be paid by a linear rate.

Drip courses, when formed of flat bricks, shall follow the same specifications and are paid for at the same rate as eaves bricks. Sometimes these are built in brick on edge.

Bricks on edge are also laid in flooring and small, minor partitions – and are paid for in m^2 measure.

3.4 CLASSIFICATION OF ORDINARY BUILDINGS : 1ST CLASS, 2ND CLASS, AND 3RD CLASS

With a large amount of data about cost and general specifications of a building one can determine the cost of a building (single, or more storeys high) per m^2 of its plinth area, or covered area as the case may be. This unit cost (subject to variance with escalating material and labour costs) is a tool in the hands of a practising engineer to immediately (whenever asked to do so) estimate the total amount of money to be earmarked for a given construction – it forms the first approximate estimate of cost which needs to be refined by actual, elaborate procedure as outlined so far in this presentation.

When one talks of general specifications of a building (residential, public utility, office complex etc.), it covers all the main items of work. As an example, usual general specifications can be associated with different classes of a single storey residential/office building assumed up in Table 3.1.

Table 3.1 : General Specifications and Classifications of Single Storey Residential/Office Buildings

Item of Work	1st Class Building	2nd Class Building	3rd Class Building
Concrete in Foundations	LC or CC	LC	LC
Brick masonry in foundations and up to plinth top	1st class BW in lime or cement mortar	1st class BW in lime mortar	2nd class BW in lime mortar
DPC (Over plinth top)	Shall consist of CM (1 : 2) for 2.0 cm thickness; and, for 2.50 cm thickness it shall be 1 : 1.5 : 3 CC with 3.5 to 5.0 % (by weight) of suitable water proofing material.	Shall consist CM (1 : 2) of 2.0 cm thickness with 3.5 to 5.0 % (by weight) of suitable water proofing material.	No DPC may be provided at all, or very ordinary type be made (i.e. just nominal one).
Superstructure	It shall consist of 1st class BW with lime or cement mortar.	1st shall be of 2nd class BW in mud mortar, except for the use of LM (lime mortar) in sills, pillars, etc.	Only 2nd class BW in mud mortar shall be used.
Roofing	Roof shall comprise RCC slab with an insular layer, and LC terracing over it. Thickness of RCC beams (if any as per design provisions) shall not be less than 30.0 cm.	Flat terraced roof shall be provided that is supported over wooden battens and beams. Or, a reinforced brick (RB) roof shall be provided; or Jack arch roof (in BW) shall be given with usual terracing. Verandah roof shall consist of tiles or asbestos cement (AC) sheeting.	Tile roofing or galvanized iron (GI) sheeting is provided on ordinary beams. Sometimes mud over planks, or bricks on planks supported by ordinary wooden beams is given.
Flooring	Flooring for drawing and dining room, bath room and WCs shall be of mosaic (chips in appropriate CM). For bed rooms, flooring shall be coloured and polished – 2.5 cm CC over 7.5 cm LC Other floors in the building (say, passages, store rooms, etc.) shall be without colour (2.5 cm CC over 7.5 cm LC).	For all inside floors (i.e., other than verandah) flooring shall consist of 2.5 cm CC over 7.5 c.m LC. Verandah floor shall be of bricks – flat over LC. These shall be finished with cement pointing.	Brick-on-edge floor directly over well-rammed earth.

Finishing	Inside and outside walls shall be cement plastered. Further, drawing, dining, and bed rooms shall be distempered; other rooms (kitchen, stores, etc.) shall have walls white washed (i.e., inside) in three coats. Outside walls shall be colour washed in two coats over one coat of white wash.	Inside walls shall be plastered in lime or cement mortar. Outside walls shall also be lime or cement mortar-plastered or shall be painted. Inside walls shall be white washed in three coats; and outside one can have colour wash in two coats (over one coat of white wash).	Both inside and outside walls shall be plastered with LM and white washed.
Door and Windows	Chowkats (frames – 3-piece or 4-piece. In cold climates, 4-piece frames are a must) shall be of well seasoned good quality timber (or of iron). Shutters shall be paneled, glazed; or partly paneled and partly glazed – in good quality wood. In addition wire-gauze shutters may be provided. Varnishing or painting (two coats) shall be done.	Chowkats of well-seasoned inferior wood. Shutters are paneled or glazed; or partly panelled and partly glazed – in inferior quality timber. Two coats of painting shall be done.	Chowkats of wood as in 2nd class building. Shutters, however, shall be of still inferior timber. Shall be painted in two coats with ordinary paint.
Fittings in Doors and Windows, etc.	Brass fittings are provided. Iron greatings (grills) for windows shall be there.	Iron fittings shall be provided.	Iron fittings shall be provided.

General specifications about buildings that categorise them into classes (1st, 2nd, 3rd; or 'A', 'B', 'C' or 'D') also help in evaluating a given properly (this may not be a very exact evaluation) that is required to be sold/purchased, compensated for by the insurance agencies/or by the government in case of rioting, etc. It may be noted that there could be as diverse types of classification as the contents of specifications that can be framed. UP PWD has developed some important *standard specifications* for residential buildings, in order to classify them as : class 'A'; class 'B'; class 'C'; and class 'D' – a summary of this is presented as under, giving an idea about the different ways in which things can be grouped. It is an expert eye of a practising engineer that sees through this maze of words/phrases and recognizes the fact that all the points of view discern the same thing after all.

Class 'A' Building

Its foundation concrete shall have its ballast comprising fully burnt or over burnt bricks (known as *chatka* in and around Delhi) of 40 mm size with

1 : 6 (cement : sand), or 1 : 2 (white lime : surkhi); in both these mixes the proportion of kanaka (ballast) being 1.5.

Its plinth shall be filled by earth (i.e., below the flooring). DPC shall be 2.00 cm thick with 1 : 2 (cement : coarse sand) mortar having 5% water proofing compound by weight of cement.

Footing and plinth shall be built in 1st class BW in kankar lime or 1: 6 cement mortar – or it shall have hard burnt brickwork in kankar lime or 1: 6 cement mortar.

Superstructure shall be in 1st class bricks in kankar lime or 1: 6 cement mortar. Its 12.5 cm walls shall be in 1st class bricks in 1: 3 (cement, coarse sand) with reinforcement in place if it is self-supporting.

Lintels shall consist of 1 : 2 : 4 RCC, or reinforced 1st class BW, in 1 : 3 (cement : coarse sand) mortar.

Roofs (both in single or double storey) shall comprise RCC or Jack arches, or RC hollow tiles, or RB slab. Terracing shall be 11 cm concrete in LM (kankar lime) or 1 : 2 (whitelime : surkhi) mortar.

All balconies shall be of RCC.

Class ‘A’ buildings shall have granolithic floors in drawing, bed and bath rooms, while passages and kitchens shall have coloured cement floor – with WCs having white glazed tiled floor and *dado*. 2.5 cm CC shall be laid over 7.5 cm LC floor – in all rooms and verandah.

Granolithic 90.0 cm dado shall be provided in bath rooms. In bed, drawing, and dining rooms there shall be granolithic 25 cm skirting. In kitchen and pantry there shall be cement dado (1 : 3) 90.0 cm high. And, there shall be no cement skirting in any room in this class of building.

Rain water pipes of CI or AC pipes shall be provided.

Chowkats (frames) of doors and windows of class ‘A’ buildings shall be of CP *teak* wood, while their shutters shall be of CP teak/P and G plyboarding. Wire gauze doors shall be provided in all outer doors of main rooms, kitchen and pantry; while for all windows and ventilators wire gauze shutters shall also be there.

Spar varnish (2 coats) shall be given on all wood work. Plastering of 1 : 1 : 6, cement : whitelime : local sand, shall be applied on all walls (inside and outside).

Distempering shall be done in all the main rooms up to a height of 3.30 m. Inside finishing shall comprise three coats of white washing, while outside finishing shall consist of buff colour washing (or painting as specified).

RCC sun shades shall be given over all doors and windows that are exposed to rains.

Sanitary items in class ‘A’ buildings shall be provided, such as :

(a) Porcelain bath tub in two bath rooms.

(b) Procelain WC in all WCs (with one Indian type).

(c) Wash basins in bath rooms and side, verandah adjacent to dining rooms.

(d) Shower in all bath rooms.

(e) Sink in pantry and kitchen.

(f) Mirror and glass shelf in all bath rooms.

(g) Towel and soap tray recess in all bath rooms.

(h) Dirty lines box in all dressing rooms.

Plinth protection (skirting the building, and laid on ground) shall consist of 2.5 cm CC over 7.5 cm LC which will be 130 cm wide – or simply brick on edge in lime mortar shall be laid.

Chick support in all verandah openings shall be in place. Curtain pelmets shall be provided for all external doors of main rooms.

Door fittings of oxidized copper colour shall be provided.

Fire place shall be provided in drawing and dining room. Hot water boiler shall be put up for two bath rooms. And, one hot case-cum-shelf facility shall be provided, either in pantry or dining room.

Class 'B' Building

Specifications for foundations shall be same as for class 'A'. Plinth filling, DPC, and footing and plinth shall be done as in class 'A'. Similarly, construction of 12.5 cm walls, lintels, roofs, balconies and terracing shall follows class 'A' specifications.

In superstructure, second class bricks in kankar lime (or 1 : 6 cement mortar) shall be done in usual *trimming* (i.e. 30 cm masonry above DPC, jambs, top of walls near roof, and 30 cm wall/pillar at verandah); for the rest second class bricks in mud shall be used.

As for WCs flooring and dado, floors in rooms and verandah (CC over LC floor), and rain water pipes specifications for class 'A' shall hold.

Granolithic floors shall be provided only in drawing room; and, coloured cement border (in floors) shall be given in dining room, and in bed rooms if so desired. No granolithic 90 cm dado shall be provided in class 'B' building. Similarly, no granolithic 23 cm a skirting, or cement skirting shall be provided. However, a cement dado (1 : 3) 90 cm high shall be given in kitchen and pantry.

For making *chowkats* of doors and windows *sal* wood shall be used; while door and window shutters shall be of CP teak, and P and G plyboarding (as for class 'A' building). Wire gauze doors shall be provided in kitchen, pantry and dining room; and wire gauge shall be given over all windows.

Painting, varnishing and plastering shall be provided as in the case of class 'A' building. Distempering shall be done in drawing room up to the height as specified for class 'A'. Finishing (outside and inside) also shall be done as for class 'A'.

Chick support shall be provided in all verandah openings, and all external doors of main rooms. Curtain pelmets shall be as for class 'A'.

Plinth protection shall be as for class 'A', but only 90.0 cm wide. RCC sun shades shall be on all doors and windows exposed to rains (as in the case of class 'A' building).

Sanitary items shall be provided as detailed below :

Porcelain Bath Tub	Shall Not be Provided
Porcelain WC	In all bathrooms (or WCs), one Indian type (with one European type in any one)
Wash basin	As in class 'A'
Dirty linen box	As in class 'A'
Shower; sink; mirror and glass shelf : and towel and soap tray recess	As in class 'A'

Door fittings shall be of iron; while no hot water boilers shall be provided.

Fire place; and hot case-cum-shelf shall be provided as in class 'A'.

Class 'C' and 'D' Buildings

Foundation concrete, plinth filling, DPC, and footing-cum-plinth shall follow specifications as for class 'A'.

Superstructure for class 'C' as per class 'A', while for class 'D' it shall be as per class 'B'.

There shall be no 12.5 cm walls at all.

Lintels and roofs (single or double storey) shall be as per class 'A'. Balconies for class 'C' shall be of RCC, while there are no balconies for class 'D'. Terracing for both shall be as per class 'A'.

In place of rain water pipes, class 'C' shall have spouts; and class 'D' too shall have spouts if necessary.

These buildings shall have no granolithic floors, white glazed tiled floor and dado, or coloured cement floors; nor shall have granolithic 90 cm dado or granolithic 23 cm skirting. Both the classes shall have 2.5 cm CC over 7.5 cm LC floor as in class 'A'.

Both shall have cement dado (1 : 3) 90 cm high in kitchen, bath rooms and WCs. However cement skirting shall be there in the dining rooms of class 'C', while in class 'D' it shall be provided wherever floors may have to be washed.

Chowkats of doors and windows shall be of *sal* wood (as in class 'B'); while door and window shutters for class 'C' shall comprise *sal* (or *shisham*) with P and G 5-ply panels, and for class 'D' it shall be country wood (battened).

For both classes : wire gauze doors shall be provided in kitchen, and in window of the kitchen; and ordinary painting (3 coats) shall be given for wood work.

Plastering shall be same as for class 'A'. There shall be no distempering, chick supports, or curtain pelmets.

Finishing (outside) shall be as for class 'A' and for inside it shall be 3 coats of white wash.

Plinth protection for class 'C' shall be 13 cm of kankar (or brick ballast), rammed to 7.5 cm, and shall be 90 cm wide : while there will be no plinth protection for class 'D'.

RCC sun-shades shall be over all doors and windows that are exposed to rains. Door fittings shall be of iron.

Rest no sanitary items shall be there in these two classes of buildings.

No hot water boiler, fire place, or hot case-cum-shelf shall be provided.

3.5 CASE STUDY : BRICK MASONRY AND OTHER ITEMS IN A BUILDING

Example 3.2

Servants' quarters (in all 8 units, 4-units in ground floor + 4 units in first floor) were proposed to be built (Figure 3.2). The Figure presents the half-plan (at ground-floor level – plan being symmetrical about the centre line as shown) of the complex.

The work could not be completed. Only the ground floor (4 units) were in place, that too without baths, latrines, etc. (to be constructed at the back as indicated); moreover, no stairs could be built in the well earmarked for the purpose. The whole ground floor construction (incomplete in itself, though) was topped with an RCC (1 : 2 : 4) roof slab 15 cm thick. Hard murran filling was done everywhere.

[**Note :** Verandah gap as well as stair case gap is 2.3 m high with respect to DPC top.]

Develop the trench plan of the structure. Also estimate the following quantities (for 4 units) :

(a) Earthwork in excavation in hard soil.

(b) Hard Murram filling.

(c) Brickwork (BW) first-class in :

(i) plinth (below and above ground level), CM (1 : 6) – including steps.

(ii) superstructure in CM (1 : 4).

(**Note :** Partition walls are to be paid cubic-content wise.)

(d) Stone rubble soling in foundations, including hand packing.

(e) Cement concrete (1 : 4 : 8) in foundations.

Figure 3.2 : Half Plan of 8-unit Servants Quarters (At Ground Floor) – Example 3.2

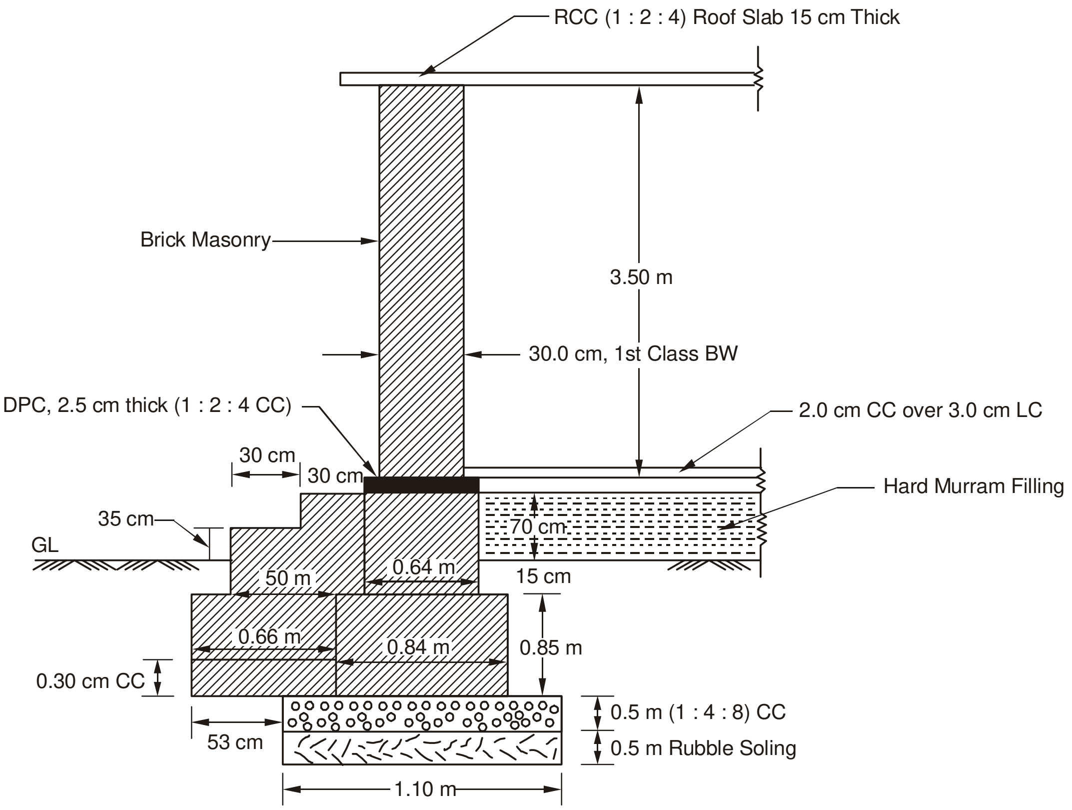


Figure 3.3 : A Typical Cross-section Combining Steps and a Wall with Foundations (Example 3.2)

Solution

With the help of the given plan (at plinth level) and the typical wall section (Figures 3.2 and 3.3), the required trench is drawn as shown in Figure 3.4. However, the student is expressly advised to first try, on his/her own, drawing the trench plan and then compare with the one shown in Figure 3.4. And, now it should be very easy to proceed with the preparation of *bill of quantities*.

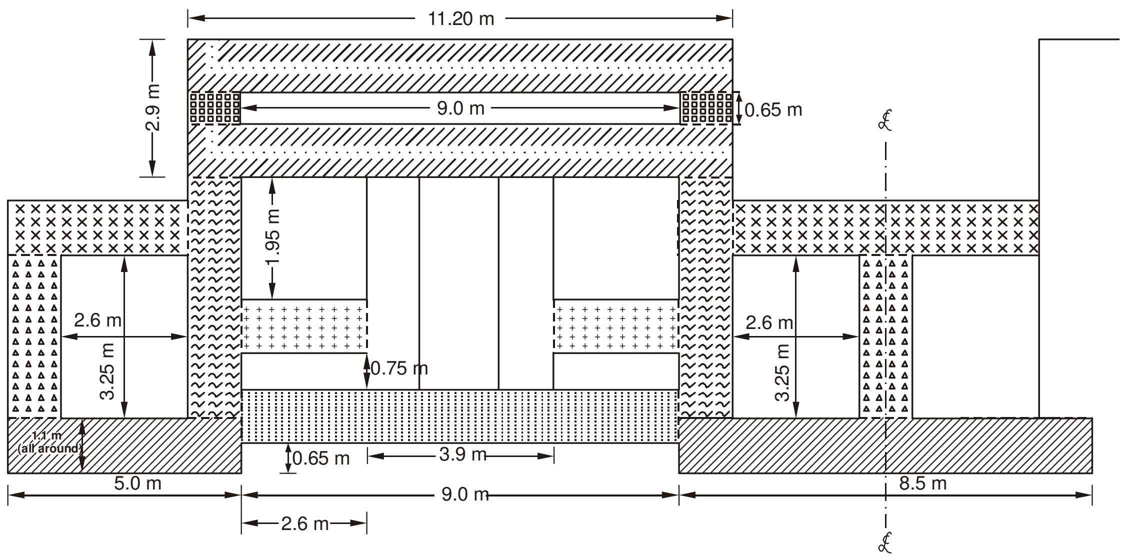


Figure 3.4 : Trench Plan of Servants Quarters – Example 3.2 – Walls Clubbed together while Estimating Quantities are filled with different Markings (Symbol)

Bill of Quantities – Example 3.2

Sl. No.	Description	No	Measurements L (m)	B (m)	H/D (m)	Quantity (m^3)	Total
(1)	*Earthwork in excavation in hard soill*						
	(i) Front long walls of living rooms (hatched portion in Figure 3.4)	2 1	5.0 8.5	1.1 1.1	2.0 2.0	22.0 18.70	
	(ii) Long walls of front verandah (dotted)	2	9.0	1.1	2.0	39.60	
	(iii) Rear long walls of living rooms (crosses)	2	3.7	1.1	2.0	16.28	
		1	6.3	1.1	2.0	13.86	
	(iv) Rear long walls – back verandah, and wall between back verandah and kitchen (slanting dash-and-dot)	4	11.2	1.1	2.0	98.56	
	(v) Long walls between kitchen and front verandah (plus signs)	4	2.6	1.1	2.0	22.88	
	(vi) Crossing walls of living rooms (triangles)	3	3.25	1.1	2.0	21.45	
	(vii) Cross walls between staircase and kitchen-cum-verandah group (plain – no signs used)	4	3.80	1.1	2.0	33.44	
	(viii) Cross walls between living room and kitchen-cum-verandah group (wavy, short markings)	4	4.45	1.1	2.0	39.16	
	(ix) Cross walls of back verandah (squares)	4	0.7	1.1	2.0	6.16	
						Total = 332.09 m^2	
	(x) Excavation for steps (in front only – which are in place)	4	1.46	0.66	1.0	3.85	
	[1.3+0.16 all round = 0.146 m]						
						Total = 335.94 m^3	

(2)	Filling rubble in foundations including hand packing (width and length of the soling item being same as for the relevant excavation item, except for its height i.e., thickness)	$\left[= \frac{\text{Total of (1) upto (ix)}}{2} \times 0.5\right]$ $= \frac{332.09}{2} \times 0.5 = 83.02 \text{ m}^3$				
(3)	Cement concrete (1 : 4 : 8) in foundations	$\left[= \frac{\text{Total of (1) upto (ix)}}{2} \times 0.5\right]$ $= 83.02 \text{ m}^3$ [or, $\frac{\text{Total of (1) upto (ix)}}{2} \times 1.0$ $- \text{Total of Item (2)}]$				
	Add CC laid under steps	4	1.46	0.66	0.3	1.156 m^3
						Grand Total = 84.18 m^3
(4)	Brickwork, first class in cement mortar					
	(a) Plinth below GL, 0.84 m thick masonry, in 1 : 6 CM					
	(i)	2 1	4.74 8.24	0.84 0.84	0.85 0.85	6.77 5.88
	(ii)	2	9.26	0.84	0.85	13.22
	(iii)	2 1	3.70 6.56	0.84 0.84	0.85 0.85	5.28 4.68
	(iv)	4	10.94	0.84	0.85	31.24
	(v)	4	2.86	0.84	0.85	8.17
	(vi)	3	3.51	0.84	0.85	7.52
	(vii)	4	4.06	0.84	0.85	11.60
	(viii)	4	4.71	0.84	0.85	13.45
	(ix)	4	0.96	0.84	0.85	2.74
	Partition wall (back verandah), 10 mm thick up to floor level [$1.45 - 2\left(\frac{0.84 - 0.64}{2}\right)$ $= 1.25$ m ; 70 + 2 + 3 = 75 cm = 0.75 m; and 0.40 m is its thickness below the floor level as mentioned, in Figure 3.2]	2	1.25	0.4	0.75	0.76
						Total 111.31 m^3
	(b) Plinth below floor level, 0.64 m thick masonry, in 1 : 6 CM – up to GL					
	(i)	2 1	4.54 8.04	0.64 0.64	0.85 0.85	4.94 4.37
	(ii)	2	9.46	0.64	0.85	10.29

	(iii)	2 1	3.7 6.76	0.64 0.64	0.85 0.85	4.03 3.68
	(iv)	4	10.74	0.64	0.85	23.37
	(v)	4	3.06	0.64	0.85	6.66
	(vi)	4	3.71	0.64	0.85	6.05
	(vii)	4	4.26	0.64	0.85	9.27
	(viii)	4	4.91	0.64	0.85	10.68
	(ix)	4	1.16	0.64	0.85	2.52
	[This part of masonry – 4(b) – up to this stage is 15/85th below GL, and 70/85th is above GL. Sometimes, rates for these two parts can be quoted separately.] **Steps**					
	Brickwork below GL	4 4	1.46 1.3	0.66 0.6	0.55 0.15	2.12 0.47
	[1.3 + 0.16 = 1.46; and 0.85 –0.30 = 0.55; and 00.5 + 0.1 = 0.60]					
	Brickwork above GL [0.35 + 0.15 = 0.50]	4 4	1.3 1.3	0.6 0.3	0.50 0.35	1.56 0.55
						Total = 90.56 m^3
(5)	Superstructure (BW) 1st class, in 1 : 4 CM					
	(i)	2 1	4.2 7.7	0.3 0.3	3.5 3.5	8.82 8.09
	(ii)	2	9.8	0.3	3.5	20.58
	(iii)	2 1	3.7 7.10	0.3 0.3	3.5 3.5	7.77 7.46
	(iv)	4	10.4	0.3	3.5	43.68
	(v)	4	3.40	0.3	3.5	14.28
	(vi)	3	4.05	0.3	3.5	12.76
	(vii)	4	4.60	0.3	3.5	19.32
	(viii)	4	5.25	0.3	3.5	22.05
	(ix)	4	1.5	0.3	3.5	6.30
						Total = 171.11 m^3
	Partition wall above plinth level (1 : 4 CM) (This wall has a DPC 2.5 cm thick.)	2	1.45	0.10	3.5	1.02 m^3
[**Note:** If the rate of payment for this partition wall is as per area, the quantity would be equal to 1.45 × 3.5 = 5.08 m^2.]						
					Grand Total	172.13 m^3

	No.	L	B	H/D	Quantity
Deductions					
Doors	2 × 6 (= 12)	0.85	0.3	1.95	5.97
Windows (W)	2 × 4 = 8)	0.85	0.3	1.10	2.24
Windows (W_1)	2 × 6 (= 12)	0.57	0.3	1.1	2.26
Cupboards (C)	2 × 4 (= 8)	0.85	0.25	1.1	1.87
Verandah gaps*	2 × 2 (= 4)	2.3	0.3	2.3	6.35
Staircase gap	2 × 1	2.5	0.3	2.3	3.45
[* Length of each verandah gap = 3.4 – {0.35 + 0.75}=2.3 m.]					
Lintels					
Over Ds	12	1.05	0.3	0.15	0.57
Over Ws	8	1.05	0.3	0.15	0.38
Over W_1s	12	0.77	0.3	0.15	0.42
Over Cs	8	1.05	0.3	0.15	0.38
Over verandah gaps	2 × 2 (= 4)	2.5	0.3	0.20	0.6
Over staircase gap	1 × 2 (= 2)	2.7	0.3	0.20	0.32
[0.85 + 0.20 = 1.05; 0.57 + 0.20 = 0.77; 2.3 + 0.2 = 2.5 and 2.5 + 0.2 = 2.7]					
	Total Deductions				24.81 m^3
Net 1st class BW (1 : 4 CM) in superstructure					172.13 (–) 24.81 = 147.32 m^3

(6)	No.	L	B	H/D	Quantity
	Hard Murram filling below floor, and above GL				
	Living rooms	4	3.71	3.06	0.70	31.79
	Verandahs	4	3.06	1.21	0.70	10.37
	Staircase	2	4.26	2.16	0.70	12.88
	Kitchens	4	3.06	2.41	0.70	20.65
	Back verandah	2 × 2 (= 4)	4.58	1.11	0.70	14.23

Note : Where, (0.64 – 0.3 = 0.34); (4.05 –0.34 = 3.71 m); [(3.4 + 0.3) –(0.64) = 3.06 m]; (1.55 – 0.34 = 1.21 m); (4.60 – 0.34 = 4.26 m); (2.5 –0.34 = 2.16); (2.75 –0.34 = 2.41 m);

and $\frac{9.8}{2} = 4.9;\ 4.9 + \frac{0.30}{2} + \frac{0.10}{2} = 5.1;\quad 5.1 - \frac{0.64}{2} - \frac{0.40}{2} = 4.58\ \text{m}$

where, 0.64 m and 0.40 m refer to plinth thickness of main and partition walls, respectively.

3.6 ESTIMATION OF BRICK MASONRY IN ARCHES

Romans were perhaps the first to use arches (brick masonry) as structural elements. They chiefly made use of arches as supporting members for carrying aqueducts over them while negotiating ditches, ravines, and drainages. These came to be used, later on, as supports for bridges, and cross-overs over gaps in buildings. The principal function of an arch is to transmit load on its abutments – pillars, bridge piers, rock formations on the flanks of a reservoir (dam) in the case of an *arch dam*. It does not suffer any tension, and is always in compression.

3.6.1 Various Types of Arches and Formulae

Mainly (apart from ornamental forms used in doors and windows basically non-load bearing in nature) civil engineering works use two types of arches :

Semi-circular Arch

With reference to Figure 3.5 one can calculate the masonry (brick or stone work) in the arch ring in cubic meters (Q) as,

$$Q = \pi \left(r + \frac{t}{2} \right) \times t \times b \qquad \text{. . . (3.1)}$$

where, r = inner radius of the arch ring,

t = thickness of the arch ring,

b = breadth of arch ring, i.e. the dimension perpendicular to paper,

$\pi\ (r + t/2) = \pi \times$ (central radius of the ring)

= length of arched masonry.

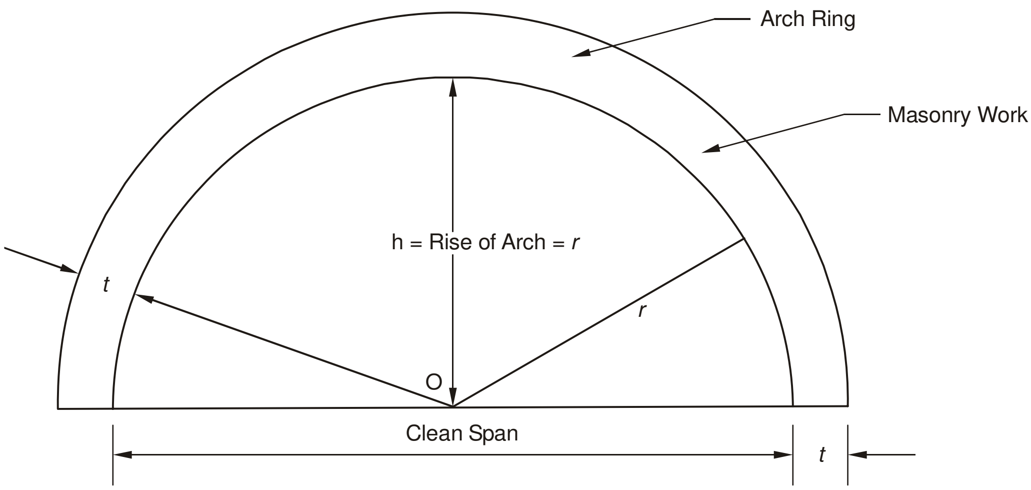


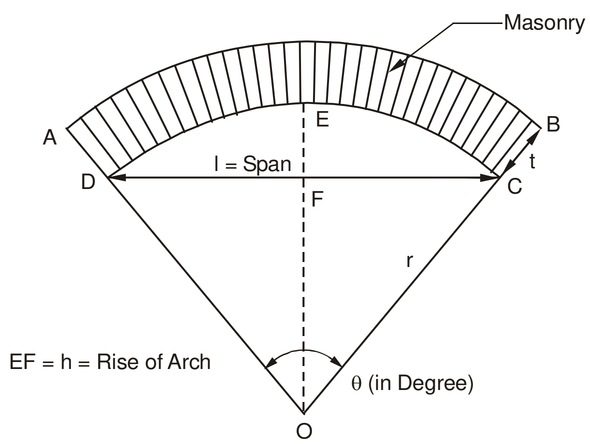
Figure 3.5 : Element of a Semi-circular Arch

Segmental Arch

When a semi-circular arch (subtending an angle of π radians (180°) at the centre of the corresponding circle) is cut short – Figure 3.6 – on either side so that the segment ABCD subtends an angle (θ) that is less than 180°, at the centre, we get a segmental arch. Its span DC is, obviously, less than the diameter of the parent circle. Therefore, the cubic content of masonry contained in this segmental arch (which is b units long – perpendicular to paper) is given by :

$$Q = \left[2\pi \left(t + \frac{1}{2} \right) \right] \times \frac{\theta}{360^{o}} \times [t \times b] \qquad \text{. . . (3.2)}$$

where, $\left[2\pi \left(t + \frac{1}{2} \right) \right] \times \frac{\theta}{360^{o}} \times [t \times b]$ gives the mean (central) length (i.e., along the mean circumferential path) of the arch.



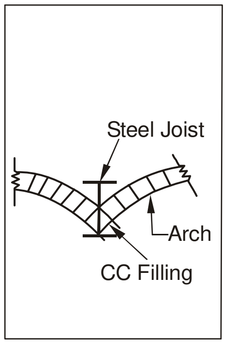


Figure 3.6 : Elements of a Segmental Arch

It can be shown that, Q can also be expressed in following two ways :

$$Q = \left[\frac{8 \times \sqrt{\left\{ \left(\frac{l + t}{2} \right)^2 + \left(h + \frac{t}{2} \right)^2 \right\}} - (l + t)}{3} \right] \times t \times b \qquad \ldots (3.3)$$

and $$Q = 2\pi \left[\frac{l}{2 \sin (\theta/2)} + \frac{t}{2} \right] \frac{\theta}{360} \times (t \times b) \qquad \ldots (3.4)$$

Jack Arch Roof

It is a roof over a hall (or room) which is basically supported by segmental arch – and, is also known as *segmental arch roof*. Each arch (there may be three, four or more such arches in the roof make up) is supported at the ends (Figure 3.6) by rolled steel joists or RCC beams. The thickness of the arch ring is commonly half-brick, its span varying from 90 cm to 200 cm; and its rise varies in between 1/6th to 1/10th of the span. Length of this arch (perpendicular to paper) is fixed as equal to the width of the room plus twice the thickness of the arch as supported over the walls. And, the curved length of the arch (i.e., length of arch ring) is the curved length of the intrados.

As per IS code of practice (IS : 1200), Jack arch roofing is measured in m^2, whose rate of payment takes into account the cost of brickwork, concrete in haunch (spandrel) filling, etc.

Example 3.3

Work out the quantity of masonry work (brick) for the following cases :

(a) A segmental arch of clear span = 2.75 m, and rise of 0.6 m. Take the thickness of arch ring as 45 cm, and wall thickness = 50 cm.

(b) A semi-circular arch of clear span = 3.0 m; and thickness of arch ring 50 cm; and wall thickness = 50 cm, and

(c) A 70^o segmental arch whose clear span (i.e. opening) is 2.5 m. Take the thickness of the arch ring as 50 cm, and wall thickness as 30 cm.

Solution

(a) Here, with reference to Eq. (3.3), we have :

$l = 2.75$ m; $t = 0.45$ m; $b = 0.50$ m and, $h = 0.6$ m

$$\therefore Q = \left[\frac{8 \times \sqrt{\left(\frac{2.75 + 0.45}{2}\right)^2 + \left(0.6 + \frac{0.45}{2}\right)^2} - (2.75 + 0.45)}{3} \right] \times 0.45 \times 0.50$$

$$= \left[\frac{8 \times \sqrt{(2.56 + 0.680)} - 3.20}{3} \right] \times 0.225$$

$$= \frac{14.4 - 3.2}{3} \times 0.225$$

$$= 0.84 \text{ m}^3$$

(b) In Eq. (3.1), the appropriate substitutions give :

$$Q = \pi \left(\frac{l}{2} + \frac{t}{2}\right) \times t \times b$$

$$= \pi \left(\frac{3}{2} + \frac{0.5}{2}\right) \times 0.5 \times 0.5$$

$$= 1.37 \text{ m}^3$$

(c) In Eq. (3.4), the appropriate substitutions give :

$$Q = 2\pi \left[\frac{2.5}{2 \sin 35^o} + \frac{0.5}{2} \right] \frac{70}{360} \times 0.5 \times 0.3$$

or, $$Q = 2\pi \left[\frac{2.5}{1.147} + 0.25 \right] \times 0.029$$

$$= 2\,\pi\,[2.43] \times 0.029$$

$$= 0.443 \text{ m}^3.$$

3.7 TYPICAL RATE ANALYSIS OF BRICK MASONRY

Brickwork is done in foundations of buildings, in plinth, and in superstructure with varying composition of mortar and their proportions. Hence, the rate for each specification has to vary according to the materials and labour involved. Over and above these rates, the cost does get escalated with the height/floor of the building up to which bricks are to be carried for placement. Special works like arch or ornamental items cost more for obvious reasons. A few examples, to illustrate this point, would be in place.

(a) 10 m^3 of Brickwork (1st class) in kankar lime in foundations and plinth (materials, labour, tools and plants, etc. are considered)

Required Material

Bricks (@ 500 bricks per m^3)	5000 Nos
Kankar lime	3.0 m^3

Labour

Mistri	0.6 Nos
Mason	7 Nos
Beldar	7 Nos
Mazdoor	7 Nos
Bhisti	2 Nos.

Tools or Plants (T and P), etc. Add the cost on lump sum bases

(b) 10 m^3 of First Class Brickwork in white lime and surkhi mortar (1 : 2) in foundations and plinth including supply of materials and labour etc.

Material Required

Bricks	5000 Nos
White Lime	1.2 m^3
Surkhi	2.4 m^3

Labour

Same as for item (a) above.

(c) 10 m^3 of First Class Brickwork in white lime and surkhi mortar (1 : 3) in foundations and plinth

Materials Required

Bricks	5000 Nos
White lime	0.90 m^3
Surkhi	2.70 m^3

Labour

Same as for items (a) above.

(d) 10 m^3 of First Class Brickwork in 1 : 6 cement sand mortar in foundations and plinth

Materials Required

Bricks	5000 Nos
Cement (0.45 m^3)	13.5 bags
Local sand	2.7 m^3

Labour

Same as for item (b) above.

(e) 10 m^3 of First Class Brickwork in 1 : 4 cement sand mortar in foundations and plinth.

Materials

Bricks	5000 Nos
Cement (0.6 m^3)	18 bags
Local sand	2.4 m^3

Labour

Same as for item (a) above.

(f) **10 m^3 of First Class Brickwork in superstructure (including required cutting and moulding of bricks as required), that includes home comb brickwork thickness of walls being not less than 1.5 bricks.**

Materials and Labour would be the same as for respective items above – (a), (b), (c), (d) and (e), but following extra labour needs to be added to each item described above :

Mason	3.6 Nos
Mazdoor	3.6 Nos
Scaffolding, etc	To be added on lump sum basis

Note :

(a) **For 10 m^3 First Class Brickwork in superstructure, as in items (a), (b), (c), or (d) and (e),** ***but for walls of one-brick*** **thickness materials and labour would be the same as for respective items, but with the following additional labour for each respective item :**

Mason	7 Nos
Mazdoor	7 Nos
Scaffolding, etc.	To be added on lumpsum basis

(b) **For 10 m^3 of First Class Work in superstructures as in items – (a), (b), (c), (d) and (e), but for half-brick thick walls, materials and labour would be the same as for the respective items, but with following additional labour for each respective item :**

Mason	5.3 Nos
Mazdoor	5.3 Nos
Scaffolding, etc.	To be added on lump sum L.S. basis

(c) **For 10 m^3 of First Class Brickwork in Arches in 1 : 3 cement and coarse sand mortar :**

Materials

Bricks	5000 Nos.
Cement (0.75 m^3)	22.5 bags
Coarse sand	2.25 m^3

Labour

Mistri	0.6 Nos

Mason	14 Nos
Beldar	11 Nos
Mazdoor	14 Nos
Bhisti	3 Nos
Tools and Plants (sundries, etc.)	LS
Formwork	LS
Scaffolding	LS

(d) For 10 m^3 of First Class Brickwork in Jack Arches in 1 : 3 cement and coarse sand mortar :

Materials

Bricks	5000 Nos
Cement (0.75 m^3)	22.5 bags
Coarse sand	2.25 m^3

Labour

Mistri	0.6 Nos
Mason	21 Nos
Beldar	15 Nos
Mazdoor	23 Nos
Bhisti	2 Nos
Tools and plants (sundries etc.)	LS
Centering and shuttering	LS
Scaffolding	LS

(e) For 10 m^3 of Second Class Brickwork in mud mortar in superstructure :

Materials

Bricks (2nd Class)	5000 Nos
Loamy soil (or any other suitable soil)	4.0 m^3

Labour

Mistri	0.3 Nos
Mason	8.0 Nos
Beldar	7.0 Nos
Mazdoor	1.0 Nos
Bhisti	1.0 No
Sundries (Tools and Plants, etc.)	LS
Scaffolding	LS

(f) For 10 m^3 of Third Class Brickwork in superstructure in mud mortar :

Materials

Bricks (3^{rd} Class) 5000 Nos

Loamy (or other, suitable) soil 4.0 m^3

Labour

Same as for item (a).

3.8 STONE MASONRY

Stones are, in contrast to brick, natural building blocks that do not need manufacturing by man, except only to dress up for proper placement in foundations, plinths, walls, bridge piers, arches, etc. Stones in fact, are used (wherever easily available) for construction purposes, and also for use as decorative facing – that is exactly for all the works wherein bricks are used. It is a question of comparative ease in availability, and in costs that *mainly* decide the use of either of these two buildings blocks.

There are various types of stone masonry in vogue, and different specifications are laid for dressing – and cutting stones. Stone required for masonry shall be dressed as specified (or / and shown) on the drawings. There are four main types of dressing – *hammer dressed*, *rought tooled*, *chisel dressed*, and *fine dressed*.

Stones shall be dressed accurately to the exact size – all visible edges shall be free from chippings.

Scabbled (or *hammer* dressed) is a stone dressed with a scabbling hammer without any picking or chiseling. *Rough tooled* stone (also known as one *line dressed*), is to be sparrow picked, or dressed with a chisel, until no portion of the dressed face is more than 6.35 mm (say, ¼ inch) from a straight edge placed on it. *Chisel dressed* stone (also known as *two line dressed*) is to be sparrow picked, or dressed with a chisel, until no portion of the face dressed is more than about 3.2 mm (1/8 inch) from the straight edge laid along it. By *fine dressing* is meant, the best surface which can be given to a stone with a chisel, and without rubbing. A straight edge, laid along the face of the stone so dressed must be in contact with the stone at every point. This work is also known as *three line dressed.*

Every cut stone work shall be worked to templates which, for appropriateness, shall be of zinc sheet. Unless otherwise specified, the measurement of all cut stone, moulded or ornamental work, shall be taken over all projections – i.e., the volume of the least *rhombohedron* in which the cut or moulded stone can be contained. The volume of each stone, but excluding its tailing, shall be worked out separately. The rate of payment should allow for the proper protection of the work (until construction is finished) from injury.

The specified type of stone for a given work shall be hard, sound, free from decay and weathering etc. having been obtained from the approved quarry, and if necessary tested for water absorption (IS : 1124 – 1974). *Stones with round surface have not to be used.*

Stones used in construction shall be of a size allowing lifting and being placed in position by hand. The length of a stone should not exceed three times its height (height should not be greater than 30 cm) and its breadth at its base should not be greater than ¾th of the thickness of the wall (nor less than 15 cm).

Random Rubble Masonry

The stones shall be hammer dressed on the face, sides, and beds allowing close position with the adjacent stones after chipping off their weak corners. Each stone will be laid on its quarry bed – and shall be wedged or pinned strongly into position in the walls by spalls or chips, which may show on the face.

No stone shall tail into the wall less than 1.5 times its height. Stones shall be arranged to break joint as much as possible – long vertical lines of joining shall be avoided. The "*bushing*" in the face shall not project more than 4 cm on an exposed face, and one cm on a face, which is proposed to be plastered. Mortar that is used shall be as per specifications.

One header or through stone shall be inserted in at least every 0.5 $m^2$of the face, and shall run right through the wall if not more than 60 cm thick – if more than 60 cm thick, a line of these shall be laid from face to back which shall overlap each other by at least 15 cm.

The hearting or interior filling between the front and back face stones will consist of the same rubble stones, not less than 15 cm in any direction – not dry work, or hollow spaces, or thick joints of mortar shall be left anywhere. The hearting will be laid nearly level with each course, except that at about 0.9 to 1.0 m intervals, vertical "*plums*" projecting 15 cm to 22 cm shall be firmly embedded to form a boud between the successive courses. Hearting must not be brought to the same level as the front and back stones by the use of chips.

All the stones shall be washed and wetted before use – removing dirt, dust, etc. The walls shall be built truly plumb or to the designed (specified) batter. Levelling up at plinth level, window sills and roof level shall be done with the specified mortar.

Quins shall be of selected stones – neatly dressed to form the required angle, and laid as header and stretcher alternately.

All the face joints shall not be more than 20 m thick.

Random rubble masonry work in cement or compsote mortar shall be constantly kept moist for a minimum of seven days. When fat lime mortar has been used, curing should be started two days after the laying of masonry and then curing must continue for seven days.

Coursed Rubble Masonry

Quality and size of stones shall be as for random rubble work.

The stones shall be laid in horizontal course not less than 15 cm in height. All the stones in each course shall be of equal height. All stones shall be set full in mortar in all bed or vertical joints. Face stones shall be hammer dressed on all beds and joints, to allow giving them approximately rectangular outline. Mortar to be used shall be specified. Bed joints shall be rough – chisel dressed. A course height may lie between 15 to 30 cm.

Face stones shall be laid alternately headers and stretchers – no face stone shall be less in breadth than its height; nor shall it tail into the work to a length less than its height. And, at least 1/3rd of the stones shall tail into the work at least twice their height, etc.

Through stones shall be inserted at appropriate intervals. The quoins shall be of the same height as the course.

Ashlar Masonry

The length of stone shall not exceed three times the height, and the breadth (on base) shall not be greater than 3/4th of the thickness of wall, or 15 cm whichever is more. The height of stone may go up to 30 cm.

In fine Ashlar work, every stone shall be dressed on all beds, joints and faces. The beds and joints must not exceed 3.17 mm (1/8th of an inch).

In pain Ashlar work, the dressed stone shall be free from any waviness – in case of exposed faces or the adjoining faces, there will be fine chisel dressing to a depth of 6 mm. Top and bottom faces shall also be chisel dressed; and also faces forming vertical joints.

In *rough tooled* on *bastard Ashlar*, the faces exposed to view shall have a fine dressed chisel draft 2.54 cm wide, all round the edges; and be rough-tooled between the drafts.

The stones shall be laid in regular courses not less than 30 cm in height. The face stones shall be laid header and stretcher alternately. Unless otherwise specified, in all walls not more than 90 cm thick, headers shall run right through the wall. Jambs for door and window openings shall be formed with quoins of the full height of the course.

Ashlar facing often has a backing of brickwork, concrete, or rubble.

The height of the courses shall be equal to an exact number of courses of brick or rubble. Bond stones shall be incorporated as in random rubble masonry. All joints shall be full of mortar, not more than 5 mm thick.

Block in Course Masonry

Stone shall be rough tooled on all beds and joints – giving rectangular shaped stones. Each course shall consist of stones of even thickness, no course being less than 15 cm in height.

Walls built in brickwork, concrete or rubble masonry may be faced with *block in course* masonry. One third of the entire length of each course shall be headers.

Beds and joints shall be rough-tooled. Bond stones shall be used as for other stone masonry.

Dry Rubble Masonry

It is commonly called *dry stone* walling; it is used to build breast and retaining walls. Largest available stones shall be used in these constructions – the largest being used in the lower courses.

Unless otherwise specified, dry stone walling shall be built with a face batter of 1 : 4 with vertical back. The base as well as the course must run at right angles to the face. The stones shall be roughly dressed to secure the maximum bedding surface without unduly reducing the size of the stone. Bond stones shall be provided in each course at intervals of 1.5 m.

Dry stone walls exceeding 6.0 m in height must be strengthened every 3.0 m by building three consecutive courses in coursed masonry in lime or cement mortar. *Weep hole* shall be left in dry stone walling built against a hill side (which is the common location for such walls).

Filling immediately behind the dry stone wells must, wherever possible, be done with stone refuse or chips.

Arch Work in Stone Masonry

Masonry in arches shall follow general specifications for masonry as such and for dressing and cutting stones, as well as the detailed specifications for the class of stonework in which the arch work is to be executed.

All stones required for the arch masonry shall be cut to a zinc sheet template made against a full sized elevation of the arch.

The stones shall be dressed on the face and on the bed and other joints. The full number of stones required for the completion of an arch are to be cut and dressed, and the arch erected dry on the ground before the commencement of work on the arch. No voussoir is to be cut or dressed after it is once *laid in situ* in mortar.

In the case of arches in walls, the two springers and the key-stone shall be through stones as well as every third stone in between.

Unless otherwise specified, the height of each stone will be equal to the thickness of the arch up to 37.5 cm (15 inches) – above this, two stones may be used with no stone being less than 15 cm in height.

Measurements

All stonework generally, as all brickwork, shall be measured in m^3, and face work, however, shall be measured in m^2.

No deductions or additions shall be made on any account for the item for which no deductions (or additions) have been specified in the case of brickwork.

In stone masonry, the type of stone, kind of masonry, and mix of mortar shall be fully described. Rates shall include bond stones, preparation of top surface of existing half-done work (meant to be raised further in height), and raking out joints prior to plastering or painting.

Rate Analysis

Rate analysis of any stonework shall, as for any other masonry work, shall involve cost of materials and unskilled and skilled labour. Schedules are available that provide the required information on these counts.

Example 3.4

What are the materials and labour component required for the following items of work :

(a) 10 m^3 coursed rubble stone masonry in superstructure in 1 : 6 cement-sand mortar, and

(b) 10 m^3 of random rubble stone masonry in superstructure in 1 : 6 cement-sand mortar.

Solution

Men and Materials Required Per 10 m^3

Sl.	Particulars	Materials	Labour

No.		Stone (Including Wastage)	Cement	Sand	Mistri	Mason	Beldar	Mazdoor	Bhisti
(a)	Coursed Rubble Stone Masonry in superstructure, in 1 : 6 cement and sand mortar	12.5 m^3	0.6 m^3 = 18 bags	3.6 m^3	0.5	16	16	8	1.5
(For complete rate analysis, add LS amount for scaffolding, T and P and sundries)									
(b)	Random Rubble Stone Masonry in superstructure in 1 : 6 cement sand mortar	12.5 m^3	0.7 m^3 = 21 bags	4.2 m^3	0.5	11	11	11	1.5
(For complete rate analysis, add LS amount for scaffolding, T and P and sundries)									

SAQ 1

(a) With reference to the motor garage [Example 2.3 and Figure 2.3], estimate the following quantities;

  (i) First class BW in plinth and foundation, in 1 : 6 cement mortar, and

  (ii) First class BW in lime mortar, in superstructure.

  By both centre-line method, and Long and Short-wall method.

  Assume the following data :

  (i) Window (W) size – 1.2 × 1.0 (height) m

  (ii) Almirah (A) size – 1.0 × 1.2 (height) m

(b) Figure 3.7 gives the centre-line plan of a residential quarter for an overseer working in Public Works Department of a State in India. Compute the quantities of the following items of work, after developing the double line plan (above plinth level) of the structure:

  (i) Brick Masonry work in superstructure, in 1 : 4 CM.

  (ii) RCC (1 : 2 : 4) in roof slab, and lintels. Due to the possibility of first floor being constructed over the ground floor, there are no projections of the roof slab over the walls. Roof slabs at 3 m height go into full wall thickness.

  Following specifications are applicable:

  (i) Height of main rooms from DPC upwards = 4.0 m.

  (ii) Height of verandah, passage, kitchen, store, bath, and WC = 3.00 m.

  (iii) Thickness of walls above the plinth level = 20 cm.

  (iv) Sizes

  Doors, *D* – 1 × 2.1 m

  Windows, W_1 – 2 × 1.5 m (it is a double shutter window)

  Windows W_2 – 1 ×1.5 m (a single shutter window)

  (v) Thickness of RCC roof slab = 15 cm

  Thickness of lintels over doors and windows = 10 cm

  Bearing of lintels on either side = 10 cm

Calculate the above mentioned brick masonry by centre-line as well as Long- and Short-wall methods.

Also draw (to scale) :

(a) Front elevation,

(b) Side elevation of right and left side, separately,

(c) Back elevation, and

(d) One sectional elevation.

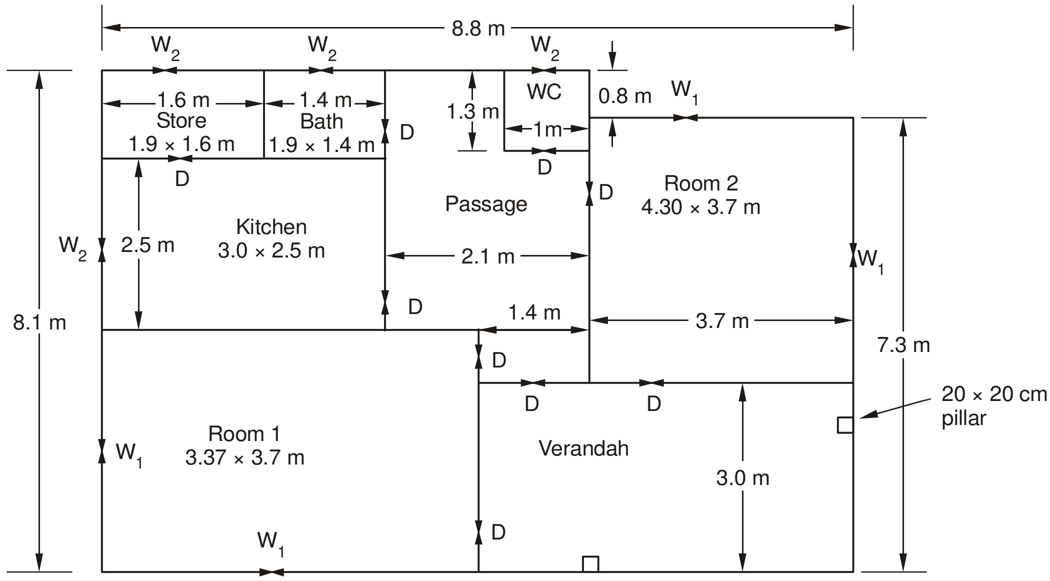


Figure 3.7 : Centre-line Plan of a Building (Not to Scale)

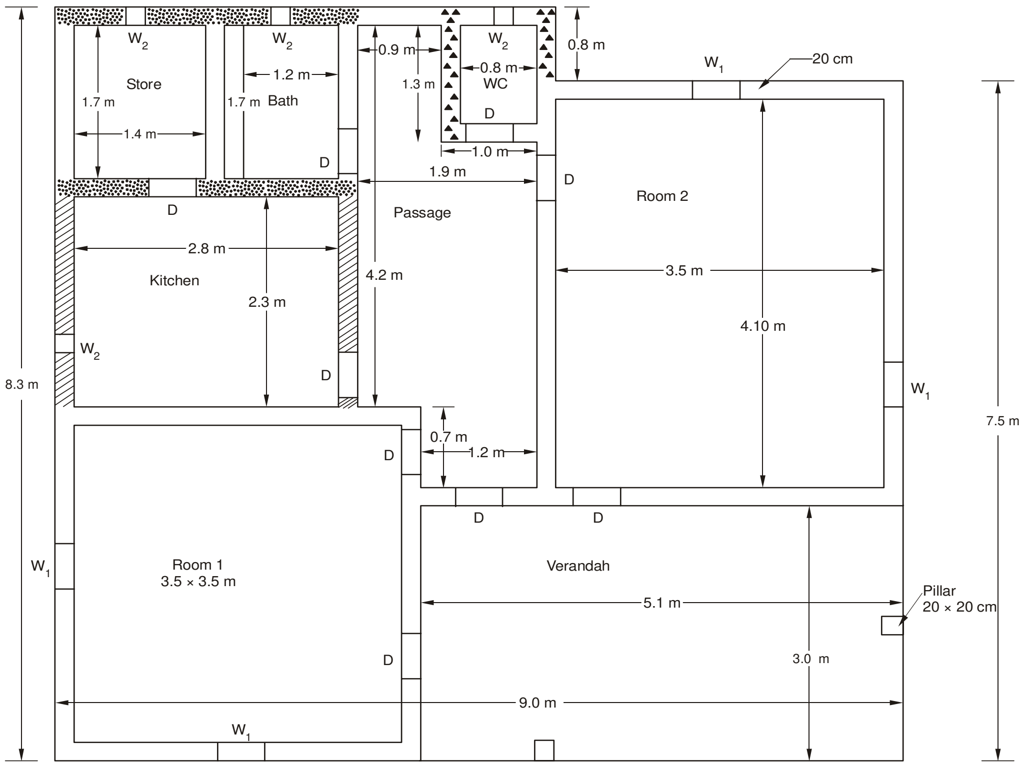


Figure 3.8 : Plan of a Building (Figure 3.7) above Plinth Level – Developed from the Line Plan (Not to Scale)

3.9 SUMMARY

Brickwork (masonry) is one of the major items of work in a building – foundations, superstructure, and arches (wherever incorporated) – and its quantification calls for a clear headed understanding of plan, elevation, and sections of a building. Thickness, i.e. width of BW varies from foundation courses (of different widths, as is generally the case) up to the superstructure (exposed walls, i.e. above the ground/plinth level).

Centre-line method, as well as Long- and Short-wall methods can be employed to estimate the quantity of BW – the former method being effective where uniformity of foundation and wall thickness is prevailing. As explained elsewhere also, in Long- and Short-wall methods the lengths of long wall keep decreasing, and while of short walls keep increasing as one proceeds upwards from the bottom of the excavation trench and the width (thickness) of courses go on decreasing.

Every kind of brickwork has to be constructed according to the relevant specifications. Buildings fall into various classes, depending, among other things, on the class of bricks and the richness of the mortar used.

Stone masonry has its own specifications but its quantity is also expressed in cubical contents (m^3) as in any brickwork. Its length, breadth, and height have to be measured for computing the contents.

3.10 ANSWERS TO SAQs

SAQ 1

(a) Depth of plinth (under the ground + above the ground)

= 30 cm + 15 cm

= 45 cm = 0.45 m

Length of centre line = (2 × 4.30) + (2 × 7.8)

= 24.2 m

Length of LW (plinth) = $7.8 + 2\left(\frac{0.45}{2}\right)$

= 8.25 m

Length of SW (plinth) = $4.3 - 2\left(\frac{0.45}{2}\right)$

= 3.85 m

Length of LW in superstructure = 7.5 + 2 (0.3)

= 8.1 m

Length of SW in superstructure = 4.0 m

Height of superstructure masonry = 3.5 + 0.025

= 3.525

(However 0.025 m being a very small amount, one could as well take the garage height as 3.5 m only.) = 3.53 m (say).

Sl. No.	Description	No	Measurements L (m)	B (m)	H/D (m)	Quantity (m^3)
(1)	*First class BW in plinth and foundations, in 1 : 6 CM*					
	(a) By centre-line method	1	24.2	0.45	0.45	4.90 m^3
	(b) By L-S wall method					
	LW	2	8.25	0.45	0.45	3.34
	SW	2	3.85	0.45	0.45	1.56
					Total	4.90 m^3
(2)	*First class BW in lime mortar, in superstructure*					
	(a) By centre-line method	1	24.2	0.3	3.53	25.63 m^3
	(b) By L-S wall method					
	LW	2	8.1	0.3	3.53	17.16
	SW	2	4.0	0.3	3.53	8.47
					Total	25.63 m^3
Deductions	[Some of the following items have already been done in the solution to Example 2.3] OPENINGS					
	Windows	3	1.2	0.3	1	1.08
	Almirahs	2	1.0	0.23	1.2	0.55
	Gate opening	1	3.0	0.3	2.3	2.07
	(Neglecting Almirah shelves that go into the masonry)					
	LINTELS					
	Over gate opening	1	3.4	0.3	0.2	0.2
	Over Windows } Over Almirahs }	5	1.2	0.3	0.1	0.18
					Total Deductions =	4.08 m^3
					Net BW in superstructure	= 25.63 (–) 4.08
						= 21.55 m^3

(b) Double-line plan, above the plinth level (say, at window level) is shown in Figure 3.8; calculations, explaining its various dimensions, are given below (for the student, to apply his/her mind to) in order the student correlates the same with the plan layout :

1	7.3 + 0.2 = 7.5
2	8.8 + 0.2 = 9.0
3	8.1 + 0.2 = 8.3
4	0.8 + 0.2 = 1.0
5	3.7 – 0.2 = 3.5
6	3.0 – 0.2 = 2.8
7	2.5 – 0.2 = 2.3
8	1.6 – 0.2 = 1.4
9	1.9 – 0.2 = 1.7
10	1.4 – 0.2 = 1.2
11	1.3 – 0.1 + 0.1 = 1.3

12	1 + 0.2 = 1.2
13	2.1 – 0.2 = 1.9
14	1.4 –0.2 = 1.2
15	3.0 –0.2 = 2.8
16	9.00 – 0.4 –3.5 = 5.1
17	4.3 – 0.2 = 4.1
18	Passage ⇒ 1.7 + 0.2 + 2.3 = 4.2
19	Verandah ⇒ (a) 3 – 0.2 + 0.2 = 3.0 1.2 + 0.2 + 3.5 + 0.2 = 5.1

Sl. No.	Description	No	Measurements L (m)	B (m)	H/D (m)	Quantity (m^3)
(1)	*BW in superstructure in 1 : 4 CM*					
	4-m high walls					
	Main Room 1					
	Long Wall	2	3.90	0.20	4.0	6.24
	Short wall	2	3.5	0.20	4.0	5.60
	Main Room 2					
	Long Wall	2	4.5	0.20	4.0	7.2
	Short Wall	2	3.5	0.20	4.0	5.6
	Total of 4-m high walls = 24.64 m^3					
	3-m high walls					
	(i) Store + Bath					
	Long Walls (dotted)	2	3.2	0.2	3.0	3.84
	Short Walls (plain)	3	1.7	0.2	3.0	3.06
	(ii) Kitchen					
	Short Walls (hatched)	2	2.3	0.2	3.0	2.76
	(iii) WC					
	Long Wall inner (triangles)	1	1.5	0.2	3.0	0.90
	Outer (triangles)	1	0.8	0.20	3.0	0.48
	Short walls (plain)	2	0.8	0.2	3.0	0.96
	(iv) Passage					
	Outer Wall	1	0.9	0.2	3.0	0.54
	(v) Verandah wall	1	1.2	0.2	3.0	0.72
	(excepting the portion considered under Room 2)					
	(vi) Pillars	2	0.2	0.2	3.0	0.24
	Total of 3-m high walls					1350 m^3
	Grand Total of Item 1					**38.14 m^3**
	Deductions					
	Door openings, *D*	9	1.0	0.2	2.10	3.78
	Window openings, W_1	4	2.0	0.2	1.5	2.40
	W_2	4	1.0	0.2	1.5	1.20
	Lintels					
	D	9	1.2	0.2	0.10	0.22
	W_1	4	2.2	0.2	0.10	0.18
	W_2	4	1.2	0.2	0.10	≈ 0.1
	Roof slab going into 4-m high walls at 3-m height					
	Room 1	1	3.90	0.2	0.15	0.12
		1	3.7	0.2	0.15	0.11
	(3.5 + 0.4 = 3.90; 3.5 + 0.2 = 3.7)					
	Room 2	1	3.90	0.2	0.15	0.12
		1	4.3	0.2	0.15	0.13
	(4.1 + 0.2 = 4.3)					
	Total Deductions =					8.36 m^3
	Net BW in superstructure					38.14

						(–) 8.36
						29.78 m³
(2)	*RCC (1 : 2 : 4) in roof slab and lintels in*					
	(i) Room 1	1	3.9	3.9	0.15	2.28
	Room 2	1	4.5	3.9	0.15	2.63
	(ii) Over store, bath, kitchen, part of passage, and WC	1	5.3	4.6	0.15	3.66
	(2.8 + 0.2 + 0.2 + 1.9 + 0.2 = 5.3 ; Associated passage ⇒ 2.3 + 0.2 + 1.7 + 0.2 + 0.2 = 4.6 ; or, 4.2 + 0.2 + 0.2 = 4.6)					
	Rest of the passage (1.2 + 0.2 + 0.2 = 1.6)	1	1.6	0.5	0.15	0.12
	Verandah	1	3.2 (= 3 + 0.2)	5.3 (=5.1 + 0.2)	0.15	2.54
	Add lintels (as calculated under item (1))					
	D					0.22
	W_1					0.18
	W_2					0.10
	Total RCC(1 : 2 : 4)					**= 11.73 m³**

Referring to Figure 3.8, following calculations are in order to compute the centre line length of 4-m, and 3-m high walls, respectively (keeping in mind the junctions of cross walls with the longer walls, where the length equal to the width of one wall is already accounted for when multiplying the centre line with the wall thickness).

(i) Centre-line of 4-m high walls

$$= 2\left[\left\{3.5 + 2\left(\frac{0.2}{2}\right)\right\} + \left\{3.5 + 2\left(\frac{0.2}{2}\right)\right\}\right] + 2\left[\left\{4.1 + 2\left(\frac{0.2}{2}\right)\right\} + \left\{3.5 + 2\left(\frac{0.2}{2}\right)\right\}\right]$$

$= 30.8$ m

(ii) Centre line length of 3-m high walls

Passage/verandah = 1.2

WC walls = [(0.8 + 0.8) + (1.3 + 0.2) + 0.8]

WC/Bath passage = 0.9

Store/Bath = 1.7

Kitchen/Store-Bath = 2.8

Sub-Total = 10.5 m

Walls surrounding (excepting one 4-m high side kitchen, store and bath)

= 2.3 + 0.2 + 1.7 + 0.1 + 0.1 + 1.4 + 0.2 + 1.2 + 0.1 + 0.1+ 1.7 + 0.2 + 2.3

= 11.6 m

∴ Total length of this centre line = 22.10 m

(Only Brickwork)							
Sl. No.	**Description**		**No**	**Measurements**			**Quantity**
				L (m)	**B (m)**	**H/D (m)**	**(m^3)**
(1)	*Brickwork in superstructure*						
	(i)	4-m high walls	1	30.8	0.2	4	24.64
	(ii)	3-m high walls	1	22.1	0.2	3	13.26
	(iii)	Pillars	2	0.2	0.2	3	0.24
				Gross quantity of BW			= 38.14 m^3
	Deductions are same as for L/S method						(–) 8.36 m^3
				Net BW in superstructure			= 29.78 m^3

UNIT 4 ESTIMATION OF QUANTITIES IN RCC FORMWORK AND IN TRUSSES

Structure

4.1 Introduction

Objectives

4.2 General Specifications : Trusses and Formwork

4.3 Case Studies : RCC Formwork

4.4 Case Studies : Trusses (Timber and Steel)

4.5 Activities to Take up for Deeper Understanding of the Process of Quantity Estimation

4.6 Summary

4.7 Answers to SAQs

4.1 INTRODUCTION

Estimation of materials (say, timber, mild steel, etc.) in RCC formworks is as much difficult as it is easy. It is difficult; if the juxtaposition of its components, their various dimensions, and purpose are not completely understood: and, it is very easy once the assembly is conceived full and clearly.

In the determination of quantities, either in timber or steel truss, it is comparatively easier to comprehend the make-up of the work. Length dimensions of various truss members (finished product) can always be read from drawings or measured off the drawing sheet if that is drawn to scale. It is accurate to retrieve the information from the design data that has been worked out.

Objectives

After studying this unit, you should be able to

- know about the general specifications of the items involved in RCC formworks, and trusses (of timber as well as steel),
- develop the intuition to conceive the important details of the relevant drawing, and
- estimate the various quantities required to be determined in these works.

4.2 GENERAL SPECIFICATIONS : TRUSSES AND FORMWORK

General specifications, as said earlier also, help all the concerned – the designer, estimator, as well as the executing engineer – to perform appropriately in the respective area of the job. General specifications, in fact, are relevant every time, and at every place, affording a tool to bring the work to the desired perfection.

Timber Trusses

Work shall be done as per drawings, using only specified timber. All scantlings shall be very accurately planed smooth to the full dimensions and rebates, roundings, as per design. No patching or plugging, whatsoever, shall be tolerated.

Joints shall be simple, strong and neat. All joints – mortise and ***tennon,*** mitred, scarfs, etc. – must fit in fully and accurately without wedging or fillings. Holes of correct sizes shall be drilled before inserting screws or bolts. No screws shall be driven with hammer. All screws, bolts and nails shall be dipped in oil before using. Heads of nails and screws shall be sunk and puttied or dealt with as instructed.

Posts and beams shall be free from sap wood, large or loose knots, shakes, cracks, etc. These shall be properly dressed, fitted and fixed as designed. No beam is to be scarfed or joined in the middle unless shown in the drawing. All parts of timber in contact with masonry shall be coated with tar, etc. Clear spaces of about 4.0 cm to 5.00 cm in width shall be left on each side of beams that are to be embedded in masonry built in lime mortar.

Timber buried in the ground shall be charred and tarred. Woodwork exposed to the weather should be tarred or painted if the wood is seasoned; *otherwise it should be allowed to remain unpainted until seasoned.*

Timber sections shall be cut to correct lengths, and measured with a steel tape. A great accuracy shall be adopted in the fabrication of various members so that these can be assembled without being unduly packed, strained or forced into position.

Frame work of a roof does differ with respect to different forms of roof. Roofs may be flat, sloped or inclined. Supports for flat roofs are simple in construction***, but it is limited to small spans as sound timer longer than 6.0 m (20 ft) are rarely procurable, and even when available, are too heavy and expensive.*** Sloped roofs are suitable and economical for all spans. By various arrangements of timber pieces (posts, scantlings, beams, etc.) in fabricating a frame work, and by special devices of fixing beams and supports, great spans can be covered in buildings. Steel frame work is more common particularly where timber is costly or not easily available.

Sloped Roofs

Sloped roofs gabled or hipped are also in use. In the former the roof is formed by the intersection of two planes which slope upwards from the wall plates at the side of the building, meeting at an angle at the ridge, the end walls forming the gable. In the second case, the roof is formed by planes sloping up from the sides and the ends of the building to the ridge forming hips, the wall plates being on the same level all round.

Couple roof frame work is formed by the meeting of two beams on rafters fixed at an inclination. Their feet are nailed or notched on a wall plate embedded on the top of the wall and their heads meet upon a ridge board to which these are secured by nails. ***Such a frame work is suitable for small spans upto 4.25 m – (14 ft).***

Couple close roof is an improvement on the couple roof, and is formed by connecting the feet of the rafters by a tie beam, that prevents them from spreading and thrusting the walls out. ***It is economical for spans up to 5.5 m (18 ft).*** If the tie beam has to support a ceiling it may be held up by an iron rod (termed *king rod*), from the ridge.

Collar-beam roof is a variation of the couple close roof where a greater headway is required, the tie beam being raised half way up the rafters. However, it is a bad form of construction as the rafters bend in the middle and the thrust is borne by the walls. The situation can be improved by adding a tie beam or tie rod at the foot of rafters. This roof could be used only for small buildings not exceeding ***5.5 m in span.***

King post roof (truss) has a frame work consisting of rafters, king post, struts and tie beam known as ***King Post Truss***. These are used for spans up to 9.0 m (30 ft). In this truss, rafters are supported at the middle by means of props (termed braces or struts) – thus, their effective spans being reduced to half. Thus, the rafters are able to bear twice the load that these could carry otherwise. The heads of the struts are *tennoned* into the rafters and their feet into the foot of the king post. In order to guard against any cross strain coming under the rafters, the heads of the struts shall be fixed almost immediately near the purlins.

Queen post roof (truss) is best suited upto a span of about 14.0 m (≈ 45 ft). If the span is more than 9.0 m, the tie beam shall require more than one support – this is provided by means of two *Queen* posts. The queen posts, between them, carry about two-thirds of the weight of the tie beam and any addition of load brought upon the tie beam. The heads of the queen posts are kept apart by a straining beam and this feet are tennoned into the tie beam and prevented from moving inwards by a straining sill.

For spans greater than 14.0 m, roof trusses shall be designed by various combinations of posts and struts – however, then steel trusses prove economical.

Once the pitch (inclination of rafters to vertical) is known, the length of principal rafters can be ascertained by drawing the arrangement on a sheet. For too long rafters, it is appropriate to divide them into portions about 2.5 m (8 ft) long, placing a strut under each point of division. In actual practice, trusses shall be set up along the building, about 2.5 m to 3.00 m apart, and across these trusses (principals) are laid purlins, which fix them to their positions.

First a full-size truss diagram (as per drawing) shall be drawn on a levelled platform. From this full-size diagram, templates of all joints (as for tennons, mortices, scarfs etc.) shall be made to be used in guiding the fabrication work. Templates of corresponding truss members shall also be made – plate holes for screws and bolts shall thereafter be marked on these and drilled. These templates shall later be laid on wooden members, and the holes for screwing and bolting marked on them. The ends of the wooden members shall also be marked for the purposes of cutting. The base of RCC columns and the position of anchor bolts shall be carefully set out. Individual truss members must be first (before the final fabrication) assembled together to ensure close abutting or lapping of the surfaces of these various members.

After the trusses are fabricated, these shall be hoisted and placed in position very carefully. Trusses shall be screwed to walls by means of holding down bolts – hoisting having been done by using hoisting equipment. Trusses shall be stayed temporarily till these are finally secured permanently in position, and then purlins shall be laid connecting the trusses with each other.

Woodwork shall be measured for finished dimensions. Length of each piece shall be measured overall to the nearest cm – it takes care of projections for tennis, scarves or mitres. Width and thickness shall be measured to the nearest mm. Unless otherwise specified, iron fixtures (such as bolts and nuts, MS plates, holding down bolts) and staining, priming, painting or polishing of the trusswork shall be paid for separately.

Formwork for RCC – Floor, Beams, and Columns

If the reinforcement is adequately designed and appropriately placed a reinforced concretework never fails after construction. However, during construction, chances are there for the collapse of the work due to faulty design/construction of the forms. Thus, a meticulous design of the formwork is a pre-requisite for the trouble free construction of an RCC work. These days reputed firms specialize in this job. A responsible engineer must ensure the proper design and construction of formwork.

In order to construct a satisfactory concretework, the forms shall have to be durable and rigid, and well braced to prevent bulging or twisting. Forms shall have the required strength to take the oncoming loads. Horizontal members (like, floor-sheathing, joints, etc.) should withstand the weight of raw concrete and loads coming during the construction activity, and the vertical members (wall-sheathing and supporting studs) must be able to resist the hydrostatic pressure developed in the raw concrete it supports.

All the timber pieces (members) shall be of the best quality that is available. They shall be sound, straight grown, free from sap, shakes, loose knots, worm holes, etc. *Thorough seasoning is of great importance but partially seasonal timber is the best material for formwork* – too much dry timber tends to swell due to the absorption of moisture from green concrete; and, green timber tends to dry out and shrink in hot weather, causing fins and ridges on the concrete.

Different boarding thickness shall be used with various slab depths, live load being taken about 3.6 kN/m^2 (≈ 75 lbs per square foot). Bending moment (M) can be calculated as $M = \frac{w\,l^2}{10}$, and the deflection being limited to about 3.2 mm (≈ 1/8 of an inch). For sheathing planks, under vertical loads, these values do apply. Generally, for joists and beams (carrying joists) also deflection shall not exceed 3.2 mm for the dead loads and a live load of about 2.0 kN/m^2 (40 lb per ft^2).

Wooden forms shall be dressed equal in depth to the thickness of the slab at the sides. Forms shall rest on stakes driven into the ground within 30 cm of each end of each separate piece, and at intervals of not greater than 1.5 m elsewhere. Forms shall be held by stakes (driven into the ground along the outside edge) at intervals not more than 1.8 m, two stakes being placed at each joint. These shall be nailed firmly to the side stakes, and shall be appropriately braced, wherever needed, to resist the pressure of concrete/impact of the tamper (or vibrations of the electrical vibrator as the case may be). Forms shall be capped along the inside upper edge with 5 cm angle irons.

Metal forms (if used) shall comprise shaped steel sections, like as channels, etc. They should be at least 3.0 m in length for tangents and for curves having radius 45 m and above. Smaller pieces upto 1.5 m can be used for curves having radius less than 45 m. The depth of the forms shall be the same as the thickness of the slab – using adequate number of bracing pins or stakes to prevent any displacement of forms due to pressure of the concrete slab or impact of tamper, etc.

Forms shall be set to the exact alignment (and grade) at least 30 m in advance of the point where concrete is to be deposited. Before the setting of forms, these shall be thoroughly cleaned. After setting is done satisfactorily, forms should be thoroughly oiled prior to placing concrete against them. Forms, when in place, must be subject to checking, and correction of alignment and grade from time to time. It is important that forms shall be rigid: an essential condition for the even running of the intended finished surface.

No forms shall be removed until at least 24 hours have elapsed after the placement of concrete against them; and every care shall be taken while removing them ensuring no damage to concrete. Forms need be cleaned thoroughly before any reuse. [All the considerations discussed in Section 2.5.2 about formwork do apply along with the points discussed ***herein***.]

Where metal forms are used, all bolts and nuts (that go with this arrangement) shall be counter sunk, and well ground to provide a smooth, plain surface.

Chamfers, bevelled edges and mouldings shall be shaped in the form itself. Openings for fan clamps and other such fittings shall be provided in the shuttering as required. As far as possible the clamps shall be used to hold the forms together – wherever the use of nails is unavoidable, minimum number of nails shall be used, and these shall be left projecting so that these can be withdrawn easily. Use of double headed nails should be preferred.

For special type of locations – for tall structures, etc. – the use of moving/climbing forms shall be resorted to.

In long spans, suitable camber shall be given to the horizontal members – to counteract the effects of deflection under dead load, etc. Assembly of the formwork shall be so done as to allow the desired camber to the provided – say, bottom boards of beams require a camber of about 6.0 to 7.5 mm for a span of 1.5 m, i.e. $1/24^{th}$ of the spans, i.e., about 4 to 5 mm per meter (1 in 250). For cantilevers, camber at free end shall be $1/50^{th}$ of the projected length or so.

Temperature and humidity of air, and the nature of stress to which a member is subjected to (direct compression as in columns; flexure as in beams and slabs), and the relative proportions of dead and live load – all do influence the time required to keep the formwork in position. In cold (wet) whether, hardening of concrete is retarded and the forms must be kept in position a little longer. Also, wherever bending stresses (flexure) do occur, (as in slabs and beams) forms are kept longer than where direct compression acts (generally columns). Moreover, if the ratio of dead load to live load is quite high, the member has to bear a greater proportion of load immediately after the forms are removed – thus delayed removal is desirable.

As has been said earlier in a slab and beam construction, sides of beams shall be stripped first, and next follows the removal from under the slabs, and lastly from the under-sides of beams. Thus, one more aspect of the design of formwork consists in allowing an ordered removal of its components, such as :

(a) First, non-load bearing members (shutters to vertical faces) : column boxes, sides of beams, and wall forms,

(b) Next, shutters of soffits to slabs; horizontal, and inclined members : i.e., those carrying light loads – slabs, roofs, floors, canopies, etc.,

(c) Lastly, soffit shutters carrying heavy loads – beams, and girder bottoms.

However, the golden rule always remains that under no circumstances the forms shall be struck until the concrete (RCC) attains a strength of at least twice the stress to which it may be subjected at the time of striking.

Leaving formwork longer in position helps in curing the work and is a good policy. Section 2.5.2 gives a Table that must, at least, be followed while striking the formwork.

The method of measurement of formwork is based on IS Code 1200 Part V. *The actual surface of any type of formwork*, described herein later on, and rates of payment depend on the type, classification, etc. of the formwork) *in contact with concrete or any other material requiring form work shall be measured in* m^2 *and paid for accordingly*. Where the formwork is required to be lined with some material – wall board, hard board, polyethylene sheet or paper lining, or to be coated with a liquid or lime wash – such a formwork shall be so specified (described) and measured separately, for appropriate payment. Further, whenever a lining of well board, or asbestos cork slab, etc., is of a permanent nature, and is to be left in, it shall be measured separately for appropriate payment.

It is a general practice not to make any deductions for openings up to 0.4 m^2. Raking or circular cutting, and moulded or rounded edges shall be measured in running meters, and paid accordingly as per rates decided upon (after due rate analysis). Moulded stoppings shall be enumerated – i.e. paid by numbers.

Formwork of secondary beams shall be measured up to the sides of the main beams – however, no deduction shall be made from the formwork of the main beam where the secondary beam intersects it. Similarly, no deduction shall be made from the formwork for stanchions (or columns) casings at the intersections with beams.

Every formwork needs supports, braces, wedges, struts (Figures 4.1 and 4.2), and also mud sills, piles and/or any other suitable supports to achieve rigidity and stability. Also bolts, wire ties, clamps, spreaders, etc. are needed to keep the sheathing together. It also includes filleting to make up chamfered edges or splayed external angles (not more than 20 mm wide) to beams, columns, etc.; and, includes raking or circular cutting.

If found necessary, temporary openings in the formwork shall be allowed to admit pouring of concrete, inserting vibrators. Holes can be incorporated to clean/remove dirt, etc., from the inside of the sheathing prior to concerting. Necessary arrangements should be in place for dressing the formwork with oil in order to prevent adhesion of concrete to the formwork.

Formwork should be so assembled as to provide due allowances for overlaps (if needed); allow providing splayed edges, notching, battens, strutting, nailing/bolting, wedging; and, above all allow smooth easing, striking, and removal after the due time period is over. All formwork will include the necessary working scaffoldings, ladders, gangways, etc.

Generally, formworks are measured and paid for as per the given classifications, such as :

(a) Formwork for foundations, footings, base of columns, etc.

(b) Formwork for flat surfaces – soffits of floors, roof slabs, landing, etc. However, for floors that exceed 20 cm in thickness, heavy forms are required, and, hence, the formwork shall be measured separately specifying the floor thickness.

(c) Formwork for vertical surfaces – say, walls, partitions, etc., (including associated pilasters, buttresses, etc).

(d) Formwork for curved surfaces of a given radius, type of curve being taken into account.

(e) Formwork for battered (or sloping) surfaces.

(f) Formwork for the sides of columns, piers, and stanchions.

(g) Formwork for staircase, etc.

This list can be extended to cover other items of civil engineering works.

Moreover, the rates of payment for the formwork shall depend on the nature of the material used, and its make-up, such as :

(a) Wrought iron formwork – sheathing presenting planed surfaces.

(b) Sheathing of steel sheets, plywood sheets, moulded plaster, or sheathing made of tongued and grooved boards.

(c) Specially lined sheathing for ornamental surfaces.

4.3 CASE STUDIES : RCC FORMWORK

With a view to gaining access into the so-called intricacies of estimating the quantities of various items of a given RCC formwork (already designed for withstanding the expected loads during the period of the construction activity) following solved examples are presented as an introduction to this aspect of the job of an estimator.

Example 4.1

Figure 4.1(a) and (b) give the typical details of a formwork for the given RCC work – several halls having columns, beams, and slab.

Estimate the quantity of wood (Teak) required to be paid for (for constructing its various components) with respect to one beam (5.5 m span), one column, and slab of one hall.

Figure 4.1(a) : Details of RCC Formwork (Slab, Column and Beam) : Example 4.1 (Not to Scale)

Figure 4.1(b) : Section [Along A-B : Figure 4.1(a) – (i)] giving Details of Formwork (Not to Scale)

Solution

Before making a conventional bill of quantities, preliminary calculations are necessary to arrive at the needed dimensions, as shown below :

Length to be Covered

Length of slab to be covered = 6.0 – twice half-beam width

$$= 6.0 - 2\left[\frac{0.25}{2}\right]$$

$$= 6.0 - 0.25$$

$$= 5.75 \text{ m}$$

Breadth of slab to be covered $= 5.5 - 2\left[\frac{0.25}{2}\right]$

$$= 5.25 \text{ m}$$

Length of ballies (with reference to the slab of the hall) to be used in the formwork

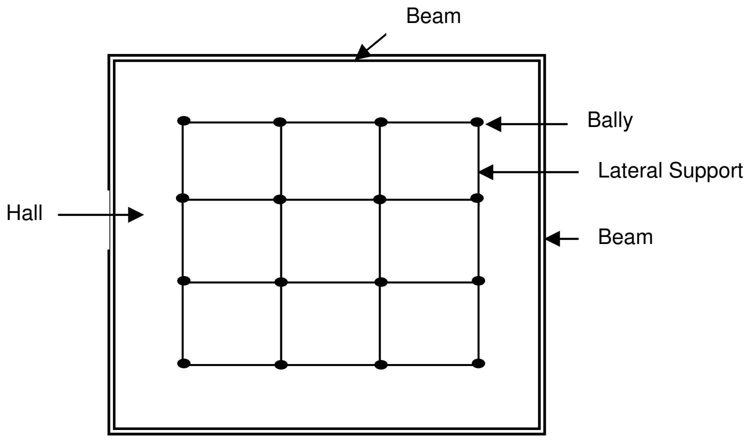
= (3 × 1.2 + 0.65 = 4.25 m) – 0.075 m at top – 0.075 m at bottom

= 4.10 m

[A gap of 7.5 cm at the top is shown in the Figure, and is needed to conveniently place the ballies in position, and the bottom gap (0.75 cm) is needed to accommodate the base plate and the wedges.]

Cross-section of a *bally* $= \frac{\pi}{4}(0.10)^2$

$$\approx 0.008 \text{ m}^2$$



(Web of Ballies and Lateral Supports – at One Level)

Number of *ballies* needed for one hall = [No of rows of *ballies* perpendicular to 5.5 m-side @ 1.2 m c/c] × 4 (i.e., along 6.0 m-side, as shown in the Figure)

$$= 4 \times 4 = 16$$

Number of lateral supports needed for *ballies* at one level in one hall = 12

Number of lateral supports needed for *ballies* at three levels (Figure 4.1(b)) in one hall = 3 × 12 = 36.

Beam to be Covered

Vertical length of 2.5 cm thick vertical planks

$$= 53 - 15 - 2.5 = 35.5 \text{ cm}$$

Horizontal length of 2.5 cm-thick horizontal plank

$$= 25 + 2 \times 2.5 = 30 \text{ cm}$$

Vertical length of laterals = 53 – 15 – 2.5 + 2.5 = 38 cm

Number of these laterals in one beam (on two sides)

$$= 2\left[\frac{6.0\,\text{m}}{0.9} + 1\right] = 2\,[6.6 + 1] \approx 2(7) \approx 14$$

Number of tapering blocks on every base beam

$$= 2 \text{ (i.e., on both sides of the beam)} \times \left(\frac{5.5}{1.2} + 1\right)$$

$$= 2 \times [4.5 + 1]$$

$$\approx 2 \times (5) = 10$$

Similarly, number of base beams = 1 × 5 = 5.

And, number of struts (on both sides of the beam) – with each base beam = 2 × 5 = 10.

Length of a ***bally*** under the beam = 4.25 – 0.405 – (0.075 + 0.10)

$$= 3.67 \text{ m}$$

[where, 53 – 15 + 2.5 = 40.5 cm = vertical length from bottom of slab to top of base beam; and, 0.075 + 0.10 = (height of base plate and wedges) + (thickness of base beam)].

Number of these ballies = 5 (as explained alone)

Area of this ***bally*** (0.1 m ϕ) = 0.008 m^2 (as explained earlier also)

Number of base plates (as is obvious) = 5

Column

Vertical length of column to be covered = 4.25 m

$$\text{Number of laterals} = 2\left(\frac{4.25}{1.2} + 1\right)$$

$$= 2\,[3.5 + 1] \approx 2\,[4] \approx 8$$

Now an estimate of quantities is presented below in the usual format :

Estimate of Quantities for Formwork for RCC Item (Example 4.1)

Sl. No	Description of Item	No.	Measurements			Quantity	Total
			L (m)	B (m)	H/D (m)		
1.	*Woodwork for the formwork of one slab (i.e. for one hall)*						

	(i) Planks (2.5 cm thick)	1	5.75	5.25	0.025	0.755 m^3	
	(ii) Beams (10 × 4 cm) – each is 5.5 m long, and their total number is 4 (one on each centre line in the plan)	4	5.50	0.10	0.04	0.022m^3	
	(iii) Ballies (10 cm ϕ)	16	4.1	0.008 m^2	–	0.525 m^3	
	(iv) Lateral supports (10 × 5 cm @ 1.2 m c/c)	36	1.2	0.1	0.05	0.006 m^3	
	(v) Base plates (30 × 30 × 5 cm)	16	0.30	0.30	0.05	0.072 m^3	
							1.38 m^3
	(vi) Pairs of wedges (This minor item can be expressed in numbers)	16				16 Nos.	16 Nos.
2.	*Woodwork for one RCC beam formwork*						
	(i) Planks						
	(a) Side plank	2	5.5	0.025	0.355	0.0986 m^3	
	(b) Bottom planks	1	5.5	0.30	0.025	0.041 m^3	
	(ii) Laterals (5 × 4 cm) @ 0.9 m c/c	14	0.38	0.05	0.04	0.011 m^3	
	(iii) Tapering blocks on base beams – 23 × 5 × 7.5 cm. (the last dimension is perpendicular to paper)	10	0.23	0.075	0.05	0.0086 m^3	
	(iv) Base beams (10 × 7.5 cm) @ 1.2 m c/c	5	0.48	0.10	0.075	0.018 m^3	
	(v) Struts (below base beams) – 5 × 5 cm, 0.30 m long	10	0.3	0.05	0.05	0.0075 m^3	
	(vi) Ballies (10 cm ϕ)	5	3.67	0.008 m^2	-	0.15 m^3	
	(vii) Base plate (30 × 30 × 5 cm)	5	0.3	0.3	0.05	0.023 m^3	
	(viii) Blocks (a minor item – allowing, say, 0.03 m^3)	-	-	-	-	0.03 m^3	
							0.39 m^3
	(ix) Pair of wedges	5				5 pairs	5 pairs
3	*Column* (*one*) *woodwork for its formwork*						
	(i) Planks (2.5 cm thick)						
	(a) In *x*-direction	2	4.25	0.3	0.025	0.064 m^3	
	(b) In *y*-direction	2	4.25	0.35	0.025	0.074 m^3	

	(ii) Laterals (6.3 × 5 cm) @ 1.2 m c/c	8	0.53	0.05	0.063	0.013 m^3	
	(iii) Blocks – allowing 0.012 m^3					0.012 m^3	
							0.163 m^3
	(iv) Bolts (1.25 cm ϕ) (with nuts, etc.)		4	2		8 sets	8 sets

Example 4.2

Figure 4.2 details out a formwork (designed by a civil engineer for dead and live loads that may act while the construction activity proceeds) for an RCC beam (10 cm-dia bolts with washers are used in this work – 40 cm long). Estimate the quantity of various components and the total woodwork required, so that whenever needed this data is used to calculate the rate of payment that can be fixed on a rational basis.

[**Note :** *The length of beam (8.00 m) may be taken as including both side bearings – though no bottom plank cover can be laid over the walls that bear the beams. Nails are included in the rate for woodwork.*]

Solution

Nails are included in the rate for woodwork.

Bill of Quantities

Sl. No.	Description of Item	No.	Measurements			Quantity	Total
			L (m)	B (m)	H/D (m)		
Word work in the given form work							
1.	Side planks – 2.5 cm thick, 50 cm wide.	2	8.05	0.50	0.025	0.20 m^3	8.0 + (2 × 2.5 cm) = 8.05 m
2.	Bottom planks – 5 cm thick	1	7.8	0.35	0.05	≈0.14 m^3	30 + 2 (2.5) = 0.35 m; & 8.0 – 2 × bearing on either side = 8.0 – (2 × 0.1) = 7.8 m
3.	End planks – 2.5 cm thick	2	0.55	0.35	0.025	≈ 0.01 m^3	50 + 5 = 0.55 m & 30 + (2 × 2.5) = 0.35 m
4.	Side stiffeners – 4 cm thick, @ 1.0 m c/c	2 × 9	0.55	0.10	0.04	0.072 m^3	$\frac{8}{1} = 8 + 1 = 9$
5.	Bottom supports	9	0.50	0.10	0.05	0.023 m^3	
6.	Brackets – 5 × 5 cm	2 × 9	0.50	0.05	0.05	0.023 m^3	
7.	Prop braces – 5 × 10 cm	2	7.8	0.1	0.05	0.078 m^3	Length = 8 – 2 (0.1) = 7.8 m
8.	Bearing plates for props	9	0.3	0.3	0.05	0.041 m^3	
9.	Wedges	9	0.2	0.15	0.08	0.022 m^3	
10.	10 cm – dia, ballies (i.e. props)	9	2.5	0.008 m^2	–	0.18 m^3	Sectional area of a *bally* = $\frac{\pi}{4}(0.1)^2$ = 0.008 m^2

Note : *Sometimes ballies are paid for in Nos when dia and length are specified.*							
						Total	$= 0.789\ m^3$ $= 0.80\ m^3$ (say)
1.	*Bolts and Washers* 10 cm - ϕ tie bolts (40 cm long) with washers	10 (say)	–	–	–	10 Nos.	

Figure 4.2 : Formwork (Centering + Shuttering) of RCC Beam (Part of a Roof) – Example 4.2 – Not to Scale

For the sake of a rate analysis, about 5% of 0.80 m^3 can be added to the total wood required (= 0.8 + 0.04 = 0.84 m^3) as wastage to arrive at the grand total. After the total cost of the timber work is arrived at, about 20% of that cost can be taken as the salvage value of timber and ballies when the set up becomes unserviceable – assuming that the setup becomes unserviceable after using it 20 times over. This salvage value gets deducted from the total cost of timber and ballies. And, the remaining net amount can be divided by 20 to get the cost figure for using the set-up once – to this figure, the cost of labour and sundries gets added to arrive at the total material and labour cost of the set-up. Adding 10% of this amount as contractor's profit, and dividing the sum (x, say) by the volume of the beam gives the rate of formwork per m^3 of the RCC work.

Surface Area of the Shuttering in Contact with RCC in this Example

$$= 2\,(8 \times 0.5) + (8.00 - 2 \times 0.10) \times 0.3 + 2\,(0.5 \times 0.3)$$

where, 0.10 m is the bearing of the beam on either side.

$$= 8.0 + 7.8 \times 0.3 + 2 \times 0.15$$

$$= 10.64 \text{ m}^2$$

Hence, the rate per m^2 (which is the standard unit of measurement for payment in the case of formwork used) = $\dfrac{x}{10.64}$

= Rs. y (say).

4.4 CASE STUDIES : TRUSSES (TIMBER AND STEEL)

Following solved examples are presented with the aim of making the student familiar with the various components of the two types of trusses (timber and steel) and different types of quantities that need be estimated.

Example 4.3

A godown measuring 18 ×10.5 m is having a pitched roof – consisting of Queen-post trusses (at 3.0 m c/c), purlins, common rafters with battens and Mangalore tiles (Figure 4.3). **Short walls of the godown are provided with gables.**

Estimate the quantities of the following :

(a) Woodwork in each truss, and all the trusses,

(b) Woodwork in purlins, and common rafters,

(c) Woodwork in eaves boards, and barge boards,

(d) Area of tiled roof,

(e) GI sheet eaves gutter, and

(f) Concrete bed blocks.

Figure 4.3 : Queen Post Truss (with Wall of Godown Included) Section – Example 4.3 (Not to Scale)

Specifications are as follows :

(a) Queen-post truss shall be of second class country cut teak wood. Its rate shall include joinery, iron straps, and oiling with 3 casts of double boiled linseed oil, including erection into position, and complete in all respects.

(b) Tie beam shall be in 3 pieces (4.11 m each) – full-span tie (in one piece) is not possible to obtain. Material for three pieces and due wastage makes up the total quantity.

(c) Queen post = 2.3 m (finished dimension) long.

(d) Principal = 4.4 m long.

(e) Strut = 2.21 m long. Straining beam = 3.8 m long.

(f) Straining sill = 3.05 m long.

(g) Common rafter = 7.2 m long.

(h) Concrete bed blocks = 50 × 60 × 19 cm.

(i) Rate for purlins covers providing and fixing in position. Woodwork shall be of second class country cut teak wood, including joinery, and three coats of double boiled linseed oil after fixing in position.

(j) Rates for eaves board and barge board include – providing and fixing. These shall comprise first class country cut teak wood; and the rates shall also cover oiling with three coats of linseed oil, and painting with three coats of green oil paint as per detailed specifications.

Note : Rates for all woodwork are per m^3.

(k) Rates for Mangalore tiled roof cover : providing, and laying of the best quality (as specified) of tiles, includes teak wood battens of 3.75 × 1.9 cm section at 26.5 cm distances apart; also included is oiling with three coats of linseed oil, etc. complete. Rate for roof tiles is per m^2.

(l) Rate for eaves gutter covers: providing and fixing half round GI sheet gutter, 15cm dia., including iron brackets; fixing these in position, etc; complete in all respects. Rate for this is per m.

(m) Rates for concrete bed blocks (1: 2 : 4 mix) includes centering, and cutting and finishing sides smooth, etc., and complete in all respects. Rate is per m^3.

Solution

Common rafters are placed @ 53 cm c/c, thus their total number

$$= \frac{18.38}{0.53} = 34.67 \approx 34 \text{ (say) } + 2 \times \text{(one at each end)} = 36.$$

And, number of trusses = 5 (Figure 4.3) – because there are two gables : one at each end of the godown.

The required bill of quantities is tabulated as under :

The Bill of Quantities – Example 4.3 – in Queen Post Truss

Sl. No	Description of Item	No.	Measurements			Quantity
			L (m)	B (m)	H/D (m)	
1	*Woodwork in one Queen Post Truss – providing and fixing as per given specifications.*					
	(i) Tie beams	3	4.11	0.125	0.125	0.193 m^3
	(ii) Queen posts	2	2.3	0.125	0.15	0.043 m^3
	(iii) Principals	2	4.4	0.125	0.18	0.20 m^3
	(iv) Struts	2	2.21	0.10	0.075	0.032 m^3
	(v) Straining beam	1	3.8	0.125	0.15	0.071 m^3
	(vi) Straining sill	1	3.05	0.125	0.15	0.057 m^3
					Total (one truss)	= 0.596 m^3
	Total Woodwork for Five Trusses (5 × 0.596)					= 2.98 m^3
2	*Woodwork in Purlins and Common Rafters –* providing and fixing as per specifications.					
	(a) Purlins	6	18.38	0.125	0.15	2.07 m^3
	(b) Common rafters	2 × 36	7.2	0.10	0.075	3.89 m^3
					Total	= 5.96 m^3
3	*Woodwork in eaves boards and barge boards* – providing and fixing as per specifications					
	(a) Eaves boards	2	18.38	0.025	0.15	0.138 m^3
	(b) Barge boards	2	18.38	0.025	0.23	0.211 m^3
					Total	= 0.349 m^3
4	*Mangalore tiled roof* – providing and laying as per specifications	2	18.38	7.2	-	264.67 m^2
					Total	= 264.67 m^2
5	*Eaves gutter* – providing and fixing as per specifications	2	18.38	-	-	36.76 m
					Total	= 36.76 m

6	*1 : 2 : 4 mix concrete bed* – providing and laying as per specifications *(there being 5 trusses)*	2 × 5	0.60	0.50	0.19	0.57 m^3
					Total	= 0.57 m^3

[**Note :** After working out the cost (for any given set of rates for various items), one can express the cost of this roofing per 10 m^2 of the area covered.]

Example 4.4

A galvanized corrugated iron roof is to be installed over eight trusses, from end-to-end of the godown shed (Figure 4.4). The roof covering will be 22 BWG galvanized iron with 20.5 cm gutters at the eaves.

Figure 4.4 : A Steel Roof Truss : Example 4.4 (Not to Scale)

The trusses will be made of steel throughout, anchored down the side walls, and put at 2.9 m c/c spacing. The roof covering shall project 0.9 m from the last truss at both the ends of the shed.

There will be 4 down pipes on each side – each one 6.10 m in length, including bends and elbows.

All the steel work in trusses and purlins will be given three coats of ready-mixed superior oil paint of approved shade (or colour).

The detailed drawings (not given here) show 6 sheets of corrugated iron – each 2.10 m long – and 2 sheets of 3.00 m length along the width of each slope of the roof. The usual width of a sheet may be assumed 0.81 m, and the overlap be taken as 2 corrugations of 8.5 cm each.

Estimate the various quantities as per the details given. [***Lengths of various truss members can also be directly measured from the drawing if that is drawn to scale.***]

Solution

Total length of roof

= (No. of trusses – 1) × 2.9 + 2 × Given end projection

= (8 – 1) × 2.9 + 2 × 0.9

= 22.1 m

In ordering the roofing material for any roof the exact number of corrugated iron sheets, that would be required, shall have to be stated without any ambiguity :

No. of sheets required, along the length of the roof (considering one row) would be equal to :

$$\Rightarrow \quad \left[\frac{22.1}{\left\{0.81 - \frac{2 \times 8.5}{100}\right\}}\right]$$

$$\Rightarrow \quad \frac{22.1}{0.64}$$

$$\Rightarrow \quad 34.5 = 35 \text{ Nos. (say)}$$

Hence, total number of sheets required (considering all the rows):

(a) ⇒ $6 \times 35 = 210$ Nos. of 2.1 m × 0.81 m

(b) ⇒ $2 \times 34 = 68$ Nos. of 3.0 m × 0.81 m

[**Note :** 34.5 has been rounded off to 35 – so 35 and 34 numbers are a little arbitrary; and one can always calculate exactly as per given drawings.]

The bill of quantities of various items of the truss is prepared as given below :

Bill of Quantities of Steel Truss – Example 4.4

Sl. No.	Description of Item	No.	Measurements L (m)	B (m)	H/D (m)	Quantity
1.	***Steel in one truss***					
	(i) T. S. Rafters (100 × 65 × 10 mm) @ 12.2 kg / m	2	90	–	–	219.60 kg
	(ii) Brackets for gutters (L. S. 50 × 50 × 6 mm) @ 4.5 kg/m [Straight portion = 30 cm; curved portion = $\pi \times \left(\frac{20.5}{2}\right) = 32.2$ cm. Total Length = 62.2 cm.]	2	0.622		–	5.60 kg
	(iii) Knees (LS – 60 × 60 × 10 mm) for purlins, @ 8.6 kg/m [length = 100 mm = 0.1 m, to fit on TS rafter.]	2 × 6	0.1			10.32 kg
	(iv) Tie rod (F.B – 60 mm ×10 mm), @ 78.5 kg/m^2	1	15.2	0.06		71.60 kg
	(v) Sloping FB – (4) in the *legend* – 60 mm × 10 mm), @ 78.5 kg/ m^2	2	2.29	0.06		21.57 kg
	(vi) FB (60 mm × 10 mm) – (5) in the *legend* – @ 78.50 kg/ m^2	2	2.44	0.06		22.98 kg
	(vii) FB (60 mm ×10 mm) – (6) in the *legend* – @ 78.50kg/ m^2	2	3.35	0.06		31.56 kg
	(viii) FB (60 mm × 10 mm) – (7) in the *legend* – @ 78.50 kg/ m^2	1	2.67	0.06		12.58 kg
	(ix) TS vertical struts (80 × 80 × 8 mm) – (8) in the *legend* – @ 9.6 kg/m	6	1.30	–		74.88 kg
	(x) Foot plates (10 mm thick) @ 78.50 m^2	2 × 2	0.45	0.50		70.65 kg
	(xi) Gusset plates, 10 mm thick, @ 78.50 kg/ m^2					
	Item 9 in the *legend*	1	0.38	0.23		6.86 kg
	Item 10 in the *legend*	1	0.30	0.20		4.71 kg

	Item 11 in the *legend* [Foot of struts]	6	0.30	0.19		26.85 kg
	Item 12 in the *legend* [Head of lower – end struts]	2	0.23	0.23		8.31 kg
	Item 13 in the *legend* [Head of centre struts]	2	0.27	0.23		9.75 kg
	Item 14 in the *legend* [Head of struts near the kind rod]	2	0.23	0.23		8.31 kg
	(xii) Anchor plates @ 62.8 kg/m^2	2	0.45	0.45		25.43 kg
	(xiii) Rivets in trusses and knees[= 5% of sum of item (i) to (*xi*)]	$\frac{5}{100} \times (606.13)$			–	30.31 kg
	(xiv) Anchors bolts 0.025 m ϕ – @ 4.6 kg/m on the average.	2 × 4	0.66			24.30 kg
	(xv) Heads and nuts – say, $\frac{1}{6}$ of item (xiv)	$\frac{1}{6} \times 24.30$				4.05 kg.
	Grand Total for 1 Truss					**= 690.22 kg**
	Total for 8 Trusses (8 × 690.22 kg)					= 5521.76 kg
	Add 5% for wastage $= \left(\frac{5}{100} \times 5521.76\right)$					= 276.09 kg
	Grand Total For 8 Trusses					**5798.00 kg (say)**
2.	*Mild Steel Purlins* @ 8.6 kg/m	2 × 6	22.10 (total length of roof)	–	–	2280.72 kg
3.	*Steel in wind ties* (*3 on each side on of pitched roof, not shown in the Figure*) *– FB, 3.2 cm × 0.6 cm thickness - @ 47.1kg/m^2*	2 × 3	22.1	0.032	–	199.85 kg
	Total of (2) and (3)					**2480.57 kg**
4.	*Painting as per specifications in one truss*					
	(i) Rafters	2	9.0	0.33	–	5.94 ≈ 6.00 m^2
	Surface width of T-section	⇒ 2 × 100 mm + 2 × 65 mm = 330 mm = 0.33 m				
	(ii) Brackets for LS gutters	2	0.622	0.20		0.2488 ≈ 0.25 m^2
	Surface width of L section	⇒ (2 × 50) + (2 × 50) = 200 mm = 0.2 m				
	(iii) Knees for purlins	2 × 6	0.1	0.240	–	0.288 ≈ 0.29 m^2
	Surface width	⇒ (2 × 60) + (2 × 60) = 240 mm = 0.24 m				
	(iv) Tie rods taken al1 pieces together	1	15.2	0.14		2.128 ≈ 2.13 m^2
	Surface width	⇒ (2 × 60) + (2 × 10) = 140 mm = 0.14 m				

	(v) Vertical struts (taking the given average length into consideration) (or, one can compute the surface area, by one by one strut)	6	1.3	0.32		2.496 ≈ 2.5 m^2
	Surface width	⇒ (2 × 80) + (2 × 80) = 320 mm = 0.32 m				
	(vi) King rod	1	2.67	0.14		0.3738 ≈ 0.374 m^2
	Surface width	⇒ (2 × 60) + (2 × 10) = 140 mm = 0.14 m				
	(vii) Foot plates					
	(a) 2 (2 at each wall × 2 sides)	8	0.45	0.5		1.8 m^2
	(b) Thickness-wise	*This item could have been neglected because of extremely low value*				0.0036 m^2
[**Note :** For each plate, thickness area = 2 (10 mm × 45 mm) = 900 mm^2 = 0.0009m^2. For 2 plates thickness area = 0.0018 m^2; and, thus, for 4 plates (i.e. for both walls), thickness area = 0.0036m^2.]						
	(viii) Gusset plates (neglecting thickness-wise surfaces)					
	(a)	2 sides	0.38	0.23		0.17 m^2
	(b)	2 sides	0.30	0.20		0.12 m^2
	(c)	2 sides × 6 Nos. for one truss	0.3	0.19		0.684 ≈ 0.7 m^2
	(d)	2 × 2	0.23	0.23		0.2116 ≈ 0.21 m^2
	(e)	2 × 2	0.27	0.23		0.2484 ≈ 0.25 m^2
	(f)	2 × 2	0.23	0.23		0.2116 ≈ 0.21 m^2
	(ix) Anchor bolts (2πr = 2π × 2.5 = 15.7cm)	4 × 2 walls	0.66	0.157		≈ 0.83 m^2
	(x) Anchor plates (neglecting thickness-wise areas	2 × 2 sides	0.45	0.45		0.81 m^2
	Total painting for one truss					**= 16.65 m^2**
	Total painting for 8 trusses (8 × 16.65)					**= 133.2 m^2**
5.	*Painting (as per specifications) for steel purlins, and wind ties.)*					
	(a) Purlins	12	22.1	0.24	–	63.65 m^2
	(width for painting)	⇒ (2 × 60) + (2 × 60) = 240 mm, neglecting thickness area				
	(b) Wind ties	6	22.1	0.076	–	10.08 m^2
	[width of painting	⇒ 2 × 3.2cm + (2 × 0.6cm) = 7.6 cm]				
					Total	**= 73.73 m^2**
					Grand Total of Painting (133.2 + 73.73)	**= 206.93 m^2**
6.	*Galvanized Corrugated Iron Roofing* Both slopes of the pitched roof (with overlaps)	2 (i.e. two slopes)	22.1	9.0	-	**397.8 m^2** (to be paid to the contractor or this area)

7.	*23 cm GI ridging*	1	22.1	-	-	**22.1 running meter**
8.	*Gutters and Down Pipes*					
	(a) Gutters	2	22.1	-	-	**44.2 running meter**
	(b) Down pipes	4×2	6.1	-	-	**48.8 running meter**

It is left to the student to prepare an *abstract of cost* on the basis of cost on the basis of following rates :

(a) Steel including cutting, fabricating, welding, and erection into position – Rs. 40/- per kg.

(b) Painting (as per specifications) – Rs. 10/- per m^2.

(c) GI roofing (including laying, etc.) – Rs. 100/- per m^2.

(d) GI ridging – Rs. 5/- per metre.

Add 5% towards contingency; and also suitably for tools and plants, and for work charge establishment to arrive at the total cost of the work.

4.5 ACTIVITIES TO TAKE UP FOR DEEPER UNDERSTANDING OF THE PROCESS OF QUANTITY ESTIMATION

It is in the interest of gaining the desired skill and speed in estimating the quantities involved in formwork and trusses that the student should take up the following suggested activities :

RCC Formwork

Collect the actual field data for various formworks – beams, columns staircases, roof slabs, etc. – most easily available with private (reputed) construction firms, and/or with PWD (or CPWD) engineers. The data should comprise drawings and bill of quantities that have already been prepared.

The student should himself/herself work out the data, and then compare with the details worked out by the source agency.

Design of any formwork is subject to minor variations from agency to agency – these finer points should be noted.

Trusses – Timber and Steel

The relevant data from government and/or private agencies should relate to Queen Post and King Post Trusses, and to various forms of steel roof trusses, bridge trusses (road and railway). One's solutions can be compared with the already available solutions.

This much exercise should put the student on a firm footing and make him/her on ace estimator – what is, however, needed is consistent hard work. Everything comes for a price.

Rate Analysis for the above items should also be studied as to how an agency works out these things.

SAQ 1

(a) Explain how trusses are more economical and efficient than load bearing beams?

(b) Under what conditions are pitched roofs recommended for buildings? Which regions in our country go in for trussed roofs?

4.6 SUMMARY

Trusses (timber and steel) have their own general specifications for their appropriate construction and erection, as have various formworks required for RCC items to be constructed. These specifications also guide the designer and an estimator to classify various items of these works to be paid appropriately as per the rates of payment arrived at prior to any exercise in estimation. Specifications clearly lay down the methods of measurement and the relevant units to be adopted.

It is always advantageous to work out the required dimensions (if not directly available from drawings or written data) of an item to make the procedure of preparing a bill of quantities a pleasant exercise, and avoid any ambiguities, doubts or confusions.

4.7 ANSWERS TO SAQs

Refer to relevant preceding text in the Unit or other useful books listed in section 'Further Reading' to get the answers of SAQs.

UNIT 5 ESTIMATION OF IRON AND STEEL AND THE QUANTITY OF RCC IN BUILDING ITEMS

Structure

5.1 Introduction

Objectives

5.2 General Specifications : Iron and Steel

5.2.1 Preparation of Bar Bending Schedule

5.2.2 Rolled Steel Beams, Structural Steelwork and Other Items

5.2.3 Measurement of Steel and Ironworks

5.2.4 Roofing Over Trusses

5.2.5 Collapsible Gates and Shutters

5.3 General Specifications for RCC Work

5.3.1 Proportioning and Mixing of Cement Concrete

5.3.2 Placement of Reinforcement

5.3.3 Joints in RCC Works

5.4 Rate Analysis : Joists and RCC Works

5.5 Case Studies

5.6 Summary

5.7 Answers to SAQs

5.1 INTRODUCTION

Every reinforcement cement concrete (RCC) item of work – grillage foundation, DPC, lintels over doors/windows/almirahs, beams, slabs, columns, etc. – consists of coarse and fine aggregates, cement and mild steel (MS) reinforcement bars. These resist mostly tension, (in which pure concrete is very weak) and shear force. Twisting moments are resisted by special RCC members.

After a proper design of an RCC element, to resist the oncoming dead and live loads, a construction engineer is provided with drawings and specifications (details) that make it possible to estimate the quantity (number, length, and size) of steel rebars of various diameters. Knowing the respective numbers, and taking (from the given standard tables) the weight per metre of such size (i.e. diameter), one can estimate the weight of steel that is required and is paid by weight.

Bar bending schedules – a table showing shape, length, size and number of each type of steel – are prepared to guide the construction personnel to place the reinforcement appropriately.

Objectives

After studying this unit, you should be able to

- estimate the bulk quantity (volume) of RCC in a given structural element,
- take out the quantity of MS reinforcement required in the element,

- prepare a bar-bending schedule for reinforcement, and
- know about the importance and use of specifications in a steel and RCC work.

5.2 GENERAL SPECIFICATIONS : IRON AND STEEL

All *iron work* shall be manufactured from steel, wrought iron and/or cast iron as specified in the detailed specifications.

All smith-work shall come clean and sound from the anvil, not burnt or injured in any way. All bends shall be made cold wherever possible. Where, in order to bend *angles*, *tees* or other *rolled* sections which will be subject to direct stress, it is necessary to use heat, these shall be annealed subsequently in every case (except that of girder web stiffners). Any piece which has become overheated, strained, unsound, imperfect, or reduced in section, shall be replaced by a sound one.

All exposed edges shall be finished square and smooth by filing, milling or planing. Ends of straps, when exposed, shall be finished generally to an octagonal or semicircular shape as per specifications, and filed smooth. After fabrication, work shall be cleaned of all scale, rust, etc. with wire brushes, and oiled and/or painted as per specifications.

Holes of a diameter greater than 9.5 mm (i.e. 3/8th inch), or a material of thickness greater than 4.70 mm (i.e. 3/16th inch) shall not be punched, except that, where proper machine punching is carried out in a workshop; all other holes shall be drilled. All burrs left by punching or drilling shall be removed before assembly.

All bolts and nuts shall be made in accordance with Indian Standard Specifications – and unless specified otherwise, the bolt-heads and nuts shall be hexagonal. All nuts shall fit hand-tight. The head and shank of every bolt shall be forged from the solid mass; and the shank must be truly cylindrical, and the head concentric. Whereas shall be provided in all cases where the combined thickness of the members to be connected is less than the unthreaded portion of the bolt. Steel or wrought iron tapered washers shall also be provided, for all heads and nuts bearing on bevelled surfaces.

Generally, the specified dimensions, of a rivet, as shown on the drawings, refer to the diameters of the cold rivet. Each rivet shall be of sufficient length to form a head of the standard dimension. For rivets of diameters of 15.87 mm (≈ 5/8th inch) and above, the diameter of the rivet, before being heated shall not be less than the diameter of the hole it is intended to fill by more than 1.58 mm (≈ 1/16th inch). Rivets shall be heated to a red heat from head to point when inserted, and shall be upset immediately in the entire length so as completely to fill the holes. All loose rivets, and rivets with cracks, badly formed, or with deficient heads, or with heads which are unduly eccentric shall be cut and replaced. Flattened rivet heads shall be allowed where clearances are required.

All steel and ironworks, with the exception of reinforcing bars for cement concrete, and the items to be embedded in brickwork or stone masonry, shall, on completion of the work (item) be scraped free from rust and scale with steel wire brushes, cleaned, and *thoroughly coated with double boiled linseed oil, laid on* *hot. All structural steelwork and such other steel or iron work as may be specified shall be given one heavy coat of best red oxide in best double boiled linseed oil, such work being included in the rate*. Where further coats of paint have to be executed (as per specifications) all the requirements, for painting metal works (iron and steel), shall again be followed, such as :

(a) Surface of ironwork shall be absolutely free of rust or scale – using a scraper/steel wire brush. The surface shall be dry and dusted clean before applying any paint. *No chemicals of any kind shall be used for cleaning the iron*.

(b) If cleaning has been completed the day before or earlier, the surface shall be brushed just prior to painting.

(c) No painting shall be carried out in wet weather, and wherever possible paint shall only be applied to ironwork when it has been warmed by the sun.

(d) When re-painting ironwork, if the old paint is sound, it shall be rubbed with wire brushes and scrapers – all loose paint to come off. However, if this paint is in bad condition it shall be burnt off with a blow lamp (gas-flame jet).

The rate for first coat of paint covers the cost of all preliminary cleaning and removing of rust, scale and loose paint – but does not allow for removing paint. Burning of old paint shall be paid for separately.

Galvanised iron shall not be painted until it has been exposed to the weather for a year. However, if necessary to paint it sooner, a coat composed of copper acetate and water (in due proportions) shall first be given – this being paid for separately. In the absence of any specified special paint for galvanized iron, the first coat shall be composed of genuine red lead mixed with raw linseed oil and turpentine in equal proportions (to give the necessary consistency).

Conventionally, ironwork can be classified for the purpose of fixing rates of payment, into five categories, such as :

(a) Structural steel work,

(b) First class forged work,

(c) Second class forged work,

(d) Unforged or cold iron work, and

(e) Rolled steel beams.

The rate of payment for each category depends on the work for which the material is used – expectedly, the rate includes the cost of material.

Where ironwork has been fabricated from rolled steel bars, plates or given sections, it shall be measured by the standard weight of these sections. The weight of rivets, bolts or nuts that have been used shall also be counted – *no deductions will be made for the metal removed from holes*. However, if it is possible to weigh the finished work, the payment can be made by its actual weight.

Usually, unless stated otherwise, the rate of erection of iron/steelwork includes the supply of all derricks and tackle necessary to hoist iron or steelwork into the required place/position.

First Class Ironwork (sometimes termed first class forged work) shall consist of forged work (say, weighing less than a kilogram) and shall be of an ornamental type that requires special labour, care and finish. This type of work shall accurately conform to the specifications depicted by its drawings (or patterns, or samples) – its all sides and edges shall be finished in a thoroughly workman-like manner. Also, wherever, the work is to fit into each other, or to move on a hinge, a fine workmanship shall be applied to impart a good fit. The rate should be for the finished work fixed in position, including material, and two coats of paint.

Second Class Ironwork (also known as second class forged work) shall consist of all ordinary forged work weighing more than about a kilogram. This class of work comprises all works, such as, grills, gratings, railings, etc. It also includes parts of trusses (like tie bars) in which labour has been expended on forging. Further, steel or iron record racks can be included in this class of work although no forging is called for here, because of the light sections involved and the complexity of the work. Workmanship shall be such as to give the exact dimensions of the item – and all bars must be a full fit in the hole through which these pass or in which these are fixed. In making grated doors or window-gratings for, say, jail, other buildings, the ends of square bars shall not be reduced to a section less than that which will just allow their insertion into a circular hole of diameter equal to the side of the bar. When placed in position in its frame, before rivetting, the end of each bar must project to a length equal to the diameter of this hole, to admit of a proper rivet head being formed. The rate of payment is for finished work fixed in position that includes material and one coat of paint.

Cold ironwork (also known as unforged ironwork, or third class ironwork) shall consist of all work on which no labour has been expended on forging, but only on cutting to length, filing the ends, drilling and fitting. It includes all portions of trusses and railings which are not forged and *includes the preparation of reinforcing for cement concrete or reinforced brickwork*. The only exception is steel or iron record racks, which will be paid for as second class ironwork (as said earlier) on account of their light section.

Reinforcing bars (falling under cold ironwork class) shall be bent exactly to size as shown in the drawings (and in bar bending schedule) – with correct curvature and without damaging the bar in any way. Laps shall not be inserted (unless expressly allowed) in bars less than 4.25 m in length – and where allowed shall be paid for as a single length of bar.

The rate for cold ironwork is for work fixed in position including material, and includes two coats of paint, *except in the case of ironwork required for reinforcing* (which is included in the rate for RCC work, per m^3 of RCC work. In fact, either, to reiterate, an RCC work is taken as one item which includes concreting, centering and shuttering, and mild steel reinforcement; or all the three components are measured and paid for separately). The rate for reinforcing (if, sometimes, paid for separately) shall provide for the bars, their bending and placing in positions, and includes wire and tying with wire. It also allows for removing of loose scale and rust but the bars *shall not be oiled or polished in anyway*.

However, the construction agency (say, a contractor/firm) has to know about the actual, and exact dimensions (diameter, and length) of bars, their shape, and number of each description so as to provide the required reinforcement at site. After designing on RCC work, its bar bending schedule is prepared for reference – calculations are based on actual (as per design) requirements including permissible overlaps, hooks, cranks, etc. *No deductions are to be made in the volume of the concrete that may occur due to the presence of reinforcement. Bending wire is included* in the steelwork, and separate measurements are made for the same.

Every reinforcement bar, longitudinal, round or rectangular in shape, as used in beams has to be hooked at the ends (i.e., bent over into hooks for better anchorage in the surrounding concrete mass) as depicted below; and a longitudinal bar is bent at 30^o to 60^o, but, generally the bend is given at 45^o angle (at about $\frac{1}{4}$ to $\frac{1}{8}$ of the span of the bar) to enable the reinforcement to cross over to the top of the beam or slab, taking care of the reverse bending moment near the supports. Also, if necessary because of greater lengths involved, sometimes longitudinal bars have to be overlapped while using more than one length along a line. All these details shall be provided in the relevant bar-bending schedule.

5.2.1 Preparation of Bar Bending Schedule

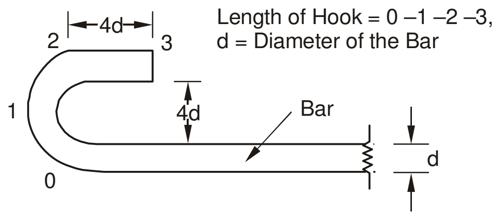
Figure 5.1 depicts the shape and proportions of hooks and bends in the reinforcement bars – these are standard proportions that are adhered to :

(a) Length of one hook = $(4d) + [\sim (4d + d)]$ – where, $(4d + d)$ refers to the curved portion $\approx 9d$.

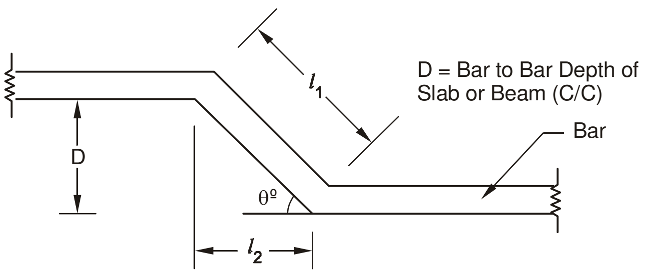
(b) The additional length (l_a) that is introduced in the simple, straight end-to-end length of a reinforcement bar due to being bent up at θ^o (say, 30^o to 60^o, but it is generally 45^o) $= l_1 - l_2 = l_a$

where, $\frac{D}{l_2} = \tan\theta$; and $\frac{D}{l_1} = \sin\theta$

$\therefore$ The additional length $= \frac{D}{\sin\theta} - \frac{D}{\tan\theta}$



(a) Standard Hook



(b) Bent-up Bar

Figure 5.1 : Hooks and Bends in MS Bars

Giving different values to θ (= 30^o, 45^o and 60^o, respectively), we get different values of l_a, as tabulated below :

Sl. No.	θ^o	$\frac{D}{\sin\theta}$	$\frac{D}{\tan\theta}$	Additional Length of Bent-up Bar, l_a
1	30^o	$\frac{D}{0.5}$	$\frac{D}{0.5733}$	**0.27 *D***
2	45^o	$\frac{D}{0.707}$	$\frac{D}{1.0}$	0.414 *D* ≈ **0.42 *D*** (0.42 *D* is generally the value that is adopted)

3	60°	$\frac{D}{0.866}$	$\frac{D}{1.732}$	0.577 $D \approx$ **0.58 D** (0.58 D is usually adopted)

Bar bending schedule (or schedule of bars) is, in essence, a list of reinforcement bars, vis-à-vis, a given RCC work item, and is presented in a tabular form for easy visual reference. This table summarises all the needed particulars of bars – diameter, shape of bending, length of each bent and straight portions, angles of bending, total length of each bar, and number of each type of bar. This information is a great help in preparing an estimate of quantities. Figure 5.2 presents the procedure to arrive at the length of hooks and the total length of a given ms bar.

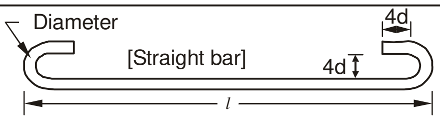
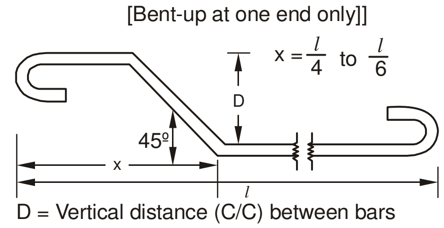
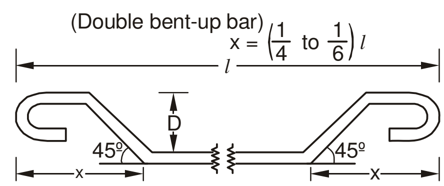
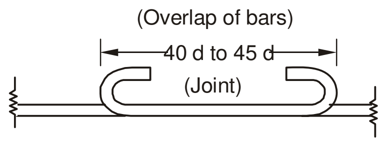
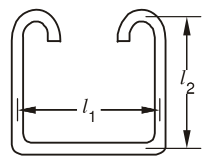
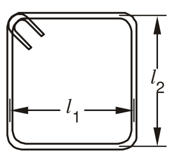
Sl. No.	Details of Bar Shape	Length of Hooks	Total Length of Bar
1.		2[9d] = 18 d (both hooks together)	[l + 18 d]
2.		2[9d] = 18d (both hooks together)	[l + 18 d + 0.42 D]
3.		2[9d] = 18d (as for above cases)	[l + 18 d + 2 × 0.42 D]
4.		2[9d] = 18d	Overlap length at joint = [(40 d to 45 d) + 18 d]
5.		[Here, one hooks height = 14d] 2 × (14d) = 28 d	[$l_1 + 2l_2$ + 28 d]
6.		2(12d) = 24 d	[$2(l_1 + l_2)$ + 24 d]

Figure 5.2 : Details of Bar Shape

5.2.2 Rolled Steel Beams, Structural Steelwork and Other Items

Rolled steel beams are generally supplied by the government (through its departments) to the contractor FOR destination station – thus, only a labour rate shall be liable to be paid to the contractor for further carriage and installation in position; the rates may include two coats of paint.

Where two or more parallel joists are used as a lintel, these shall be connected with bolts and separators, so as to form a single unit. Separators shall be placed near each bearing as well as at intervals of not more than 1.25 m. Separators and connecting bolts shall be paid for separately as cold ironwork, on the basis of the actual weight of material used in them.

In structural steel work (say, on bridge construction, etc.) all plates, bars and sections must be carefully levelled and straightened by pressure and not by hammering, before and after these are worked upon. All drilling, punching and rivetting shall be done in accordance with the general specifications for iron and steel work.

All steel work intended to be rivetted or bolted together, shall be in contact over the whole of the surface. In revitted work, all parts in contact shall, before assembling, be painted on each surface with one heavy coat of pure *red oxide* freshly ground in pure double boiled linseed oil, and the surfaces brought in contact while still wet. All members, when built, shall be true and free from twists, kinks, buckles or open joints between component pieces.

Trusses shall be drawn out to full size on a level platform, a steel tape and an accurate square being used for laying out. The members shall be drawn in, and the joints arranged as shown in the drawings. Wooden templates shall be made to correspond to each member and plate in the truss, and rivet holes drilled accurately into them.

The rate in truss work (or any structural work) is with reference to the item fixed in position, cleaned, finished and painted with one coat of paint – and includes material, etc.

Rainwater Pipes

Down pipes (for rain water) shall be provided to all the buildings taller than one storey, and in case of all walls that are unprotected by a varandah. Rain water pipes shall be of cast iron in 6 feet lengths (say, 1.8 to 2.0 m), with socket joints and shall have lugs cast on for fixing. Rates shall cover proper cast shoes and heads as well as cast branches, bends and iron rails (supply and fitting). *A general thumb rule apportions such size to a pipe as to provide one square cm of bore per 0.865 m^2 of roof area drained* (*i.e. one square inch per 60 square feet*)*, but no pipe shall be less than 7.5 cm in diameter*. The spacing shall be so arranged (depending on the position of openings in the wall) as to be about 7.5 m.

The pipes shall be fixed by bolting the lugs to proper iron stirrups or hold fasts of a flattened U-shape. The head shall be flat and of the same size as the lug and shall have holes to correspond with those in the lug. The legs of the stirrups shall have splayed ends and at least 15 cm must be embedded in the wall. *The stirrup must be fixed so as to hold the pipe about 2.5 cm from the wall in order to facilitate painting*.

The rate of payment includes the outside and inside pipes as well as fitting and fixtures with two coats of paint. The paint shall be such as will resist the bitumastic coating with which these come from the manufacturers.

Unless otherwise specified, for pent roofs, gutters shall be provided, semi-circular in shape, and of twice the diameter of the down pipes. Gutters shall be made of 18 gauge galvanished iron sheet, properly fashioned and laid at a slope of 1 in 120 (10 cm in 12 m). Where gutters do not run straight, the slope shall be doubled. The rate for gutters shall include all supports (or WI brackets, and nozzles, stop ends, angles or returns).

Roof Ventilators

Roof ventilators shall be made of 22 gauge iron sheet. If made from ungalvanised sheet these shall, on completion, be painted with two coats of bitumastic solution, after removing all scale and dirt. The cylinder shall be about 23 cm in diameter and project 15 cm above the surface of the roof when fixed. The canopy shall be a cone – it shall be fixed to the cylinder by flat iron bars so that the base of the cone is level with the top of the cylinder. This block shall be given two coats of hot creosote or solignum – and shall preferably be fixed in place in the centre of the roof. The opening between the cylinder and the cone shall be closed with galvanised iron webbing to prevent the ingress of birds and wasps. The wire-gauge shall be in continuation of the cylinder and fixed to the flat iron bars holding the canopy.

The rate shall cover providing the ventilator complete with cylinder, canopy, supports, wire-gauge, and base block (wood or CC), and fixing all (complete in all respects), on the roof. *The unit of measure shall be by number*.

"Click" Hooks

It is appropriate to build in iron "*click*" *hooks* into the inner face of all the exterior varandah walls, at a level 5 cm above the top of lintels or arch openings – *this shall be done whilst the work is in progress and shall not be driven after the completion of the wall*.

The hooks shall be made from 10 mm diameter rods. The end to be inserted into the wall shall be ragged or splayed, and shall be of such a length as to allow of at least 15 cm being inserted into the wall. The projecting lug shall stand out 2.5 cm from the finished face of the wall or plaster and shall be about 4.00 cm deep. *All hooks must be placed in a straight line, and the projections and depths must be uniform throughout*.

5.2.3 Measurement of Steel and Ironworks

The procedure for the measurement of steel and ironworks is laid down in IS 1200 : Part VIII.

The dimensions (excepting cross-section and thickness of a plate) shall be measured to the nearest 0.001 m except for reinforcement which shall be measured to the nearest 0.005 m. Areas, excluding cross-sectional measurements, shall be worked out to the nearest 0.001 m^2. Weights shall be worked out to the nearest *one kg*. Mill tolerance shall be ignored when weight is determined by calculation. Priming coat shall be described and included in the item of fabrication.

Steel work shall be measured by weight in the absence of any other instructions. Various items of steel work shall be classified and measured separately under various categories – each classification being fully described. Bolted, rivetted, and welded structures shall be described separately.

If not specified otherwise, weight of cleats, brackets, packing pieces, bolts, nuts, washers, distance pieces, separators, diaphragms, gusset plates (*for which overall square dimensions shall be considered*, and not the actual polygonal shapes), fish plates, etc. shall be added (as a percentage of total weight of the work or on the basis of actual numbers) to the weight of the respective items. In rivetted work, allowance shall be made for the weight of rivet heads. *No deductions shall be made for bolt holes* (excluding holes for anchor or holding down bolts).

Deduction in the case of rivet or bolt hole shall, however, be allowed if its area exceeds 0.02 m^2.

The weight of steel sheet, plate, strip, etc. shall be taken from the relevant Indian Standards **(it is based on 7.85 kg/m^2 – for every mm sheet thickness norm)**. Also, for all rolled steel sections, steel rods and steel strips, weight given in the relevant IS Code shall be used. For all forged steel and steel castings, weight shall be calculated on the basis of 7,850 kg/m^3 (i.e. 78.50 quintal per m^3).

Generally, 2.5% of the total weight of an item is added to the total weight to allow for shop and site rivet heads in rivetted steel works. And, also generally no allowance shall be made for the weld metal with reference to welded steel works. However, welding under stanchion bases (or steel grillages) shall be described and enumerated for payment.

Bearings for steel structures (say, trusses, bridges, etc.) shall be classified as – rocker, roller, sliding etc. and fully described and enumerated for payment. Similarly, tubular structures shall also be completely described, and expressed (measured) by weight for payment.

As explained in solved problems (in this Unit) if reinforcement in an RCC item is required to be paid separately (or for the sake of ordering from the market), it shall be measured *by weight in kg*, which shall include cutting to lengths, making hooked ends, cranking or bending (straight or spiral). Also, designed overlaps etc. shall be included in the weight measure. Wire netting etc. in an RCC work (used as an encasement) shall be described and *measured in m^2*. *Binding wire for reinforcement* shall not be measured – and, shall be, however, included in the item description. Hoop iron is, generally, fully described and measured in running metres.

Grid flooring and grills shall be described including size and weight of each item, and shall be *measured in m^2 on the basis of overall area*. Cast iron work shall be measured by weight for each classification.

5.2.4 Roofing Over Trusses

Corrugated Iron (CI) sheets shall be of specified gauge; the galvanising shall be in perfect condition. The sheets shall rest on horizontal purlins, spaced so as to come under their ends, and to afford one line (or better two lines) of intermediate support. The roof trusses must be designed for purlin spacing to suit the standard lengths of sheets to avoid unnecessary cutting. Each sheet shall be laid with 15 cm at the end, and a lap of *two corrugations* at the sides, and laid so as to be turned away from the rainy quarter.

These sheets shall be laid on the scanttings or purlins that afford a true plane surface – lines of the corrugations remaining truly parallel (and normal) to the sides of the area meant to be covered. Each sheet must be fastened at the corners, at every third corrugation along the ends, and evenly at the sides at intervals of not more than 60 cm.

Holes for nails, screws, rivets and other fastenings shall be made on the ground – the sheets shall be placed on trestles, and holes punched in the ridges of the corrugations with very sharp punches, in such a manner that the arrises of the punched hole will come on top when the sheet is in laid position. If four sheets overlap at corners (depending on the shape of the roof), the holes shall be drilled and not punched. *No holes shall be there in the valleys of corrugations*. All sheets shall be joined to each other with bolts and fixed to wooden purlins with screws, and to angle iron (*L*-iron) or *I*-iron purlins with hook bolts. In each case, a dome washer shall be used at the top – screws, bolts, hook-bolts, nuts and washers shall invariably be galvanised.

Corrugated galvanised steel sheet roofing (CGS) shall be of the thickness specified, as said earlier and shall conform to IS : 277 – 1969. Sheets shall be free from cracks, split edges, twists, surface flaws, etc. These shall be clean, bright and smooth. The sheets shall not show any signs of rust or white powdery deposits on the surface. The corrugations shall be uniform in depth and pitch, and shall be parallel. Sheets shall be cut to suit the dimensions/shape of the roof – either along their length or width, or in a slant (across their lines of corrugations) at hips and valleys. Sometimes ridges and hips are covered by special ridge and hip sections. Lapping in CGS sheet shall be painted with a coat of approved steel primer, and two coats of painting with approved paint for steel works, and then finished in place.

Corrugated iron sheets shall not be built into gabbles and parapets – however, shall be bent up along the edge, and suitable flashing shall be provided; otherwise a projecting drip course shall be built, as part of the parapet, to cover the joint by at least 7.5 cm.

Wind ties (40 × 6 mm, flat section, generally) shall be fixed at the eaves' ends of the sheets. The rate for sheets shall include the cost of all materials and labour.

The bill of quantities must fully describe the materials and workmanship. Measurement to be made are done in accordance with IS : 1200 – Part-IX. Portions of roof covering overlapped by ridge or hip, etc. must be included in the measurement of the roof. The superficial areas of roof covering and cladding as laid shall be measured (on the flat) in *m^2 without allowance* for laps and corrugations, if any, cutting across corrugations. Sheeting that is curved or bent to curvature shall be measured separately.

Any opening exceeding 0.4 m^2 shall be deducted and the cutting required shall be measured in running metres.

Ridges, hips and valleys shall be measured along the central line in running metres. Ridges and hips shall be covered with ridge and hip sections of plain galvanised sheet with a minimum lap of 20 cm on either side over the CGS sheets. The end laps of ridges and hips, as well between ridges and hips shall also be not less than 20 cm. The ridges and hips shall be of 60 cm overall width plain GS sheets (0.6 mm or 0.8 mm thick) and shall be properly bent to shape.

Where great durability is desired, and also where the nature of work requires the sheeting (valleys, gutters and flashings) to be laid in a complicated form, or where the flashing has to be laid with many steps, requiring extensive cutting, milled lead sheets are used.

Valleys shall be designed to carry the maximum discharge from the roof without overflowing over, and shall be constructed wherever possible with a sunk channel or gutter. Valleys must not be less than 15 cm wide at the bottom.

Gutters, whether eaves gutter or valley gutter, shall not have a fall of less than 1 in 120. Valleys are also, sometimes, paid for by superficial area; and valley gutters, and eaves gutters by length. Flashings shall be paid for by superficial area – the rates being different for different specifications. The rate for valleys, gutters and flashings is for completed work fixed in place, including all laps and seams.

5.2.5 Collapsible Gates and Shutters

Collapsible gates are a fabricated item – fabricated from mild steel sections as per design (drawings and specifications). These gates comprise vertical double channels (each 20 × 10 × 2 mm) at 10 cm c/c, braced with flat iron diagonals (20 × 5 mm), and top and bottom rails of T-section (40 × 40 × 6 mm) with ball bearings (40 mm ϕ). Whenever a collapsible gate is not placed within the opening (being fixed along the outer surface) T-section at the top is replaced by flat iron (40 × 40 mm). The relevant specifications shall describe the bolts, nuts, locking mechanism, etc.

T-section rails (runners) shall be fixed to the floor, and also to the lintel at top, with necessary embedments, and bolts, etc.

The height and width (breadth) shall be measured correct to a cm. The height of the gate shall be measured as the length of the double channels and width from outside to outside of the gate. The area of the gate shall be calculated in m^2, correct to two places of decimal.

Rolling shutters may have shutters either push and pull type or be operated with chain and crank arrangement. Special bearings, if any, shall be paid for separately.

Shutters comprise Mild Steel (MS) laths 1.25 mm thick. Springs shall be coiled type (of high tensile spring steel wire or strip). Guide channels (of mild steel) shall be provided as per design.

Clear width and clear height of the opening for rolling shutter shall be measured correct to an *mm*; and the area in m^2 shall be calculated correct to two places of decimal.

5.3 GENERAL SPECIFICATIONS FOR RCC WORK

Any concrete work, and as much an RCC work, begins with mixing the ingredients of concrete : coarse aggregate, fine aggregate, and cement. Aggregates : natural sand (or stone dust, when stone crushers are producing the material almost everywhere these days), gravels (or crushed stone) – have to be upto standard specifications laid down for them. These components shall be hard, strong, durable, and also clean and free from clay films, and other adherent coatings.

Aggregates shall contain no deleterious material that may reduce the strength and affect durability of concrete or affect steel reinforcement. Aggregates of following description shall not be used in the concrete mix :

(a) coarse aggregate of porous nature – with over 10 percent increase in its dry weight, after immersion in water for 24 hours.

(b) fine aggregate containing organic material in sufficient quantity as to impart a darker colour than the standard colour.

(c) fine or coarse aggregate containing clay lumps exceeding 1 percent by weight of the material – say, loam, silt, clay, etc. removable by decantation.

The more rounded, hard and non-porous the aggregate, the smaller is the quantity of water required for mixing – thus, one gets greater density for the given consistency, and, therefore, stronger the concrete. *A coarse aggregates of pebble, and, a fine aggregate of water worn* sand, therefore, is best suited for RCC work. If for any reason water worn aggregate is not used – then broken or crushed stone shall be roughly cubical. *Elongated and spicular pieces retard workability and promote weakness*.

Grading of aggregate is an important factor that promotes a good quality concrete; and, therefore, shall receive due attention. A grading schedule that should form an ideal to be aimed at is outlined below :

Table 5.1

Sl. No.	Description of RCC Item	Grading of Coarse Aggregate
1.	(a) Beams exceeding 40 cm effective depth (b) Columns exceeding 40 cm minimum outside dimension (c) Slabs exceeding 22 cm effective depth	(i) Coarse aggregate graded from 3.8 cm to 4.7 mm. (ii) Fine aggregate graded from 4.7 mm to 0.25 mm COVER FOR THIS CLASS OF WORK SHALL BE 5.00 cm.
2.	(a) Beams exceeding 20 cm but of less than 40 cm effective depth (b) Columns exceeding 20 cm but of less than 40 cm minimum outside dimension (c) Lintels exceeding 20 cm of effective depth and width (d) Slabs exceeding 15 cm effective depth	(i) Coarse aggregate graded from 2.5 cm to 3.0 mm (ii) Fine aggregate graded from 3.00 mm to 0.25 mm COVER FOR THIS CLASS OF WORK SHALL BE 3.8 cm
3.	(a) Columns (or posts) not exceeding 20 cm minimum outside dimension, but exceeding 100 cm^2 in sectional area (b) Lintel exceeding 10 cm, but not exceeding 20 cm effective depth and width (c) Slabs exceeding 10 cm, but not exceeding 20 cm effective depth (d) Battens exceeding 100 cm^2 in sectional area	(i) Coarse aggregate graded from 19.00 mm to 3.00 mm (ii) Fine aggregate graded from 3.00 mm to 0.25 mm COVER FOR THIS CLASS OF WORK SHALL BE 2.5 cm
4.	(a) Lintels and slabs under 10 cm effective depth (b) Posts and battens under 100 cm^2 sectional area	(i) Coarse aggregate graded from 1.25 cm to 2.5 mm (ii) Fine aggregate graded from 2.5 mm to 0.25 mm COVER FOR THIS CLASS OF WORK SHALL BE 19.00 mm

As a rough thumb rule, sometimes it is postulated that the coarse aggregate shall normally be of 19 mm maximum size for heavily reinforced work – however, a larger size may be used, provided that the maximum size is not greater than three quarters of the cover or of the minimum clear lateral distance between any two reinforcement bars, whichever is less. Fine aggregate, in conjunction with this norm, shall be of such a size that it shall pass through a mesh 4.76 mm square, measured in the clear. *What is of essence, herein, is that the grading between these limits shall be such, as to produce a dense concrete of the specified proportions and consistency.* **In the preparation of a special grade concrete, the "Fineness Modulus" method shall be used for determining the limits for fine and coarse aggregates, to produce the densest concrete with the materials available.**

5.3.1 Proportioning and Mixing of Cement Concrete

Cement concrete shall be prepared by mixing the appropriately graded aggregates with cement in specified *proportions* with the *necessary* quantity of water. The grading and quantity shall be such as to give maximum compressive strength of 140 kg/cm^2, and 210 kg/cm^2 at 7 days and 28 days, respectively, for 1 : 2 : 4 mix. Sample testings shall be carried out as per laid down norms.

Proportioning shall be done by weight. However for minor works proportioning by volume may be allowed. Boxes of 35 × 25 × 40 cm usual size shall be used as measuring devices for sand and coarse aggregate (usually called only *aggregate*) in day-to-day construction work. The unit of measurement for cement shall be a bag of 50 kg (= 0.0347 m^3); and while measuring the aggregate, shaking, ramming or heaping shall not be done. Proportioning of sand shall be on the basis of its dry volume – for damp sand, allowance for bulking has to be made.

For hand mixing of the material – a smooth, water tight, clean platform of suitable size shall be chosen. Measured quantity of sand shall be spread evenly, and cement shall be poured on the sand and then distributed evenly over this sand – mixing shall be done intimately with spade, turning the mixture over and over again till one gets an even, uniform colour throughout the mass, free of all streaks. Over this (spread out) mass of sand and cement, a measured quantity of coarse aggregate shall be spread evenly – or, one can first spread the coarse aggregate, and then spread sand-cement even mix over it. This shall now be mixed (with spade/shovel) at least three times – turning over from centre to side, then back to the centre, and again to the sides. About three quarters of the total quantity of water (as per mix design) shall be added while the material is turned in towards the centre. Rest of the water quota shall be added slowly while the whole mixture is turned over and over again – achieving a uniform mix, uniform colour, and the desired consistency throughout the mass. *When an increase or decrease in strength is desired, the quantity of cement be varied as per requirement* – the proportion of aggregates remaining unchanged. For quicker pace of work and to prepare quality concrete machine batching and mixing is being done almost everywhere these days.

The amount of water to be used in the mix depends on the desired consistency – however, it shall not be more than 34 litre (for 1 : 3 : 6 mix) per 50 kg of cement; for 1 : 2 : 4 mix, it shall not be more than 30 litre; not more than 27 litres (for 1 : 1.5 : 3 mix); and not more than 25 litre for 1 : 1 : 2 mix. For vibrated concrete the limit for water quantity is decided with reference to avoiding segregation. However, regular slump tests (as per IS Codes) shall be carried to monitor the requirement of water for each specific item of work. As a rough guide following slump values meet the requirements.

Sl. No.	Description of RCC Work	Acceptable Slump
1.	Mass concrete, rammed	1.27 mm to 2.54 cm
2.	RCC slabs	5.00 cm to 10.00 cm
3.	RCC beams and columns	5.00 cm to 10.00 cm (according to the difficulty involved in placing)

4.	Thin vertical walling in layers, between shuttering	15 cm to 17.50 cm
5.	Chuted (poured) concrete	12.7 cm to 2.28 cm (according to conditions)

Note : *The values for slump prescribed in IS Codes shall, however, prevail in all cases* (*as referred to in Unit 2*).

As a practical guide for the addition of water to the 1 : 2 : 4 mix (to be adjusted afterwards – as per the required slump) to yield the desired value of slump the following table comes handy :

Maximum Size of Aggregate	**Litres of Water Required per m^3 of Cement to give a Slump of**						
	25.4 mm	38.10 mm	50.80 mm	63.50 mm	76.2 mm	101.60 mm	152.40 mm
38.10 mm	1011.40	1027.50	1059.60	1075.60	1091.70	1123.80	1155.90
25.4 mm	1043.5	1075.6	1107.70	1123.8	1139.80	1155.90	1204.10
19.05 mm	1123.8	1171.9	1204.1	1236.20	1252.20	1284.3	1364.60
12.70 mm	1284.30	1332.50	1348.50	1380.60	1396.70	1428.80	1476.9

When the fine aggregate is quite damp, the aggregate shall first be inundated (i.e. placed under sufficient water to saturate it), and reduce it to its volume when dry (bulking takes place while sand is wet). The whole of this water in which sand is immersed shall be used for mixing the concrete, and its quantity deducted from that which is required for the mix.

5.3.2 Placement of Reinforcement

Round bars shall be used in preference to square bars for purposes of reinforcement. Use of drawn wire as reinforcement is not done, except it may be used in unimportant structures. Steel reinforcement shall be conforming to the IS Codes that are relevant for different types of steel.

All reinforcement shall be clean and free from loose mill scales, dust, etc. – that may destroy or reduce its bond with concrete. Steel shall be stored so as to prevent distortion, corrosion etc.

Minimum clear distance between parallel bars shall be 1.5 times the diameter of round bars (or 1.5 times the diagonal of a square bar, if ever used) – but in no case shall the spacing between bars be less than 2.50 cm, nor less than 1.5 times the maximum size of coarse aggregate.

Main reinforcement in floor or bridge slabs shall be spaced not more than 20.32 cm apart (clear), and transverse reinforcement not more than 30.0 apart.

Overlapping bars shall not touch each other and shall be spaced apart by 25 mm or 1.25 times the maximum size of the coarse aggregate whichever is greater, with concrete in between these. Overlaps shall be staggered, and shall not be positioned to the locations of maximum bending moment or shear force.

Reinforcement bar web shall be woven as per given drawings. Bars crossing each other shall be tied together at every intersection with two strands of annealed steel wire (0.9 to 1.6 mm in diameter). Tack welding shall be done in place of using binding wire

Measurement of bars (*if not included in the overall cost of an RCC item*) *shall be in running metre for each diameter that is used.*

5.3.3 Joints in RCC Works

Joints in columns shall be made at the underside of the floor. Haunches and column capitals shall be considered as continuous, with and as part of, the floor.

Construction joints in floors shall be located near the middle of the span of slabs, beams or girders, unless a beam intersects a girder at this point, in which case the joints in the girders shall be offset a distance equal to twice the width of the beam. Adequate provision shall be made for shear by use of inclined reinforcement.

Expansion joints shall be so designed that the necessary movement may occur with the minimum resistance at the joint. Reinforcement shall not extend across an expansion joint, the break between the two sections shall be complete. Exposed expansion joints between two distinct concrete members shall be filled with an elastic joint-filler of approved quality.

Buildings exceeding 60.0 m in length, and of width less than about half the length, shall be divided by means of expansion joints, located near the middle, but not more than 60.0 m apart, to minimize the destructive effects of temperature changes and shrinkage. Where there is an abrupt change in the width of a building, and expansion joint shall be provided.

It is appropriate to distinguish between the expansion joints and construction joints that are essentially caused by a pause/break in the placing of concrete.

5.4 RATE ANALYSIS : JOISTS AND RCC WORKS

As discussed in almost all the Units of this block, rate analysis of an item involves having knowledge about the requirements of material and labour (skilled as well as unskilled) that are needed in the completion of a given unit (say, m^3, m^2, or a metre, or a number) of a given item of work – such as, we require the following labour or material to complete the following jobs :

(a) Fixing 16 mm (5/8 inch) diameter MS rods in ordinary work (like in window, grills, etc.) :

Black smith (2^{nd} class)	–	1 No.
Carpenters	–	2 Nos.
Beldar	–	3 Nos.

(All for 16.5 running metres)

(b) Fixing of 40 × 38 × 3 mm flat hold fasts :

Blacksmith (2^{nd} class)	–	1 No.
Mason	–	1 No.
Beldar	–	1 No

(All for fixing 36 Nos of hold fasts)

(c) Quantity of GI sheets (corrugated) for covering of roof (per 100 m^2) = 128 m^2 – taking care of overlaps also, etc.

(d) For first approximation of the quantity of MS rods that is commonly required for ordinary slabs, lintels, etc. generally it is estimated as 1% of the volume of that particular RCC item, @ 78.50 quintal per m^3 – 7850 kg/m^3 – say, for 200 m^3 of given RCC work, MS bars that are required by weight $= \left[\frac{(200) \times 1}{100} \times 7850\right] \text{kg} = 15{,}700 \text{ kg}$.

However, it has to be clearly understood that the exact (and appropriate) estimation requires the study of design, drawings and bar bending schedules [refer solved examples of this Unit].

In MS (mild steel) and iron work, the quantity (by weight and lengths also) is known prior to going in for the actual construction, it is the labour component that plays the final role in determining the basic cost (without considering contractor's profit). Schedules are available with the concerned agencies (government or/and private) to obtain this essential information.

Sl. No.	Description of Work	Material Requirement	Labour Requirement	Remarks
1.	Fixing rolled steel joists in position – handling, hoisting – sections not exceeding 300 kg; and hoisting upto 7.5 m height from G L.	Excluding material cost	Skilled labour – 0.1 No. Mason – 0.2 No Beldar – 1 No. Coolie – 2 Nos. [Add rent of equipment required for hoisting]	For one quintal total weight of all the joists done
2.	As for Item No. (1) but for heavier section – exceeding 300 kg in weight, and hoisting up to 7.5 m height from GL.	Excluding material cost	Skilled labour – 0.1 No. Mason – 0.2 No Beldar – 1 No. Coolie – 3 Nos. [Add rent of equipment required and ropes]	For one quintal total weight of all the joists done
3.	Mild steel or iron work of small sizes and sections – like, hold fasts, tie rods, holding down bolts, gratings etc. – as separate items by themselves, i.e., not included in the overall rate of an item in which these are a component. Wrought to desired shape with bolts, nuts, etc. and fixing in position.	(i) Milid steel – 1 quintal (ii) Wastage = 2.5% of (i) above (iii) Add Sundries, etc. (All for 1 Quintal weight of item)	Blacksmith – 2 Nos. Hammer man – 2 Nos. Coolie – 2 Nos.	For one quintal total, (i.e. including nuts and bolts) weight of the work
4.	Mild steel or iron work of heavy sizes – trusses, built-up gates, door frames, roof work, etc. – including making to form, drilling holes, etc.	(i) M. S. – 1 quintal (ii) Wastage 2.5% = 2.5 kg (iii) Welding rods, i.e. Sundries	Blacksmith – 2 Nos. Hammer man – 2 Nos. Rivetter/welder – 0.5 No. Coolie – 2 Nos. [Add rent for equipment for welding and hoising]	For one quintal total weight of the work
5.	MS or iron in plain work – reinforcement for RCC (or reinforced brickwork – RB) – as a separate item if not covered by overall RCC rate. It includes making to the required web, including bending etc.	(i) M. S. – 1 quintal (ii) Wastage 5% = 5 kg (iii) Sundries at L. S.	Blacksmith – 2 Nos. Coolie – 3 Nos.	All for 1 quintal weight of MS

A typical rate analysis of an RCC work, vis-à-vis, in a column [1 : 1.5 : 3 mix of CC – having 2 cm-diameter stone ballast (coarse aggregate)] with respect to 10 m^3 of work would involve following men and material :

Material

(i) Coarse aggregate (i.e. stone ballast) – of 2 cm gauge = 8.4 cm^3

(ii) Coarse sand = 4.2 m^3

(iii) Cement (2.8 m^3) = 84 bags

(iv) Mild steel bars @ 1.5% (approximately) $= \frac{1.5}{100} \times 10 = 0.15\ m^3$

@ 78.5 quintals/m^3 $= 0.15 \times 78.5$

$= 11.775 \approx 11.78$ quintal

Labour

Mistri	-	0.5 No.
Mason	-	3 Nos.
Beldar	-	15 Nos.
Coolie	-	15 Nos.
Bhisti	-	7 Nos.

Add Sundries (rent for equipment, etc.) as a LS amount.

Centring and Shuttering (Including Erections as well as Dismantling)

(i) Timber planks and ballies as per design

(ii) Second class carpenter - 10 Nos.

(iii) Beldar - 10 Nos.

(iv) Add nails and tools as LS amount.

Bending and Binding of Steel Bars

(i) Blacksmith - 12 Nos.

(ii) Beldar - 12 Nos.

(iii) Tools, etc. - Add on LS basis.

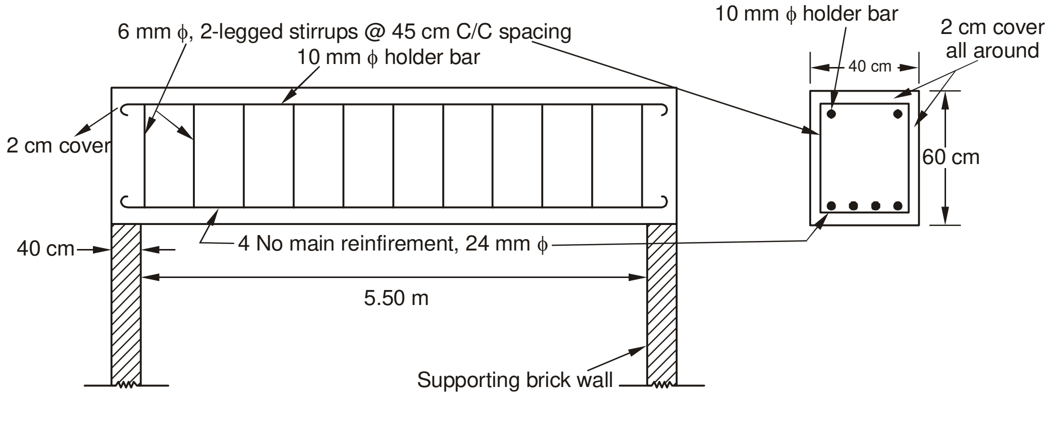
5.5 CASE STUDIES

A solved example on how to estimate a steel truss (and roofing sheets) has been given in Unit 4; and also Unit 3 deals with how to estimate an RCC item (volumetric contents) in buildings as one item whose rates of payment cover MS reinforcement also.

Following examples are given to explain the procedure to accurately estimate in detail MS reinforcement requirements of a given piece of RCC work : with a view to be able to order the required bars of designed diameters, or/and to pay for it separately if the overall RCC item does not cover this component.

Example 5.1

A 5.5 m, clear span, simple RCC beam (Figure 5.3) rests (bears) on 40 cm thick walls. The beam is of 60 cm depth; and, carries main reinforcement of 24 mm diameter, 10 mm holder bars, and shear reinforcement (6 mm dia., 2 legged stirrups) as shown.



(a) L-section **(b) Cross-section**

Figure 5.3 : MS Reinforcement of a Simple RCC Beam (Not to Scale)

Estimate the total quantity of MS reinforcement for different diameters.

Solution

Length of a bar (longitudinal) = [Actual (gross) length of beam] – 2 (end cover) + 2 (hook length)

(a) Length of 24 mm ϕ bars

$= [550 + (2 \times 40)] - 2\ (2) + 2 \times (9 \times 2.4)$

$= 669.2$ cm $= 6.69$ m

≈ 6.70 m

(b) Length of 10 mm ϕ holder bars

$= [550 + (2 \times 40)] - 2\ (2) + 2\ (9 \times 1.0)$

$= 644$ cm $= 6.44$ m

≈ 6.5 m

(c) Full length of two-legged 6 mm ϕ stirrups (shear reinforcement)

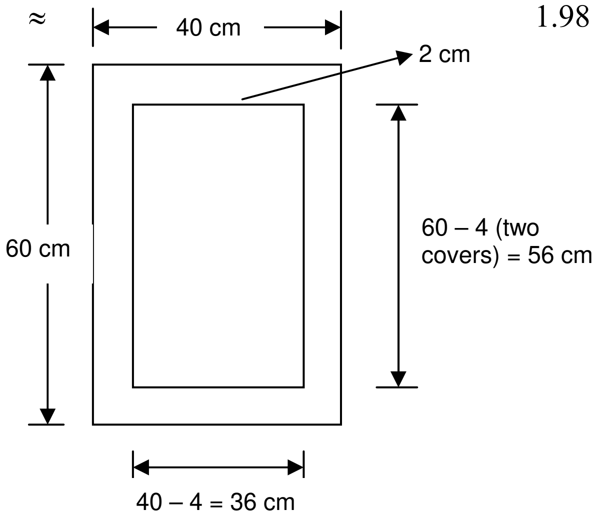
$= 2\ (56 + 36) + (24 \times \text{diameter})$

$= 2 \times 92 + (24 \times 0.6)$

$= 184 + 14.40$

$= 198.4$ cm

$\approx$ 1.98 m



(d) Total number of stirrups in the beam

$$= \frac{\text{Length of beam}}{\text{Spacing}} = \left\{ \frac{[550 + (2 \times 40)] - 2 \times 2 \text{ (i.e. cover)}}{45} \right\}$$

$= 13.91$ cm $\approx 14 +$ one

$= 15$ Nos.

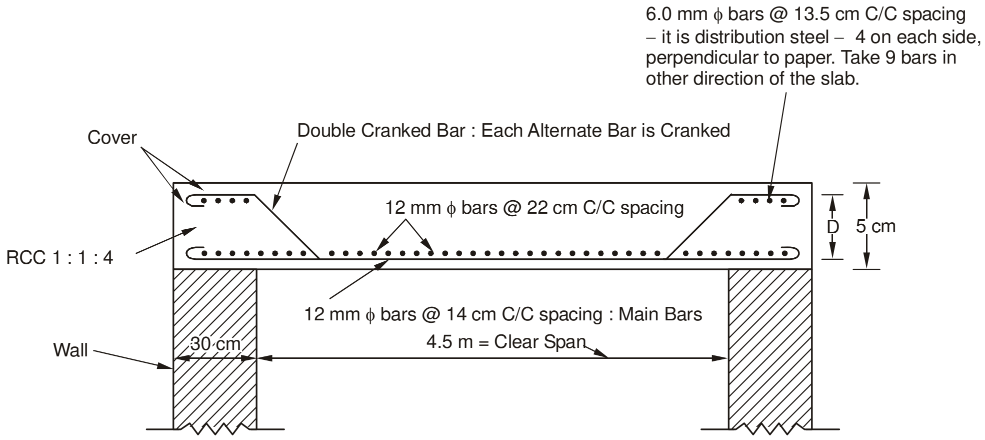
Based on these, above given, dimensions, a bill of quantities can be framed as shown below :

Bill of Quantities

Sl. No.	Particulars of Item	No.	Dimensions			Quantity
			L (m)	B (m)	H/D (m)	
1	*MS work in the reinforcement of the beam*					
	(i) Main reinforcement (bottom) base – 24 mm ϕ @ 3.55 kg/m	4	6.7	–	–	@ 3.55 kg/m = 26.8 × 3.55 = 8.06 kg
	(ii) 10 mm ϕ holder bars @ 0.62 kg/m	2	6.5	–	–	13 × 0.62 = 8.06 kg
	(iii) 6 mm ϕ stirrups @ 0.22 kg/m	15	1.98	–	–	29.7 × 0.22 = 6.534 kg
						Total = 109.734 kg
						≈ 109.73 kg (say)

SAQ 1

(a) Figure 5.4 shows the section of an RCC slab over a room (4.5 × 6 m – internal dimensions), along the shorter span of the room.



[**Note :** Double cranked bars (cranked on both sides, as shown) are bent at 45°. Bottom bars are alternately double cranked. Temperature reinforcement (6 mm f) is laid both ways – other side not shown.]

Figure 5.4 : Section of a RCC Slab (6.0 × 4.5 m – Internal Dimensions of Room) – (Not to Scale)

Prepare a bill of quantities of mild steel; and also prepare a bar bending schedule for this work.

Take each end cover as 4 cm; and 1.2 cm at top and bottom as well.

Also estimate the quantity of concrete required in this slab; and centering and shuttering work as well.

(b) Figure 5.5(a) shows the details of reinforcement (main as well as distribution steel) of an RCC retaining wall. Figure 5.5(b) details out the curtailment of main steel on earthfill side, which is a common feature of the retaining walls – in order to conform to the requirements of varying bending moment over the height of the wall (maximum occurring at the heel level).

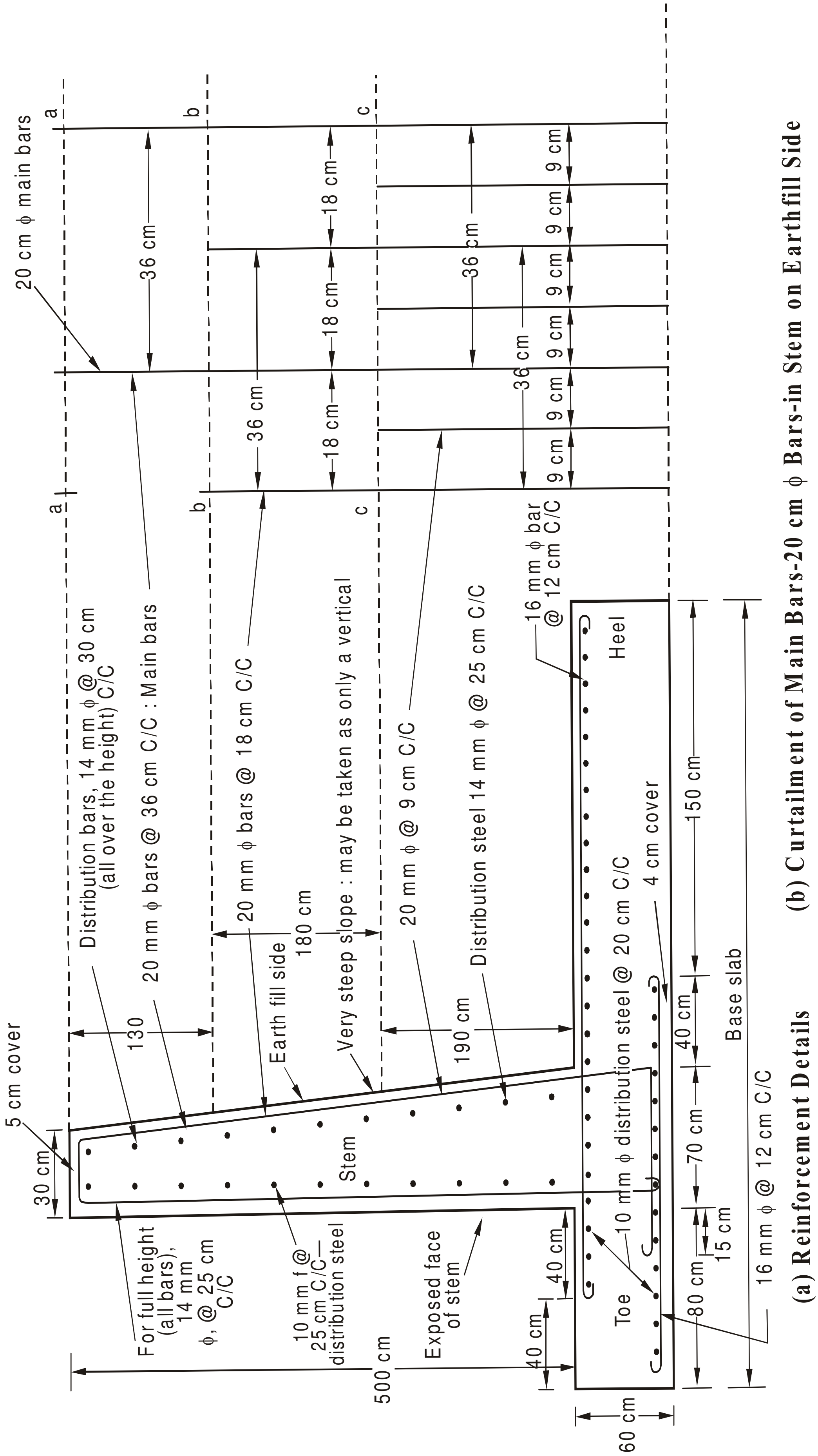


Figure 5.5 : RCC Cantilever Retaining Wall Section (Not to Scale)

Assuming the length of the wall (perpendicular to paper) to be 30.0 m, and the length-end cover for bars equal to 5 cm, 2.5 cm cover for main bars of the stem, and 3 cm cover for both toe and heel steel, compute the quantities for the following items :

(i) RCC (1 : 2 : 4) work without reinforcement, but including shuttering, etc.

(ii) MS reinforcement including bending, binding (wire included), and laying.

5.6 SUMMARY

General specifications (in addition to detailed specifications – in vogue with various agencies working in construction industry) give an idea about why the rates should vary from item to item in the same category of work. Every specification entails specific change/addition/deduction in an item of work when compared with other items of the same genre. Hence, rates do differ – due to varying labour component, or/and material component.

Preparation of bar-bending schedule for an RCC work – column, slab, beam etc. – is an important activity. It enables to estimate the steel quantity for various bar diameters; and also go into MS reinforcement placement very appropriately. Understanding of the relevant drawings is thus the basic requirement of this exercise to be done purposefully.

5.7 ANSWERS TO SAQs

SAQ 1

(a) Hook length = $9 \times d$

Inclined length (cranked length) of bar when bent-up (for 45^o angle)

$$= \sqrt{(2D^2)} - (D) = 0.42\ D$$

[**Note :** Deduction of one D is necessary if full uncranked bar is considered to start with, as will be clear below.]

D = 15 cm – (Cover at top + Cover at bottom)

= 15 – 2 (1.2) = 12.60 cm

Calculations for Length of Bars

(i) *Main bars* (*12 mm* ϕ)

(a) Straight bars along shorter span

= [Width of slab] – 2 [End covers] + 2 (Hook lengths)

= [450 + (2 × 30)] – (2 × 4) + 2 (9 × 1.2)

= 510 – 8 + 2.16

= 523.60 cm

= 5.236 m

(b) Double cranked bars along shorter span

= 510 – 8 + 21.6 + 2 (length of bent-up portion)

= 523.6 + 2 × (0.42 × 12.6)

= 534.184 cm

= 5.34 m

(c) Straight bars along longer span (i.e. perpendicular to paper)

= [Length of slab] – 2 (End covers) + 2 (Hook lengths)

= [600 + (2 × 30)] – (2 × 4) + 2 (9 × 1.2)

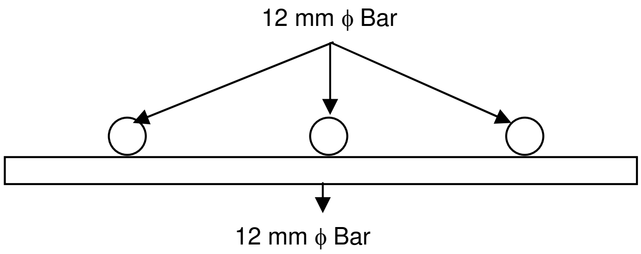
= 673.6 cm

≈ 6.74 m

(d) Double cranked bars along longer span

= [660 – 8 + 2 × 9 × 1.2] + 2 × 0.42 (11.4)

[**Note :** Here, 12 mm ϕ bar is placed above another 12 mm ϕ bar.



⇒ D = 15 – 1.2 (i.e., 12 mm ϕ) – 2 × 1.2 (i.e. twice the cover)

= 11.4 cm]

= 683. 176 cm

≈ 6.83 m

(ii) *Temperature (Distribution) Reinforcement – 6 mm ϕ*

(e) Bars along shorter span

= Width of slab – End covers + Hook lengths

= 510 – 8 + (2 × 9 × 0.6)

= 512.8 cm

= 5.13 m

(f) Bars along longer span

= 660 – 8 + 2 × 9 × 0.6

= 662.8 cm

= 6.63 m

Calculations for Number of Bars in Each Size

(i) Longer span (along 6 m internal dimension of the room), straight main bar, @ 22 cm c/c – laid alternately, i.e. at a spacing of 44 cm

$$= \frac{510 - 8}{2 \times 22} = 11.4 \approx 12 \text{ Nos. (say)}$$

(ii) Longer span (along 6 m internal dimension of the room), double cranked bar, @ 2 × 22 cm c/c – i.e. laid alternately

= 12, as for (i) above

(iii) Shorter span (along 4.5 m internal dimension of the room), straight main bar – laid alternately

$$= \frac{660 - 8}{2 \times 14} = 23.28 \approx 24 \text{ Nos.}$$

(iv) Shorter span (along 4.5 m internal dimension of the room), double cranked bars – laid alternately

= 24 Nos. as for (iii) above

(v) Longer span distribution (temperature) steel bars, 6 mm ϕ = 8, as shown in Figure 5.1.

(vi) Shorter span distribution steel bars, 6 mm ϕ = 9, as given in Figure 5.4.

Following Table gives the bar-bending schedule in the typical format, for ready reference and use in construction activity :

Bar-bending Schedule

Sl. No.	Description	Shape and Dimensions of Bar (cm)	Diameter (ϕ) of Bar (mm)	Number of Bars	Total Length of Bar (including hooks) – (m)
1.	Longer span (along 6 m internal dimension of room) – straight main bar		12	12 (i.e., counting alternate bars)	6.74
2.	Longer span, double cranked bar (along 6 m internal dimension of room), main reinforcement		12	12 (i.e., counting alternate bars)	6.83
3.	Shorter span, main bar (along 4.5 m internal dimension of room)		12	24	5.24
4.	Shorter span, double cranked bar (along 4.5 m internal dimension of room)		12	24	5.34
5.	Longer span distribution steel (i.e. bars)		6	8	6.63
6.	Shorter span distribution bars		6	9	5.13

By now all the required information is available to make a bill of quantities, as is done hereunder :

Bill of Quantities

Sl. No.	Description of Item	No	Dimensions			Quantity
			L (m)	B (m)	H/D (m)	
1.	*RCC (1 : 2 : 4) without steel reinforcement, and shuttering etc. and laying*	1	6.6	5.1	0.15	5.05 m^3
						Total = **5.05 m^3**
2.	*Centering and shuttering* – erection, use, and dismantling included :					
	(i) Bottom of slab (resting on walls)	1	6.00	4.5	–	27.0 m^2
	(ii) Edges of slab					
	(a)	2	6.6	–	0.15	1.98 m^2
	(b)	2	5.1	–	0.15	1.53 m^2
						Total = 30.51 m^2
3.	*MS work in reinforcement* (including bending, binding and placing in position – including binding wire)					
	(a) 12 mm ϕ bars (longer span)					
	(i)	12	6.74	–	–	80.88 m
	(ii)	12	6.83	–	–	81.96 m
	(b) 12 mm ϕ bars (shorter span)					
	(i)	24	5.24	–	–	125.76 m
	(ii)	24	5.34	–	–	128.16 m
				Total	=	416.76 m @ 0.89 kg/m **= 370.91 kg**
	(c) Distribution steel (6 mm ϕ)					
	(i)	8	6.63	–	–	53.04 m
	(ii)	9	5.13	–	–	46.17 m
				Total	=	99.21 × 0.22 kg/m **= 21.83 kg**
						Grand Total (MS) = 392.74 kg

(b) (i) Average width (thickness) of stem $= \dfrac{70 + 30}{2} = 50$ cm = 0.5 m

(ii) Width of base slabs = 80 + 70 + 40 + 50 = 340 cm = 3.40 m

(iii) Length of main reinforcement (20 mm ϕ) – vertically on earth-fill side upto level a – a.

= (5 + 0.60) – 0.05 (i.e. top cover) – (0.04 + 0.016, i.e., bottom cover-cum-16 mm bar diameter) + (2 × 9 × 0.02, i.e., twice hook lengths) + (0.70 + 0.15, i.e. horizontal portions)

= 5.60 – 0.106 (take ≈ 0.11 m) + 0.36 + 0.85 = 6.70 m

These bars are placed @ 36 cm c/c (for full stem height)

Number of these bars = {[30 m – 2 × 0.05 (i.e. twice end covers)] / 0.36} + 1 = 84.055 ⇒ 84 Nos. (say)

(iv) Length of 20 mm ϕ main bars @ 36 cm c/c, upto level b – b

$= (5.6 - 1.3) - 0.06$ (i.e. $0.056 \approx 0.6$) $+ 2 \times 9 \times 0.02 + 0.85$

(It may be noted that here, no top cover of 5 cm need be considered) = 5.45 m

Number of these bars (upto b-b)

$$= \frac{30 - 2 \times 0.05}{0.36} + 1 \approx 84 \text{ [\textit{Refer Figure 5.5(b)}.]}$$

(v) Length of 20 mm ϕ main bars (upto level c – c) @ 18 cm c/c

$= (4.3 - 1.8) - 0.06 + 0.36 + 0.85 = 3.65$ m

$$\text{Number of bars } = \frac{30 - 0.1}{0.18} + 1 \approx 167 \text{ Nos.}$$

(vi) Length of horizontal distribution steel (of stem) – earth-fill side – 14 mm @ 25 cm c/c

= 30.0 – (2 × cover) + 2 overlaps (say 3-lengths used) + 2 × 3 hook lengths

$= 30 - 2 \times 0.05 + 2$ (40×0.014, i.e. $40 \times d$) $+ 6\ (9 \times 0.014)$

= 31.776 m

$$\text{Number of bars } = \frac{5.6 - 0.05 - 0.06}{0.25} = 21.96 \approx 22 \text{ Nos.}$$

(vii) Length of 14 mm ϕ vertical bars (full-height, exposed side) – up to level a – a @ 25 cm c/c

= 5.6 – top cover – bottom cover + 2 hook lengths

$= 5.6 - 0.05 - 0.06 + (2 \times 9 \times 0.014)$

$= 5.742 \approx 5.74$ m

$$\text{Number of bars } = \left(\frac{30 - 0.1}{0.25}\right) + 1 = 120.6 \approx 121 \text{ Nos.}$$

(viii) Length of 10 mm ϕ horizontal bars @ 25 cm c/c

= 30 – (2 × 0.05, i.e. end covers) + 2 overlaps + 6 hook lengths

$= 30 - 0.1 + (2 \times 40 \times 0.01) + (6 \times 9 \times 0.01) = 31.24$ m

$$\text{Number of bars } = \left(\frac{5.6 - 0.05 - 0.06}{0.25}\right) + 1 = 21.96 \approx 22$$

(ix) Length of 16 mm ϕ bar @ 12 cm c/c (in base slab) – heel bars (at the top)

$= (4.40 - 0.40) - 0.03$ (i.e. one cover) $+ 2\ (9 \times 0.016) = 4.258$ m

$$\text{Number of bars } = \left(\frac{30 - 2 \times 0.05}{0.12}\right) + 1 = 250 \text{ Nos.}$$

(x) Length of 16 mm ϕ bar @ 12 cm c/c (bottom of the slab)

$= (0.80 + 0.70 + 0.4) - 0.03 + 2 \times 9 \times 0.016$

= 2.158

Number of bars = 250 Nos., as for (ix).

(xi) Number of 10 mm ϕ, distribution bars @ 20 cm c/c – both for top and bottom of the base slab

$$= \left(\frac{2.97 + 1.87}{0.2}\right) + 1 = 25.2 \approx 25 \text{ Nos. (say)}$$

Length = 30.0 – 2 × 0.05 + 2 × 40 × 0.01 + (6 × 9 × 0.01)

= 31.24 m

The bill of quantities for the required items is formed as under :

Bill of Quantities

Sl. No.	Description of Item	No	Dimensions L (m)	Dimensions B (m)	Dimensions H/D (m)	Quantity
1.	*RCC (1 : 2 : 4) work* in the retaining wall (excluding MS reinforcement), including shuttering, laying etc.					
	(i) Base slab (toe + heel)	1	30	3.4	0.6	61.2 m^3
	(ii) Stem	1	30	0.5	5.0	75.0 m^3
						Total = **136.20 m^3**
2.	*MS reinforcement*, including bending, binding, placing etc.					
	(a) (i) Stem – earth-fill side – 20 mm ϕ, main bars @ 36 cm c/c, upto level, a – a	84	6.7	–	–	562.8 m
	(ii) Stem – earth-fill side – 20 mm ϕ main bars @ 36 cm c/c, up to level b – b	84	5.45	–	–	457.8 m
	(iii) Stem – earth-fill side – 20 mm ϕ main bars @ 18 cm c/c, up to level c – c	167	3.65	–	–	609.55 m
	Total (i) to (iii), 20 mm ϕ bars @ 2.47 kg/m = 1630.15 m × 2.47 = **4026.47 kg**					
	(iv) Stem – horizontal distribution bars, earth-fill					

side – 14 mm ϕ @ 25 cm c/c	22	31.776	–	–	699.072 m
Total @ 1.21 kg / m = **845.88 kg**.					
(v) Stem – exposed side – 14 mm ϕ, vertical bars, up to level a – a @ 25 cm c/c	121	5.74	–	–	694.54 m
Total @ 1.21 kg/m = **840.39 kg**					
(vi) Stem – exposed side – 10 mm ϕ @ 25 cm c/c	22	31.24	–	–	687.28 m
Total @ 0.62 kg/m **= 426.11 k**g					
(b) (i) Base slab – 16 mm ϕ @ 12 cm c/c – top heel bars	250	4.258	–	–	1064.5 m
(ii) Base slab – 16 mm ϕ @ 12 cm c/c – toe bars at bottom	250	2.158	–	–	539.5 m
Total (i) and (ii), @ 1.58 kg/m=1604.00 m× 1.58 kg/m = **2534.32 kg.**					
(iii) Base slab – 10 mm ϕ distribution bars, @ 20 cm c/c (top + bottom)	25	31.24	–	–	781.0 m
Total @ 0.62 kg m = **484.22 kg**					
Grand Total of MS reinforcement = 9157.39 ≈ 9157.50 kg					

UNIT 6 PLASTERING, POINTING, WHITE WASHING, COLOUR WASHING AND DISTEMPERING

Structure

6.1 Introduction

Objectives

6.2 Plastering

6.3 Pointing

6.4 White Washing, Colour Washing and Distempering

6.4.1 General Specifications

6.4.2 Measurements

6.5 Rate Analysis

6.6 Case Studies

6.7 Summary

6.8 Answers to SAQs

6.1 INTRODUCTION

The first thing, after the build-up of a building is complete, that is taken up in hand is the plastering of internal walls, plastering (or pointing) of external walls and plastering of ceiling (including beams). It is over this base that decorative treatments – lime washing, colour washing, distemper, and painting etc. – are applied.

Proper base surface preparations, and curing of the work are an essential activity. However, applying a plaster, and doing pointing may seem an easier work, but, in actuality these demand skill and care.

A well done job imparts a pleasing look to the wall surface or ceiling.

These items of work are generally (and most often, unless a special piece of work demands otherwise, which is very rare) measured in m^2.

Objectives

After studying this unit, you should be able to

- understand the basic (essential) specifications needed to be followed in these items of work, and
- estimate the quantities as easily as possible, given the plan, elevation, and sectional details (or as a substitute, detailed specifications) of a building.

6.2 PLASTERING

Plastering in buildings refers to the process of covering rough surfaces (brickwork in walls – kaccha or pucca brick masonry; RCC surface) with a sort of a plastic material with the purpose of obtaining a smooth, even, and regular surface that is durable and pleasing to look at. Plastering covers defective workmanship in the construction of a given piece of masonry; and, also it conceals cheap/unsound quality of material used in building up the masonry. It is only after plastering that an appropriate base is ready to further decorate the surface by white-washing, colour-washing, distempering, or painting. Plastering is done to both the surfaces of a wall one, on the external face, and, secondly, on the internal face. External plastering is also referred to as "*rendering*". Its other (rather main) purpose is to improve the resistance of the surface to the penetration of rainwater, and to other environmental influences like temperature, and humidity changes.

Plaster is a sort of mortar obtained by mixing and working together materials like cement, lime, clay, or any special substance, with fine aggregate (sand), and water.

6.2.1 General Specifications of Plastering

Lime Plastering

The mortar shall be of the specified mix say, 1 : 7 : 12 (by volume) mix of cement, lime and sand, for inside plaster; 1:1:6 (by volume) mix of cement, lime and sand for outside plaster; and, for arrises of all corners and door and window jambs the mix may consist of 1 : 3 (by volume) cement and sand.

In the work of *surface preparation*, all the joints shall be raked out thoroughly; and all loose material – dust and masonry mortar or mud of kaccha brickwork – shall be brushed off. All efflorescence shall also be removed. Raking shall be done with a hook (not hammer, etc.) to a depth of 1.25 cm (say, ½ inch). It is easier to rake out the joints before the masonry mortar has set. After raking is done, and loose material washed off by water, the surface to be plastered shall be watered for 24 hours before the plaster is applied. If any chemical retarder has already been applied to the formwork, the surface should be roughened by wire brush – leaving no retarders behind on the surface. All putlog holes shall be filled up in advance of the plastering work as the scaffolding is being taken down.

Ceiling plasters shall be done before the wall plastering is begun. Plastering on the walls shall be started from the top and worked down towards the floor.

All lime used shall be well slaked stone lime. Slaking shall be done by sprinkling water slowly on the burnt lime, which must be spread out on a dry brick platform in a 15 cm layer (all these procedures apply also to LC in foundations, etc.). *No more water shall be used than is sufficient to convert it to a fine powder*. After slaking, lime shall be left in a covered shed for a day or two before screening.

Lime that is to be used in conjunction with cement for the purpose of making mortar, shall be ground dry. Stone lime shall be measured by weight. Unslaked lime shall only be measured when freshly burnt. Sand used in the mix shall be clean, *gritty to the touch* and free from any admixture of clay, loam, salts, organic matter etc. The sand shall be of such a degree of cleanness that when a handful of it is shaken in a glass with clean water and allowed to stand for one hour, the precipitation of mud, etc. on the sand shall not exceed 10 percent.

The mortar for the plaster shall be thoroughly mixed in an iron or brick lined trough, and shall be used within 30 minutes of the cement coming into contact with water.

Wooden screeds 7.6 cm (≈ 3 inches) wide, and of the thickness of the plaster (to be applied as per design) shall be fixed vertically 2.5 to 3.0 m apart to act as gauges and guides in applying the plaster. To ensure even thickness and a true surface, plaster nearly 15 × 15 cm patch shall be first applied horizontally as well as vertically at not more than 2 cm intervals over the entire surface – this arrangement too can serve as gauges. Or, after setting up wooden screeds, the arrises shall then be plastered with 1 : 3 mortar for a space of 10 cm on each side and upto the ceiling, except in the case of openings, where it will run round them. This plaster will also serve as screeds.

The mortar shall be laid on the wall between the screeds, using a *plasterer's float* for the purpose, and pressing the mortar so that the raked joints are properly filled. In fact, the mortar shall be applied in a uniform surface slightly more than the specified thickness. This applied mortar shall be beaten with thin strips of bamboo to allow a thorough filling of joints – wooden straight edge (not less than 3.0 m) helps bringing the work to a true surface by moving the straight edge upward and side ways simultaneously as per requirement. Finally, the surface is finished off true with the help of trowel or wooden (aluminium) float, to give the required texture – smooth or sandy granular. Sometimes, a solution of lime putty is applied on the surface to facilitate workability.

Unless otherwise specified, plaster shall not exceed 12.70 mm in thickness, nor shall it be less than 6.4 mm at the thinnest part.

All the corners, angles, arrises, and junctions must be done truly vertical/horizontal as required. Rounding on chamfering corners, etc. shall not be paid for as an extra item, even though proper templates are to be used – these things being included in the rate of payment.

At the end of a day's work, plaster shall be left clean cut in a line both horizontally as well as vertically – and while starting the next day's work, all the edges of the previous work shall be scraped, cleaned and wetted with lime putty and then start applying the plaster to the fresh areas – this allows a good bond/joint between the two works. Every day's work must be closed on the wall itself, and not near to corners, etc. To avoid leakage in future the work should not be closed (at the end of the day) in a manner such that horizontal joints occur on parapet tops, etc.

Thickness (as specified in the design) of the plaster shall be measured exclusive of the thickness of the key. Extra thickness required in dubbing behind the rounding of corners etc. shall be ignored. The work must be tested frequently while in progress – using straight edge (at least 2.5 m long) and plumb bob, etc.

Curing of the work is a very important aspect of plastering, as for RCC work, and other such items. Curing must begin 24 hours after finishing the plaster – keeping the plaster wet for at least 7 days. *Generally, the date on which plastering is done shall be boldly marked on the various portions for monitoring the curing period.*

Sometimes cracks may appear in the plaster surface; and also there may be patches that sound hollow to tapping – all these defective areas shall be taken out in rectangular shape (after the work becomes dry), and redone as per laid down procedure (specification).

The method of measurements for plastering (as well as pointing) is based on IS 1200 : Part XII. Plastering work shall be fully described – mix of mortar, thickness and number of coats done, nature of base, nature of surface treatment. This description must include all arrises, external chamfers, internal rounded angles. Plastering on walls, ceiling, or roofs shall always be measured separately in m^2 – each category may be carrying different rates if the labour component differs amongst these items. Rates for scrapping (removing plaster) differ with respect to doing a plaster item – therefore, shall be measured, in m^2, separately.

Plastering (external) for heights more than 10 m above a given level (ground, say) shall be measured separately in stages. Internal plastering (buildings) shall be measured separately for each storey. Cutting to edges shall be separately measured in running metres or included in the overall item.

For isolated works (for, say cornices, rounded angles, etc.), widths shall be measured separately either in running metres or square meters, as specified.

For ceilings, measurements shall be made between walls (or partitions), and room dimensions (lengths, and breadths) before plastering shall prevail. Widths covered by cornices, etc., shall be deducted. Soffit of stairs shall be measured as if plastering is being done on a ceiling. Mouldings and ribs on ceilings shall be measured as for cornices – deductions to be made in plastering if width/girth is more than 15 cm. Flewing soffits shall be measured separately.

All repair work shall be described – thickness of doubling, etc.

When the cost of plaster to mouldings and cornices is included in the overall rate of these items, plaster shall be measured on the length and height of walls, no deductions being made for the openings of additions for returns and soffits.

For wall plastering, measurements shall be taken between walls (or partitions) – dimensions prior to plastering prevailing – and from floor (or skirting) to the ceiling itself. Cornice depths (or of coves) shall be deducted. Sides or projections shall be added to the plaster item.

In general, the rate for plaster work covers the following items :

(a) Preparing, cleaning and watering the surface to be plastered, and includes the materials,

(b) Watering and protecting the plaster after completion,

(c) Provision, erection, and removal of scaffolding,

(d) Provision of tools.

No deduction shall be made for the ends of beams, joints, posts, etc.; and, no deductions up to 0.5 m^2 area shall be made. Similarly, no additions shall be made for jambs, reveals, soffits, sills, etc., for such small openings; and, also no additions shall be made for doing finishing to ends of beams, joints, etc.

As for openings, with areas between 0.5 m^2 and 3.0 m^2 following types of deductions shall be made (yet, no deductions shall be considered for jambs, reveals, soffits, sills, etc., vis-à-vis, these openings):

(a) Where two wall faces are plastered with different plaster thicknesses/or types (or the other face is pointed) deduction should be done from the surface on the side on which width of reveals is less than that on the other side – therefore, no deduction is made on the other side. When the widths of reveals on both faces are equal, 50% of the area of the opening, shall be deducted from each surface of the wall.

(b) If both the faces of walls (internal as well as external) are plastered with the same type (specification) of plaster, deduction shall be made for one face only.

[**Note :** In effect, (a) and (b) mean the same thing – deductions for openings (Ds and Ws, etc.) to be made once.]

(c) When the width of a door frame is equal to the thickness of the wall (thin wall), or is projecting beyond the thickness of the wall, full deduction for the opening shall be made from each plastered face of the wall – i.e., deductions shall be made twice compared to the above mentioned cases.

(d) If only one face of a wall is plastered (i.e., the second face stands unplastered), full deduction for the opening shall be made provided the width of reveal on the plastered side is less than that on the unplastered side. However, no deductions shall be made if the width of reveals on both sides are equal or the width of reveals on the plastered side is more.

For an opening having an area of more than 3.0 m^2, deductions shall be made on each face : however, jambs, soffits and sills shall be measured.

Cement Plastering

Mortar mix shall be specified (1 : 4, 1 : 6, etc.). The thickness shall also be specified, such as 12 mm, 13 mm, 15 mm, or 20 mm. It shall be finished with a floating coat of neat cement. Smooth finishing shall be done with trowel immediately – all this has to be done within half an hour of adding water to the mix. It has to be stressed that, in two-coat work, when the first coat (two coats not to exceed 2.5 cm) is set, the surface shall be scratched with a sharp tool to form a key for the final coat. This coat shall be floated and finished, in the same manner and to the same specification as one-coat work.

Specifications of cement plaster shall be the same as for lime plastering (one-coat work).

Where it is not required subsequently to paint, distemper, or colour wash the plaster, it shall be finished to the final colour required and polished, plasterer's putty being used for the finishing coat. Plasterer's putty shall be made as described hereunder :

Pure fat lime shall be slaked and then immersed in water for at least 48 hours. Lime shall then be thoroughly stirred with water and strained through muslin. On settling, the surplus water shall be removed, and further water allowed to evaporate, until the paste is thick enough for use (now-a-days, readymade putty is available in the market). When a coloured finish has been specified, a suitable pigment shall be added to the putty.

The finishing coat of plasterer's putty shall be applied on the floated coat after it has set. It shall be kept wet for four days until it sets. The coat of putty shall be 3.17 mm (1/8th inch) thick, and shall be rubbed smooth with a steel plasterer's trowel as to leave a polished surface.

Plaster on Expanded Metal (or Lathing)

It is, generally, a two-coat work. The mortar used for both coats shall be 1 : 3 cement mortar. Appropriate quantity (by weight measure) of chopped jute on hemp shall be added to, and well mixed with each batch of mortar for the first coat.

Expanded metal (or similar metal fabric or lathing) shall be free from all rust, grease, etc. before plastering is started. When wooden lathing is to be treated, it should be unplanned and given two coats of creosote or any other wood preservative.

Ceiling Plaster

For common RCC slab roofing all the specifications for lime/cement plastering apply. In situations where ceiling consists of woodwork (like in pitched roofs in hilly areas), plaster shall not be used in contact with roof supports where thorough ventilation cannot be given from above. Furring bars (ceiling rafters), to which the fabric forming the core of the plaster is attached, shall be of such a size and so hung, as to allow being walked over by resting a light plank on them. Furring bars shall be of deodar wood (resistant to effects of moisture, etc.). Expanded metal shall be stretched tout and nailed to the under-surface of the bars, with small wooden spacers. Expanded metal sheets must overlap two meshes wherever these join.

Before commencing to plaster, all wood work shall receive two coats of hot wood preservative, and the expanded metal (especially all cut ends) shall receive two coats of red lead paint.

The plaster shall be applied in two coats – the first one being 1.25 cm thick, and the second coat, a thin finishing coat. Mortar used for plastering shall be 1 : 3 cement mortar – adding fine chopped jute or hemp as usual.

Mud Plaster

Mud mortar for plastering (to be used over *kuccha* or *pucca* brickwork, or sometimes even on stone masonry) shall be prepared as outlined below (and adding appropriate – by weight – quantity of chopped "*bhusa*", and mixing well) :

(a) Mud mortar shall be prepared from good-quality brick earth, or from stiff clay broken up into fine powder – to be freed from stones, pebbles, grass, roots, etc. *Efflorescing* salts shall be absent from this clay; and shall not belong to an area where white ants are present.

(b) Water shall be now added and mixed on a level ground (cleared of all debris, grass, etc.), and shall be tempered for at least two to seven days – during this time it shall be worked up at intervals with *phowrahs* or workers' feet (i.e. pugging with feet).

(c) Sand or chopped straw (*bhusa*) shall be added and mixed in the discrete quantities of the mud – this treatment is appropriate for a soil that is too clayey.

(d) This mud mortar shall be worked up to such a consistency that *it shall readily slide off the face of travel, but shall not be as wet as to form large drops while falling*.

[**Note :** *Mud mortar* (*without straw*) *can also be used to build up any brick/stone masonry – but shall not be used for a work likely to be under water at any time, and for a work that is to bear non-vertical loads.*]

Mud plaster shall be spread evenly over the wall so as to be not more than 19.0 mm (≈ ¾ inch) thick, and every portion of the wall shall be covered at least by 6.35 mm (≈ ¼ inch) thickness of the material. For roofs and floors (in low-cost housings), it shall be spread 2.54 cm (≈ 1 inch) thick. After spreading, the plaster shall be floated with a straight edge until the surface is perfectly smooth, level and true. Any cracks that open out during drying shall be filled with liquid cowdung. When the surface has dried up, it shall be *leeped* :

Leeping (*leepai*) shall be prepared by steeping cowdung in water to take off all grass, straw, seeds, etc. Sometimes, if necessary, cowdung shall be passed through a fine sieve. After this, an equal part of finely powdered clay is added to the cowdung – and, the whole is mixed in a tub and thoroughly worked up. The mixture is applied over the surface of mud plaster that is quite dry. It is finished off, with a trowel (or float) in the case of walls and roofs. For floors, it is applied and finished by hand.

6.3 POINTING

In exposed masonry surface (brick or stone), mortar joints are the weakest lines that afford access to rain water, and, thus access to dampness which is an undesirable feature. Pointing (in the absence of overall plastering of the exposed surface) is a preventive (as well as a decorative) measure. Pointing comprises raking out the joints, say, to a depth of about 13 mm (≈ ½ inch), and filling back mortar of slightly richer mix (compared to the mortar used in building the wall).

Pointing shall be done while the original mortar in the joints is still green – it gives a nice bond between the old and the new.

Rates for pointing differ mainly as per the type of pointing that is done : *flush pointing* (Figure 6.1); *weathered or cut or struck pointing* (Figure 6.2); V-grooved pointing (Figure 6.3); keyed (or grooved) pointing (Figure 6.4); raised (or Tuck) pointing (Figure 6.5); and beaded pointing (Figure 6.6).

6.3.1 General Specifications for Pointing

Pointing, besides on masonry surface, is also done on tile work. So, the type of pointing shall be specified. Its rates do include cost of scaffolding (as other works, like, plastering, colour washing, etc. do).

Surface preparation shall be specified – as is done for lime/cement plastering. Mortar to be used shall also be specified.

The specified mortar shall be applied and pressed into the joints that have been raked out by means of a pointing trowel : to give the desired geometry (flush, sunk or raised). No mortar shall be spread over the corner, edges or the surface of given masonry. Appropriate tools shall be used to give the finish. Pointing mortar can be either lime mortar or cement mortar as per specifications.

Before pointing an old brickwork or a new brickwork in mud, the joints shall be raked out with a hook (not a hammer) to a depth of 1.25 cm. Raking out of joints and surface cleaning shall be kept at least 1.25 m ahead of the pointing, and no pointing commenced until the walls are ready to receive the pointing mortar.

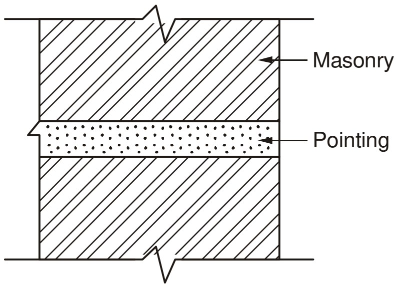


Figure 6.1 : Flush Pointing

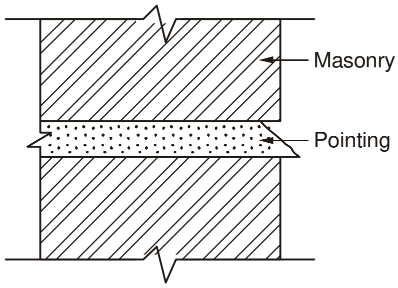


Figure 6.2 : Struck Pointing

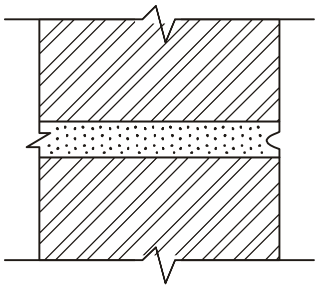


Figure 6.3 : V-grooved Pointing

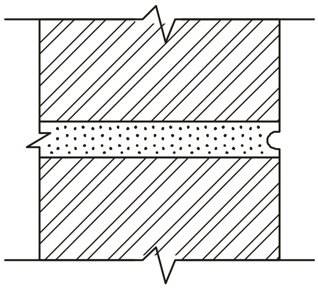


Figure 6.4 : Keyed Pointing

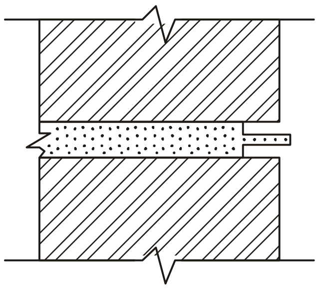


Figure 6.5 : Tuck Pointing

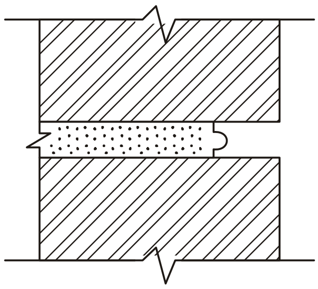


Figure 6.6 : Beaded Pointing

The practice of smearing mortar over any defects in the body of the bricks (to hide these) has to be totally discouraged.

While a piece of rough stone masonry is being pointed, the mortar shall be simply struck off with a trowel, and the work left showing boldly the irregularities in line and surface of the stones themselves.

After pointing the face of the work, it shall be cleared of all surplus mortar adhering to the face. No washing shall be done until the pointing has set.

Lime-pointed work shall be kept wet (*curing*) for five days, and cement-pointed work for ten days after completing the work – and, the work has to be protected during this time from extremes of weather.

In brickwork, pointing lines shall be truly horizontal and vertical. Lines of joints from different directions (in all types of masonry) shall meet neatly at the junctions.

Measurements shall be done as described for plastering. Various types of pointing shall be measured separately, stating the proportions of materials. Pointing on different types of surfaces shall be measured separately. All payments shall be as per m^2 of the area covered.

In case of repairs, pointing in single detached joints, or for flashings shall be measured in running metres.

If necessary, raking out of joints shall also be measured in m^2, or otherwise included in the overall rate of payment.

Deductions shall be done as for plastering.

6.4 WHITE WASHING, COLOUR WASHING AND DISTEMPERING

White-wash is prepared from white stone lime (i.e., pure fat lime) or shell lime. This unslaked lime is immersed in sufficient quantity of water, and stirred very thoroughly with a wooden pole or so – till the substance attains the consistency of a thin cream. Generally, water in the proportion of 5 litres to one kg of lime, is added for getting the desired consistency. This mix is left to stand in a receptacle (say, a tub) for about 24 hours – later being strained through a clean coarse cloth. Later gum (etc.) – dissolved in hot water – is added (5 kg of gum to a m^3 of thin cream) to impart a good sticking power to it.

It is to take off glare, and impart a pleasing effect, Indigo (*Neel*) – 3 kg per m^3 of thin cream – is added at the end. Sometimes alum or common salt is also added to increase the sticking power.

Colour wash is prepared, adding mineral colours (i.e., those not affected by lime) of the required shade to the prepared white wash. The mixture shall be stirred continuously (with a bamboo stick) while it is being applied to the walls, or ceiling.

A distemper is a water paint comprising *whiting* (powdered chalk), a colouring pigment (if so desired) and glue – all mixed in water. Distemper can give either a washable or non-washable surface – mediums used being different. Distempers are cheaper than paints or varnishes, and are easier to work. Distempers act as sealers over porous surfaces, and are generally applied over plastered surfaces on which a priming coat of whiting has been applied. Distempers for exterior work (on cement concrete, brick surface, stucco) have a weather resistant ingredient. These give more durable, smoother, and better surface than simple colour or white wash. Distempers are best used in dry climates: wet conditions yield poor results.

6.4.1 General Specifications

White Washing

Towards the surface preparation for white washing of a new surface, it shall be perfectly brushed free from mortar droppings (while under plastering work) and any other extraneous matter. Similarly, for an old surface all loose material has to be taken off (scrapped) – and, all gaps (holes) in the plaster as also all patches (less than 50 m^2 in area) shall be done completely with mortar of the original mix. The whole surface of the old white wash (if any) has to be completely removed.

New plaster to be white washed shall not be trowelled to a glazed surface for the white wash to adhere to it properly. The surface to be white washed shall be thoroughly dried before the application of white wash. If the old white washed surface is discoloured by smoke, a wash of wood-ashes and water shall be applied before the coat of white wash.

When the old plaster requires repair, it shall be cut out in a square (or rectangle), and new patch put in (as said above). All holes can be stopped with lime putty if not the mortar. Any patches of new plaster shall receive two extra coats of white-wash before the regular coat is given (patches being completely dry). Therefore, the workers repairing the patches shall work well ahead of the white-washers.

The white-wash will be applied with a brush for the specified number of coats – each coat shall consist of four strokes of the brush, one in each direction. Application of each coat shall consist of one stroke of the brush from top to bottom, and then a reverse stroke over the first trace; and one stroke horizontally from right to left, and then a reverse stroke over this trace – all to be done before the wash dries up.

Each coat of white wash shall be allowed to dry up and shall be inspected before other coat(s) is/are applied. A wall face should be fully covered – i.e., no portions to be left out for later-on completion.

When dry, a coat of white wash shall show no sign of cracking, nor come off readily on the fingers when rubbed against. White wash when completed, shall form an *opaque* coat of uniform white colour, through which the old work does not show, and shall present a smooth regular surface free from powdery matter.

For a fresh piece of work, three or more coats shall be applied.

Washing on the ceiling should be done prior to walls.

Doors, windows, furniture, floor, etc. shall be protected from any splashes of the washing.

Rate of payment shall, among other things, include cost of scaffolding.

Colour Washing

Before proceeding with the work, a sample of the tint/colour shall be examined by colour washing a patch of surface.

Method of application is same as for white washing. For any new work, a primary coat shall be white wash (with lime or whiting). As for old work, a coat of colour wash shall be applied over the patches after the base is ready.

Before taking a room in hand, sufficient colour-wash shall be kept ready to last for all the walls (and ceiling, if needed) to render a uniform tint. Work in a room shall begun quite early in the day to ensure completion before the evening.

All the specifications of white washing do apply.

Distempering

New lime and/or cement plaster or cement concrete, if distempered (or even painted) within one year of its completion, spoils the distemper or paint – not due to the work not having dried out, but due to the chemical action that goes on for many months after the work has dried. If it is imperative to distemper (or paint), the work should be re-done after a year or 18 months. Or, it is better to finish off the wall temporarily with a white wash or colour-wash made from whiting mixed with water and sized and tinted as required.

Dry distemper of required colour shall conform to IS 427-1965. The distemper colour shall be stirred slowly in clean water (0.6 litre of water per kg of distemper) – water preferably being warm. It is best to allow the mix to stand for at least ½ an hour, if not overnight before being used. The mix should be thoroughly stirred before and during use – to maintain an even consistency.

Surface preparation shall be done as discussed for other items herein – using sand paper to get a smooth base. All pittings in plaster shall be smoothed out with the plaster of Paris (mixed with the colour to be used).

Distempering shall not be carried out in damp weather, nor when the weather is excessively hot and dry.

Appropriate priming coat shall be applied over the prepared surface.

Distemper is to be applied quickly and boldly, leaving no dry edges. *The brush is to be dipped, and stroked crosswire on the wall, then immediately stroked up and down, and stopped*. Distemper shall only be applied with proper brushes – the brushes shall be washed in hot water after work, each day, and hung up to dry up. Old brushes caked with dry distemper shall not be allowed to be used on the work.

Other Treatments

Emulsion (oil bound) distemper, cement primer coat, cement paint, etc. are some of the costlier applications. *Cement primer coat* is used as a base coat on a wall finish of cement, lime or lime cement plaster or on asbestos cement surface before oil emulsion distemper paints are applied on them.

6.4.2 Measurements

All measurements of white washing/colour washing/distempering/other finishing treatment shall be based on IS 1200 : Part XIII.

Different decorative treatments shall be measured separately under various heads – white wash, colour wash, washable/non-washable distemper, etc. Preparation of surface and scaffolding shall be covered by the rates. Priming and other such treatments (washing spoilt surfaces, etc.) shall be measured separately and materials described. Work on walls, ceiling, etc. shall be measured separately. *Payment shall be made per m^2 of the surface area done*. Dimensions shall be measured to the nearest 0.01 m. Area of every individual item shall be computed to the nearest 0.01 m^2.

Corrugated surfaces shall be measured flat when fixed – and due allowance made to the area as per laid down norms (varying from 14% to 25%).

Deductions shall be made as outlined for plastering and pointing.

6.5 RATE ANALYSIS

Requirements of material and skilled/unskilled labour for various finishing items are available in the Schedules of government agencies, such as sampled in

Table 6.1. These can always be referred to whenever felt necessary. Every practising engineer must possess copies of such publications; and, in fact, some basic fundamental data, so to say, get lodged in the memory of any supervisor of works, such as :

Sl. No.	Finishing on Walls/Ceilings	Per	Labour Requirement
1.	12 mm (1/2 inch) thick plastering – *without base preparation*	100 m^2	Mason – 7.5 Mazdoor – 7.5 Bhisti – 2.5
2.	3 coats white/colour washing – without base preparation	600 m^2	White washer – 10 Mazdoor – 10

Information about materials required, remembered easily by any works supervisor, comes handy at many a time – for quick estimation, assessing the requirements, etc., such as :

Requirement of Cement and Sand (per m^2) for Plastering Work

Nominal Mix of [Cement : Sand]	Thickness of Plaster	Materials Required	
		Cement (kg)	Sand (litres) – Bulking Not Accounted for
1 : 1	5 mm	5.1	3.50
	10 mm	10.2	≈ 7.10
	15 mm	15.3	10.60
1 : 4	5 mm	2.0	5.5
	10 mm	≈ 4.0	≈ 11.10
	15 mm	≈ 5.9	16.6
1 : 6	5 mm	1.4	6.0
	10 mm	≈ 2.9	12.0
	15 mm	4.3	≈ 18.0

Requirement of Materials (per 100 m^2 of Surface) for Very Common Items

Sl. No.	Item of Decorative Work	Material Required
1.	Dry mortar (all mixed) for pointing in Brickwork	0.6 m^3
2.	Lime for one coat of white washing	10.0 kg
3.	Dry distemper for first coat	6.5 kg
4.	Dry distemper for second coat	5.0 kg

Table 6.1 : Basic Data Input for Rate Analysis of Some Items of Work

Sl. No.	Description of Item	Quantity of Item	Requirements of Men and Material	
			Labour Component	**Material Component**
1.	**Pointing and Plastering** 12 mm thick, cement and sand mortar (1:6) plastering on brickwork – including base preparation, etc.	100 m^2 surface area	Mistri – 0.33 Nos. Mason – 10 Nos. Beldar – 11 Nos. Bhisti – 3.8 Nos. (for watering) [**Note :** Add suitably (on LS basis or on actual field-value basis) for scaffolding and tools, etc.]	Cement 7.5 bags (= 0.25 m^3) Sand 1.5 m^3
2.	12 mm thick, cement and sand mortar (1:2) plastering on brickwork – including base preparation, etc.	100 m^2 surface area	Same as for Item (1) above. [**Note :** Same as for Item (1) above.]	Cement 20.25 bags (= 0.675 m^3) Sand 1.35 m^3
3.	Flush pointing with 1 : 2 cement and sand mortar on brickwork – including base preparation, etc.	100 m^2	Mistri – 0.25 Nos. Mason – 15 Nos. Beldar – 5 Nos. Mazdoor – 10 Nos. Bhisti – 3 Nos. (for watering) [**Note :** Same as for Item (1)	Cement 6 bags (= 0.2 m^3) Sand 0.4 m^3
4.	12 mm thick, cement-sand mortar (1:4) plaster on brick wall – including base preparation, etc.	100 m^2	Mistri – 0.33 Nos. Mason – 10 Nos. Beldar – 11 Nos. Bhisti – 3.8 Nos. (for watering) [**Note :** Same as for Item (1)	Cement 11.25 bags (= 0.375 m^3) Sand 1.5 m^3
1.	**White Washing and Colour Washing** White Washing three coats.	100 m^2	Labour – 1.73 Nos. (for white washing) Mazdoor – 1.73 Nos. (helper) [**Note :** Same as for Item (1) of pointing and	White lime 33 kg Add glue/gum and a blue pigment on LS basis
2.	White washing one coat	100 m^2	White washer – 0.73 Nos. Helper – 0.73 Nos. [**Note :** As usual]	White lime 11 kg Add as per Item (1) above.
3.	Colour washing one coat	100 m^2	White washer – 0.75 Nos. Helper – 0.75 Nos. [**Note :** As usual]	White lime 11 kg Colouring material 2.5 kg Gum or glue powder as per requirement.
1.	**Cement Washing** Cement Washing (one coat)	100 m^2	Labour – 1 No. (say, white washer) Helper – 1 No. [**Note :** As usual]	Cement 0.8 bag Add glue/gum on LS basis

1.	**Distempering** One coat of dry distemper, over one priming coat (on a fresh, new work)	100 m^2	Labour – 0.73 No. Distemperor – 3.5 Nos. (i.e. painter) Helper – 4.23 Nos. [**Note :** As usual]	Dry distemper 8.1 kg White lime 11 kg Gum, etc. on LS basis
2.	Second coat of dry distemper over first coat	100 m^2	Distemperor – 1.8 Nos. Helper – 1.8 Nos. [**Note :** As usual]	Dry distemper 6.5 kg

Example 6.1

Use the following data, and arrive at the rate for struck pointing with 1 : 2 cement-sand mortar on brickwork, including raking, watering, supply of materials, labour, tools and plants (T and P), for *100 m²* of work:

Cost of cement = Rs. 150 per bag

Cost of local sand = Rs. 50 per m^3

Rate for Labour

Mistri	–	Rs. 120 per day
Mason	–	Rs. 100 per day
Beldar	–	Rs. 60 per day
Coolie	–	Rs. 50 per day
Bhisti	–	Rs. 50 per day

Assume suitable rates for scaffolding; and T&P, and sundries, etc.

Solution

With reference to the standard and schedules for material and labour requirements, following tabulation is done :

Rate Analysis

Sl. No.	Particulars	Quantity/No.	Rate	Amount
1.	*Materials*			
	Cement (0.2 m^3)	6 bags	Rs. 150 per bag	Rs. 900
	Local sand	0.4 m^3	Rs. 50 per m^3	Rs. 20
			Total of (1)	Rs. 920
2.	*Labour*			
	Mistri	0.25 Nos.	Rs. 120 per day	Rs. 30
	Mason	18 Nos.	Rs. 100 per day	Rs. 1800
	Beldar	8 Nos.	Rs. 60 per day	Rs. 480
	Coolie	10 Nos.	Rs. 50 per day	Rs. 500
	Bhisti	3.8 Nos.	Rs. 50 per day	Rs. 190
	Scaffolding (LS)			Rs. 150
	T&P, etc. (LS)			Rs. 90
			Total of (2)	Rs. 3240

Total of (1) and (2) = Rs. 4160

Add 1.5% for work-charged establishment = Rs. 62.40

Add 10% for contractor's profit = Rs. 416

GRAND TOTAL = Rs. 4638.40

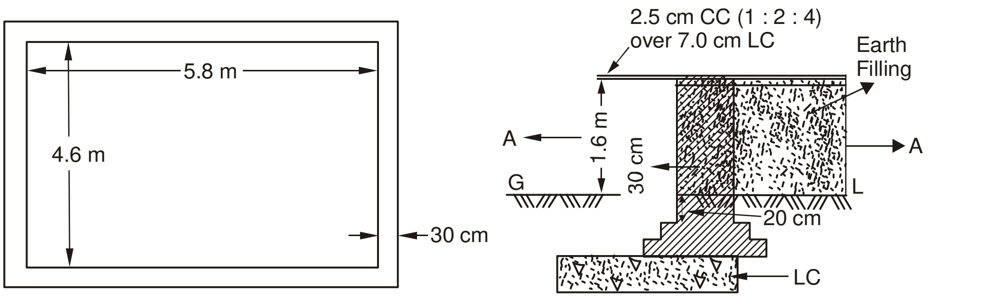
∴ Rate per m^2 = 46.384 ≈ Rs. 46.40 (say)

6.6 CASE STUDIES

Following solved examples, starting with the simplest case, are given to initiate the reader to one of the simplest procedures (yet calling for keen knowledge/conception of the layout and elevation of a structure) of estimation of quantities in a civil engineering work.

Example 6.2

A simple brick masonry platform (Figure 6.7) has to be plastered as per following specifications :



(a) Sectional Plan A-A **(b) Section through a Wall of the Platform**

Figure 6.7 : Brick-Masonry Platform – [Not to Scale]

13 mm thick plastering in CM (1 : 6) over outside face of walls, up to 10 cm below GL.

Compute the required quantity of this plastering.

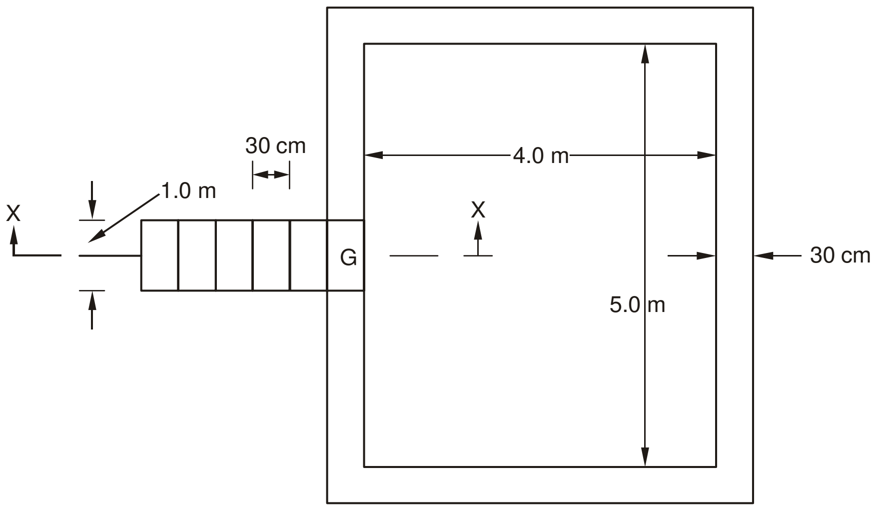
Solution

Particulars of the Item	No.	Measurements			Quantity	Remarks
		L (m)	B (m)	H/D (m)		
13 mm thick plastering as specified						5.8 + (2 × 0.30) = 6.4 (1.6 + 0.025) + 0.10 = 1.725 4.6 + (2 × 0.30) = 5.2
LW	2	6.4	–	1.725	22.08 m^2	
SW	2	5.2	–	1.725	17.94 m^2	

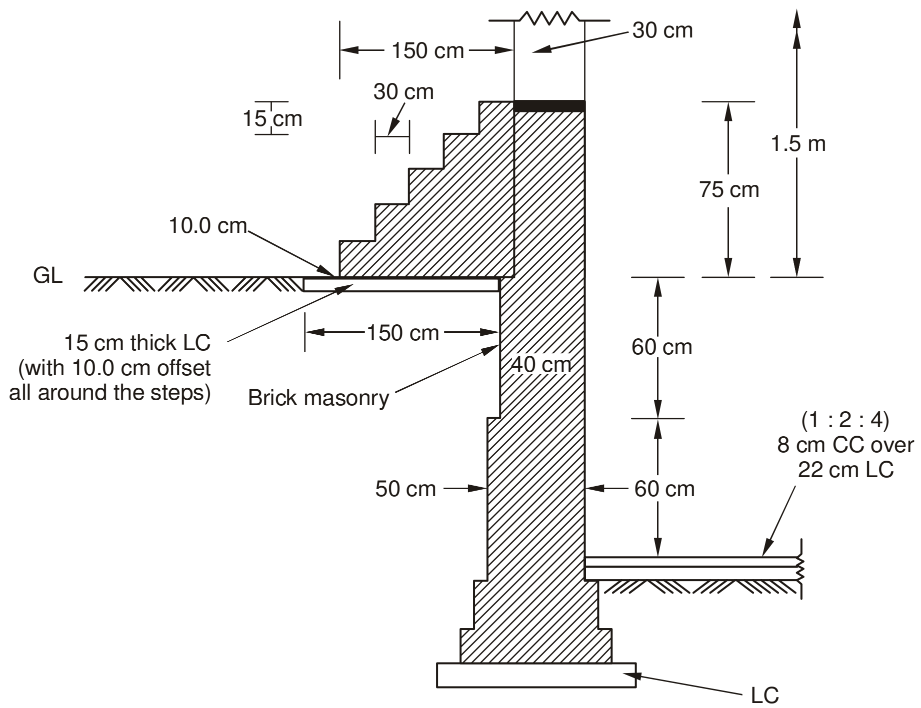
Total					$= 40.02\ m^2$ $\approx$ **$40.00\ m^2$** (say)	

Example 6.3

A brick masonry water tank (partly underground) – Figure 6.8 – is to be plastered with local cement-sand mortar.



(a) Plan at Top Level



(b) Section at X-X

Figure 6.8 : Details of an Underground Water Tank – (Not to Scale)

Estimate the following quantities :

(a) 1 : 2 CM (cement mortar), 12 mm thick plaster on inside wall surfaces,

(b) 1 : 3 CM, 10 mm thick plaster on top of the walls, top, and faces of steps,

(c) 1 : 4 CM, 10 mm thick plaster on outside of walls up to 15 cm below GL, and sides of steps; and jambs of gap "*G*".

Solution

Bill of Quantities

Sl. No.	Particulars of the Item	No.	Measurements L (m)	B (m)	H/D (m)	Quantity
1.	*12 mm thick CM (1 : 2) on inside surface of walls*					
	LW	2	5	–	2.7	27.0 m^2
	SW	2	4	–	2.7	21.60 m^2
					Total	= 48.60 m^2
	Deduct gap "*G*"	1	1.0	–	0.75	(–) = 0.75 m^2
					Net of Item (1)	**= 47.85 m^2**
2.	*10 mm thick CM (1 : 3)*					
	(a) Top of walls					
	LW	2	5.6	0.30	–	3.36 m^2
	SW	2	4.0	0.30	–	2.40 m^2
	(a) Steps					
	Treads	1	1.5	1.0	–	1.50 m^2
	Risers	1	1.0	0.75	–	0.75 m^2
					Total	8.01 m^2
	Deduct gap "*G*"	1	1	0.3	–	(–) = 0.30 m^2
					Net of Item (2)	**= 7.71 m^2**
3.	*10 mm thick CM (1 : 4) on outside surface of walls upto 15 cm below GL and sides of steps*					
	Above GL					
	LW	2	5.6	–	1.5	16.80 m^2
	SW	2	4.6	–	1.5	13.8 m^2
	Plinth projections					
	LW	2	5.80	0.1	–	1.16 m^2
	SW	2	4.60	0.1	–	0.92 m^2
	[5.6 + 0.10 + 0.10 = 5.80 m]					
	Portion of outside wall					
	LW	2	5.8	–	0.15	1.74 m^2
	SW	2	4.8	–	0.15	1.44 m^2
	Sides of steps	2	1	1.5	0.45	1.35 m^2
	$\left[\frac{15\text{ cm} + (5\times 15)\text{ cm}}{2} = 45\text{ cm} = \text{average height of sides of steps}\right]$;					
	and [1.50 – 0.1 + 0.1 = 1.5 m]					
	Jambs of gap "*G*" [1.5–0.75 = 0.75 m]	2	0.30	–	0.75	= 0.45 m^2
			Gross total of Item (3)			**= 37.66 m^2**
	Deductions					
	Area covered by steps :					
	Outer wall	1	1.0	–	0.75	0.75 m^2
	Plinth projection	1	1.0	–	0.1	0.10 m^2

	Wall portion below GL in contact with LC that lies under the steps	1	1.2	–	0.15	0.18 m^2
	[1 + 0.1 + 0.1 = 1.2 = Width of LC under steps]					
	Gap in the top portion of wall (G)	1	1.0	–	0.75	0.75 m^2
			Total deductions			1.78 m^2
			Net of Item (3)			37.66 m^2 (–) 1.78 m^2 = **35.88 m^2**

Example 6.4

A motor garage (Figure 6.9) has been plastered, and white washed as per following specifications :

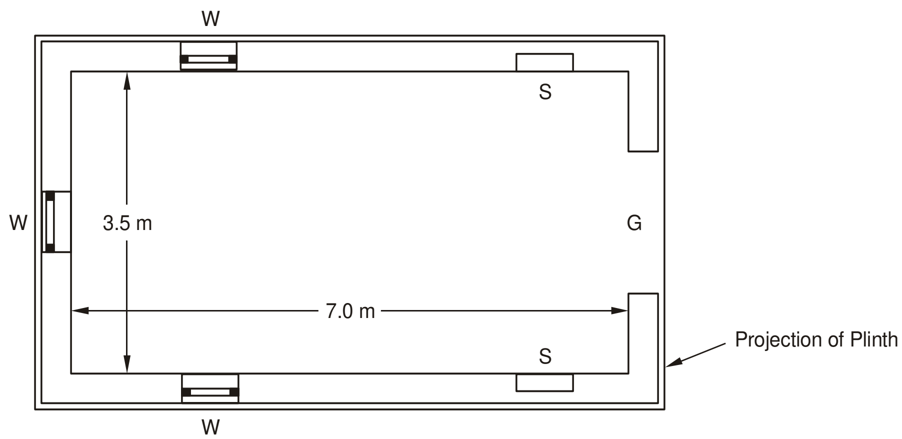
(a) 13 mm thick plaster, 1 : 6 CM, on inside,

(b) 13 mm thick plaster, 1 : 6 CM, on outside (i.e., external plaster) – up to lime concrete (LC) level,

(c) 13 mm thick plaster, 1 : 6 CM, on ceiling,

(d) white washing – 3 coats inside and outside walls, and ceiling. The rate covers both sides of the work.

Estimate the required quantities, and prepare a bill of quantities. (Rate of payment for item (a) and (b) is same, while for item (c) the rate is different.)

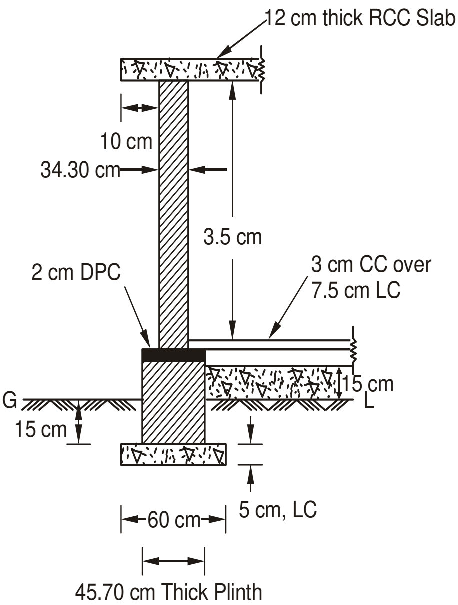


(a) Plan

Sizes of Openings

W	1 × 1.2 m
S	1 × 1.2 m
G	2.5 × 2.3 m (high)

Note : (1) There are two shelves between top and bottom ends of S – each 5 cm thick
(2) *G* has a sheet iron gate.
(3) Almirah, S = 22.9 cm deep into the wall
(4) Walls are built of traditional bricks – 22.9 × 11.4 × 7.6 cm



(b) Wall Section

Figure 6.9 : Details of a Motor Garage (Not to Scale)

Solution

Bill of Quantities

Sl. No.	Particulars of the Item	No.	Measurements L (m)	B (m)	H/D (m)	Quantity
1.	*13 mm thick, 1 : 6 CM plaster*					
	Inside of Walls					
	LW	2	7.0	–	3.5	49.0 m^2
	SW	2	3.5	–	3.5	24.50 m^2
	Jambs, sills, and soffits of almirahs (*S*)	2	4.4	0.229	–	2.02 m^2
	[Perimeter of *S* = (2 × 1) +2 (1.2) = 4.4 m]					
	Jambs of gate (*G*)	2	–	0.343	2.3	1.58 m^2
	Outside of Walls					
	LW	2	7.69	–	3.53	54.29 m^2
	[3.5 + 0.03 = 3.53 m; and 7 + (2 × 0.343) = 7.686 ≈ 7.69 m]					
	SW	2	4.19	–	3.53	29.58 m^2
	[3.5 + 0.686 = 4.186 ≈ 4.19 m]					
	Plinth, from DPC top to top of LC in foundation					
	LW	2	7.8	–	0.3 (i.e. 0.15 + 0.15)	4.68 m^2
	$\left[7 + (2 \times 0.343) + 2\left(\frac{0.457 - 0.343}{2}\right) = 7.8\right]$					
	SW	2	4.3	–	0.3	2.58 m^2

	$\left[3.5 + (2 \times 0.343) + 2\left(\frac{0.457 - 0.343}{2}\right) = 4.3\right]$					
	Plinth projections					
	LW	2	7.8	0.057	–	0.89 m^2
	SW	2	4.19	0.057	–	0.48 m^2
	[4.3 – (2 × 0.057) = 4.186 ≈ 4.19]					
					Total of (1)	169.60 m^2
	Deductions					
	W	3	1	–	1.2	3.60 m^2 (deducted once only – plastering being on both sides of the wall)
	Gate (G)	2	2.5	–	2.3	11.50 m^2
	[Gate opening is deducted twice because its jambs have been already added above.]					
	Projection of plinth under the gate floor	1	2.5	0.057	–	0.14 m^2 (This quantity is so small, it could have been neglected) –
		Total deduction				15.24 m^2
		Net of Item (1)				169.60 m^2 (–) 15.24 m^2 **= 154.36 m^2**
2.	*13 mm thick, 1 : 6 CM plastering on ceiling*	1	7.0	3.5	–	24.5 m^2
	Add soffit above the opening "G"	1	2.5	0.343	–	0.86 m^2
					Total of Item (2)	**= 25.36 m^2**
3.	*3 coats of white washing on walls- inside and outside*					
	Same as for Item (1)					154.36 m^2
	and Item (2)					+ 25.36 m^2
					Sub-Total	= 179.72 m^2
	Add projection of roof slab – soffits, and vertical face					
	LW	2	7.89	0.22 (i.e. 0.12+ 0.1)	–	3.47 m^2
	[7.686 + (2 × 0.1) ≈ 7.89]					
	SW	2	4.19	0.10	–	0.84 m^2

	[3.5 + (2 × 0.343) = 4.1862 ≈ 4.19)					
	Vertical side of the roof slab that is left on the short wall side	2	4.39	–	0.12	1.05 m^2
	[3.5 + (2 × 0.343) + (2 × 0.10) = 4.39]					
	Gross Total of Item (3)					179.72 m^2 + 5.36 m^2
						= 185.08 m^2
	Deductions					
	Plinth portion below GL					
	LW	2.0	7.8	–	0.15	2.34 m^2
	SW	2	4.3	–	0.15	1.29 m^2
	Total deductions					= 3.63 m^2
	Net of Item (3)					= 185.08 m^2 (–) 3.63 m^2
						= 181.45 m^2

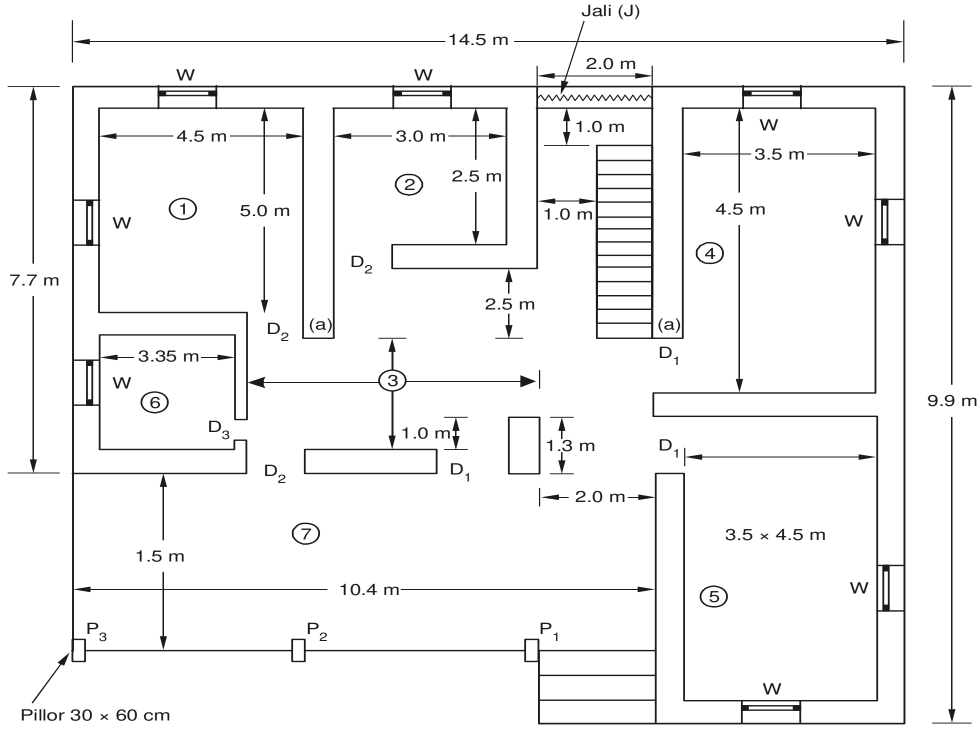
SAQ 1

(a) Estimate the following quantities of work in the ground floor of a building (Figure 6.10)

(i) 1 : 6 cement-sand plaster, 16 mm thick on internal side of walls,

(ii) 1 : 4 ceiling plaster, 6 mm thick,

(iii) 1 : 6 cement-sand plaster, 12 mm thick (external) on walls, plinth, and plinth projections,



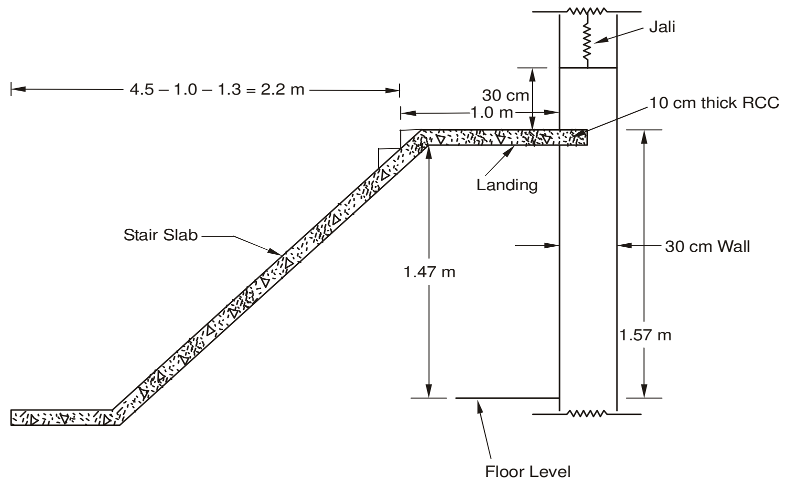
Sizes of Openings

D_1	1.3 × 2.0 m
D_2	1.0 × 2.0 m
D_3	0.8 × 2.0 m
W	2 × 1.3 m
J	2 × 2.7 m
V	0.5 × 0.5 m

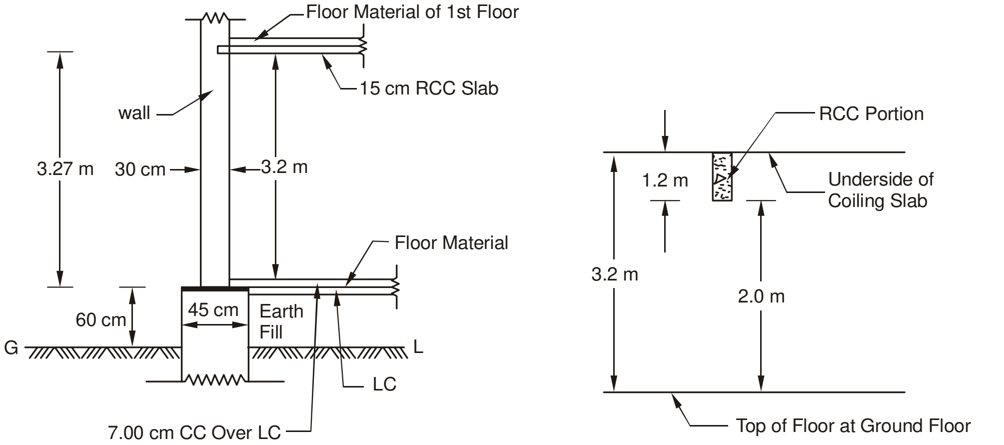
Legend

(1) Drawing room – 4.5 × 5 m
(2) Kitchen – 3.0 × 2.5 m
(3) Dining space – 4.6 × 1.8 m
(4) & (5) bed rooms = 3.5 × 4.5 m
(6) Both room = 3.35 × 1.8 m
(7) Varandah = 10.4 × 1.5 m

(a) Sectional Plan



(b) Stair Details



(c) Wall Section **(d) Details of Open End of Dining Space**

Figure 6.10 : Ground Floor Plan and Details (Not to Scale)

(iv) Finishing :

(1) Three coats of white washing on internal side of walls, and ceiling,

(2) Two coats of lime-colour washing over one coat of white washing (included in the overall rate) on external walls, columns, plinth and its projections.

Following specifications apply :

(1) 30 × 30 cm beams span, over the wall and pillars P_1, P_2 and P_3; over P_3 and the bath-room wall; and (a) to (a) in the Figure,

(2) An iron grill door (folding type) separates the dining space, etc., from the passage to stairs,

(3) Two flights of stairs (i.e., two stair slabs – waiste slabs) come in one floor height,

(4) Stair treads will not, as usual, have any plastering, but marble finish,

(5) There is one ventilator placed in the ground floor, in the kitchen,

(6) The base of Precast Jali (2.7 m high) is positioned 1.33 m below the RCC floor-slab of the first floor.

Also, assuming the first floor as similar to the ground floor, draw the elevation, two sectional elevations (at right angles to each other – one across the stairs) of the full two-storeyed building.

(b) Calculate the quantities, as asked for in (a) above, for the structures depicted in the Figures of Units 2 and 3.

(c) On the basis of Schedule of Materials – giving the various quantities of materials required for various items of work – work out the details (weight/volume) of following materials in various structures outlined in Units 2, 3, and 6 :

(i) Bricks,

(ii) Cement,

(iii) Sand,

(iv) White lime

(v) White lime (slaked)

(vi) Colouring matter

6.7 SUMMARY

After any masonry (particularly brick masonry) is in place, protective and decorative treatments (finishing) are done – plastering, pointing, white and colour washing, and distempering etc. Base surface, has to be prepared, i.e. rendered fit to receive the finishing treatment. Unit of measurement for all these works, in general, is m^2. Appropriate deductions for door, window, and other openings have to be made to arrive at the correct quantity to be paid for.

Sometimes, instead of traditional treatments, stone facings of various kinds are adopted to give a nice look to the building. In hilly regions rich people put timber (bark of Deodar etc.) facing on masonry walls, and the structural gives a very elegant look to the structure.

6.8 ANSWERS TO SAQs

It is correct and appropriate to first make a determined, sustained effort to solve an SAQ and then compare with the given answer. This would go a long way in preparing the student to deal with all problems independently and purposefully.

In fact, the philosophy behind the concept of incorporating SAQs in the body of the text is to allow space for exercising one's mind. And, moreover, the effort to solve a given problem should also goad the student to himself find problems and keep on solving them – this method leads to the desired mastery over the subject under consideration.

It is essential that students on their own delve into relevant books and records (with construction agencies), and bring themselves up in the subject.

SAQ 1

(a) The following bill-of-quantities gives a detailed analysis of the data and explains most of the finer points.

Bill of Quantities

Sl. No.	Particulars of the Item	No.	Measurements			Quantity	Remarks
			L (m)	B (m)	H/D (m)		
1.	*1 : 6 cement sand plaster, 16 mm thick on walls (on internal side)*						
	Drawing Room						
	LW	2	5	–	3.2	32.00 m^2	
	SW	2	4.5	–	3.2	28.8 m^2	
	Kitchen						
	LW	2	3	–	3.2	19.2 m^2	
	SW	1	2.5	–	3.2	8.0 m^2	
	SW-(a)	1	5.3	–	3.2	16.96 m^2	
	(One jamb of (a) wall is included in 5.3 m)						[length of (a) = 5 + 0.3]

	Dining space (3)	2	4.6	–	3.2	29.44 m^2	Appropriate deductions for open space on right shall be made later on.
		2	1.8	–	3.2	11.52 m^2	
		Deductions for open space to right (stair-side) = (1.8 + 2.5 – 1.0) × 2 = 3.3 × 2 = 6.6 m^2					
	Bed rooms						
	LW	2 × 2	4.5	–	3.2	57.60 m^2	
	SW	2 × 2	3.5	–	3.2	44.80 m^2	
	Open varandah						
	LW	1	10.4	–	3.2	33.28 m^2	
	SW	1	1.5	–	3.2	7.04 m^2	
	Bath	3 (2 + 1)	1.8	–	3.2	17.28 m^2	
		2	3.35	–	3.2	21.44 m^2	
	Pillars						
	3 faces (P_1)	2	1.5	–	3.2	9.6 m^2	P_1 (and P_2) ⇒ 0.6+0.6+0.3 = 1.5
	2 faces (P_3)	1	0.9	–	3.2	2.88 m^2	P_3 ⇒ 0.6+0.3 = 0.9
	Sides of verandah beams (over P_1, P_2 and P_3)	1	9.5	–	0.3	2.85 m^2	8.4 + 2 – 3 × 0.30 = 10.4 – 0.9 = 9.5
	(over P_3 and wall of (6))	1	1.2	–	0.3	0.36 m^2	1.5 – 0.3 = 1.2 (already counted in pillars)
	Stair case						
	SW a)	1	2	–	1.47	2.94 m^2	
	above landing⇒ b)	1	2	–	0.3	0.06 m^2	(upto below Jali)
	LW a)	1	3.2	–	3.2	10.24 m^2	(neglecting deductions done to staircase contact)
		[4.5 – 1.3 = 3.2]					
	b)	1	2.8	–	3.2	8.96 m^2	
		[2.5 + 0.3 = 2.8]					
	Passage before staircase	2	1.8	–	3.2	11.52 m^2	(i.e., two faces of one wall, in which a large deduction shall be done)
	Sides of beam over (a) – (a)	2	5.30	–	0.3	3.18 m^2	No deductions for beams over walls is being made-being negligible
		[3.0 + 0.3 + 2 = 5.3 m]					
					Total of (1) =	379.95 m^2	
	Deductions :						
	[**Note:** Doors shall be deducted once for all internal plaster to take care of jambs, etc. Similarly						

	windows shall be deducted once even when external plastering is also done. Similarly for ventilators.]						
	D_1	3	1.3	–	2	7.8 m^2	
	D_2	3	1.0	–	2	6.0 m^2	
	D_3	1	0.8	–	2	1.6 m^2	
	Opening to the right of dining space	2	(1.8– 1.0) =0.8	–	2	3.2 m^2	2 sides of opening taken. Refer Figure 6.10(d)
	2m-gap after cross over the varandah towards the stairs	1	2	–	2	4.0 m^2	Only one face considered because it was taken only once for varandah plaster. Refer Figure 6. 10(d)
					Total deduction =	22.6 m^2	
					Net total of Item (1)	379.95 (–) 22.6 m^2 = 357.35 m^2	
2.	*1 : 4, ceiling plaster 6 mm thick*						
	Drawing Room	1	4.5	5.0	–	22.5 m^2	
	Kitchen	1	3.0	2.5	–	7.5 m^2	
	Space just outside kitchen	1	2.5	3.3	–	8.25 m^2	
	Bed rooms	2	3.5	4.5	–	31.50 m^2	
	Varandah (with under-side of beams included)	1	10.4	1.5	–	15.60 m^2	Neglecting pillar deductions
	Bath	1	3.35	1.8	–	4.50 m^2	
	Underside of beams						
	(i) Soffit of beam on the left end of varandah	1	1.2	0.3	–	0.36 m^2	(1.5 – 0.3 = 1.2)
	(ii) Soffit of beam on P_1, P_2, and P_3	1	9.5	0.3	–	2.85 m^2	(10.4 – 3 × 0.3 = 9.5 m)
	(iii) Soffit of beam (a) – (a)	1	5.3	0.3	–	1.59 m^2	(2 + 0.3 + 3 = 5.3 m)
	Dining space	1	4.6	1.8	–	8.28 m^2	
	Passage before stairs	1	2.0	2.1	–	4.20 m^2	(0.3 + 1.8 = 2.1)
	Landing	1	2.0	1.0	–	2.0 m^2	(Steps and top face of landing shall be done as flooring)
	Underside of stair slab (waiste slab)	2	2.65	1.0	–	5.3 m^2	⇒ [Two waiste slabs come in one floor]
	$\left[\sqrt{\{(1.47)^2 + (2.2)^2\}} = 2.65 \text{ m}\right]$						
					Total of Item (2) =	**114.43 m^2**	

3.	*1 : 6 cement-sand plaster, 12 mm thick (external plaster) – (including plinth, and plinth projection)*						
	Back wall	1	14.5	–	3.27	47.42 m^2	(Plinth calculations done later – Refer Figure 6.10(c))
	Side wall (right)	1	9.9	–	3.27	32.37 m^2	
	Side wall (left – without varandah)	1	7.7	–	3.27	25.18 m^2	
	Front bed room wall						
	a)	1	4.1	–	3.27	13.41 m^2	(3.5 + (2 × 0.3) = 4.1)
	b)	1	1.7	–	3.27	5.56 m^2 ⇒	Wall projecting along the steps
	[4.5 – 1.3 – 1.5 = 4.5 – 2.8 = 1.7 m]						
	Columns (P_1, P_2 and P_3)	3	0.3	–	3.27	2.94 m^2	
	Column, P_3	1	0.6	–	3.27	1.96 m^2	
	Beam (on P_3 and bath room)	1	1.2	–	0.3	0.36 m^2	(1.5 – 0.3 = 1.2 m)
	Beam on P_1, P_2 and P_3	1	9.5	–	0.3	2.85 m^2	⇒ (10.4 – 3 × 0.3 = 9.5m)
	Plinth						
	LW	2	14.65	–	0.6	17.58 m^2	[14.5 + (2 × 0.075) = 14.65]
	SW	2	10.05	–	0.6	12.06 m^2	[9.9 + 0.15 = 10.05]
	(10.05 m dimension takes care of projecting front bedroom)						
	Plinth projections						
	LW	2	14.65	0.075	–	≈ 2.20 m^2	
	SW	2	9.9	0.075	–	≈ 1.49 m^2	
	Total of (3)					= 165.38 m^2	
	Deductions :						
	[**Note:** Windows have not been deducted so far. So, these will be deducted once in this item. Jali and ventilator shall be deducted.]						
	Windows	8	2	–	1.3	20.8 m^2	
	Ventilator	1	0.5	–	0.5	0.25 m^2	
	Contact due to steps						
	(a) Plinth height	No need to deduct as plastering is done on all horizontal and vertical faces of steps					
	(b) Projection of plinth	Can be calculated, but it is neglected here as a negligible item.					
	Precast Jali	1	2		1.33	2.66 m^2	
	[3.2 – (1.57 + 0.3) = 1.33 m, as already mentioned in the specifications]						
	Total deductions					23.71 m^2	
	Net of Item (3)					165.38 (–) 23.71 **141.67 m^2**	
4.	*Three coats of white washing (inside)*						

	[The required quantities shall be the sum of the quantity of internal plastering – Item (1) – and the quantity of ceiling plastering – Item 2] 364.95 + 114.43 Total = **479.38 m^2**
5.	*Two coats of colour washing over one coat of white washing on external walls, columns and plinth and its projections* It is equal to quantity of Item (3) = **141.67 m^2**

(c) Every estimating book, and *schedule of materials* give the required factors that help in estimating these ingredients in a given item.

UNIT 7 JOINERY (DOORS AND WINDOWS), GLAZING AND BUILDER'S HARDWARE

Structure

7.1 Introduction

Objectives

7.2 Methods of Measurement : Woodwork and Joinery

7.3 Builder's Hardware : For Doors, Windows and Other Items

7.4 Wooden Flooring and Ceiling

7.5 General Specifications : Joinery and Glazing

7.6 Rate Analysis (Basics) : Doors, Windows and Ceilings

7.7 Case Studies : Doors and Windows – Estimation of Quantities

7.8 Summary

7.9 Answers to SAQs

7.1 INTRODUCTION

Wood (timber) is the most common (almost universal) building material for making doors and window frames, and their shutters. However, in tropical climates, wood is subject to termite attack and needs protection. Yet, timber door/window frames (*chowkhats*) are preferred because of the achievement of exactness in their intended dimensions, and the degree of finish wood lends itself to. Timber is also utilised in constructing trusses, almirahs, and furniture, etc.

For a beginner, in the task of estimating the quantities related to doors and windows (which are basically openings in the masonry work of a superstructure), attention is drawn to the frames and shutters of these items of work. Frames shall be wrought (shaped), framed and fixed (hung) in position as per design drawings. Quality and type of timber shall be as per laid-down specifications – and it shall be sawn in the directions of grains, truly straight and square. The scantling shall be planned accurately to correct dimensions giving a smooth feel. Rebates, roundings and mouldings shall be made on them as specified, to receive the shutters adequately. Patching or plugging of any sort shall not be accepted except as permitted – assembling of parts of frames shall be perfect. However, a tolerance of ± 2/3rd of an mm shall be allowed in the finished cross-sectional dimensions of the frame – for door or window.

Objectives

After studying this unit, you should be able to

- estimate the quantity of frames to be paid for,
- estimate the quantity of shutters used in doors and windows,
- estimate the area of woodwork to be coated with paint,
- gain knowledge about the relevant specifications to be adhered to in this type of timber work, and

- understand the process as to how to analyse the rate of payment for a given item of work, say a batten door, glazed window, etc.

7.2 METHODS OF MEASUREMENT : WOODWORK AND JOINERY

The methods of measurement of woodwork (frames, and shutters), and joinery are based on IS 1200 : Part-XXI, as outlined below :

(a) For every timber item, description and type of wood to be used shall be specified; and each kind of wood shall be measured separately.

(b) All the woodwork and joinery shall be measured in m^3, or m^2 as required. The work shall be designated as "*fixed* " and "*framed and fixed* " as the case may be.

(c) All works shall include nails and glues required. Also, works, such as "*fixed with screws*" or "*fixed with bolts and washers*" shall be so described and measured separately.

(d) For other than ordinary screws, these shall be described accordingly. All screws that are used for fixing builder's hardware shall be measured along with the hardware.

(e) All the works shall be measured net as fixed – and, no extra measurements shall be accounted for shape, joints, etc., except otherwise (specially) stated. Scantlings, battens, etc. in sections other than rectangular shall be measured as the least rectangle from which the section can be obtained. For the varying section scantlings, battens, etc. the largest section shall be measured. Circular or segmental portions (these require more labour in comparison) shall be measured net (i.e. by the dimensions of the actual piece in position – for which rates include wastage of material etc.) separately. Mitred pieces shall be measured along the longest length.

(f) In the case of framed timber, length of tenons and scarfs shall be added to the site length of a framed member. Extra lengths where required to be embedded in walls and/or floors (as is usually the case for doors and windows) shall be added to the site lengths – but, generally this extra material is accounted for in the rate analysis, and clear (visible) lengths only are measured. For each wrought face a tolerance of 1.5 mm is allowed if no special specification is laid down.

(g) All items of plain woodwork exceeding 20.0 cm in width (if required in one width), shall be designated as such, and shall be measured separately.

(h) Planning shall be measured in m^2 for all wrought surfaces unless timber has been described as wrought (for which special rates do apply).

(i) Labour for the following items shall be paid for per m^2 of work done :

    (i) scribing,

    (ii) notching exceeding 15.0 cm each in girth, and

(iii) circular cutting

(j) *Door and window leaves* (*shutters*) *shall be described stating fixing methods, and shall be measured in* m^2. Each type shall be measured separately.

(k) No extra width or labour shall be measured for rebated and/or splayed meeting styles of doors and windows.

(l) Pelmet boxes (over doors and windows, etc.) shall be described and measured in running metres.

(m) Cased frames of vertical sliding windows shall be fully described, and measured in running metre, along the outer edge. Sliding doors shall be described and paid in m^2.

(n) Items concerning wooden stair case shall be measured in detail. Treads or risers shall be measured in m^2 – the area being obtained by multiplying the length of tread by the exposed width of the tread plus the rise from step to step. Winders and risers shall be included with the item itself.

(o) For painting on woodwork, measurements of panelled door and window shutters (including their frames), ceiling, planking, partitions (including frames) and all such work shall be on the **flat plane**, the extra on edges, mouldings, rebates or the like being neglected (solved examples will illustrate the allowance being made for these). The extremes of doorways shall be measured, and the work shall be paid per m^2 (or 100 m^2). For wood railing, measurements shall be in m^2, the visible length and height being measured on the flat, for each side painted. No deductions shall be made for voids.

7.3 BUILDER'S HARDWARE : FOR DOORS, WINDOWS AND OTHER ITEMS

Hardware used in buildings shall be of mild steel, iron, aluminium, or brass, etc. Some of the important (basic items) are listed as under :

Doors (Single Leaf)

3 Nos. butt hinges

1 No. tower bolt

1 No. handle

1 No. aldrop

1 No. wood cleat with a hinge

Doors (Double Leaf)

6 Nos. butt hinges

2 Nos. tower bolts (bigger size)

1 No. tower bolt (smaller size)

2 Nos. handles

1 No. aldrop

2 Nos. wood cleats with a hinge (each)

Windows

4 Nos. butt hinges

2 Nos. tower bolts (bigger size)

1 No. tower bolt (smaller size)

2 Nos. handles

2 Nos. wood cleats with a hinge each

Bath Doors

3 Nos. butt hinges

1 No. tower bolts

1 No. handle

1 No. bathroom latch with knob

Wardrobes

6 Nos. butt hinges

1 No. handle

1 No. tower bolt

1 No. hasp and staple

Further more, mild steel (or wrought iron) bars – round, square or flat – get into the make up of a building. Measurement of these bars in the openings of windows (i.e., as grills), fanlights and the like shall be of the actual length fixed and the work paid for as per weight (kg).

Steel windows are also in much use; sometimes due to comparative cheapness; and/or resistance against termite (white ant) attack. Steel windows shall be fully specified as to their section, design and glazing. The measurements shall be in m^2, the dimensions being taken overall, exclusive of lugs and holdfasts, and the work is paid for at per unit of one m^2 including all fastenings, and glass.

Ornamental wrought iron work in buildings comprises grills, gratings, railings and gates including collapsible ones – all shall be fully specified with reference to the sizes of members and the design. The measurements shall be in m^2, the visible dimensions being taken into consideration – work being paid for at per unit of one m^2. Portions embedded shall be neglected in the measurements.

Railings, gates, balustrades (all in cast iron) and the like shall be fully specified as to their design and sizes of members. Measurements shall be in m^2 of the extreme visible length and height – embedded ends (as usual) shall be neglected in the measurements; and the work, as usual, shall be paid for at per unit of one m^2.

Measurement of painting on wood, any plaster, iron or other materials shall be taken separately

Measurement of hardware items are done based on IS 1200-Part VII : 1972. The various kinds of builder's hardware shall be fully described and measured separately as per the material, finish, size, pattern and method of fixing. However, the following items of hardware shall be measured in running metre :

Curtain Rails

Curtain runners, brackets and stops shall be described, and included with the items as such, stating the number per metre of rail.

Curtain Rods or Poles

Their outer diameter shall be stated.

Sash Lines

Their girth or diameter shall be stated.

Rails for Sliding Sashes

The size of the rail shall be stated.

"Fixing of the hardware items" shall mean fitting, cutting, sinking, boring and morticing. It shall include the supply of screws (or bolts, nuts and washers in the case of hardware that are to be fixed with bolts) appropriate for the work/item. Measurement of hardware items that are fixed on to wood work and metal work shall be measured separately – understandably the rates of payment differing between them.

Steelwork and Ironwork

Methods of measurement of steel work and iron work are based on IS 1200 : Part VIII.

Also the dimensions excepting the cross-sections and thickness of a plate shall be measured to the nearest 0.001 m except for *reinforcement* which shall be measured to the nearest 0.005 m. Areas, excluding cross-sectional measurements shall be worked out to the nearest 0.001 m^2. Weights shall be worked out to the nearest 1.0 kg. Mill tolerance shall be ignored when the weight is determined by calculations. In any item of fabrication, the priming coat shall also be described and included in the item as such.

All steel work shall be measured by weight except when otherwise specified. Different items of steel work shall be classified and measured separately under different categories. Bolted, riveted and welded structures shall be described separately. No deductions shall be made for bolt holes (excluding holes for anchor or holding down bolts). Deductions for rivet or bolt hole shall however be made if its area exceeds 0.02 m^2.

If not specified, an addition of 2.5% of the weight of structure shall be made for shop and site riveted heads in riveted steel structures; and, also no allowance shall be made for the weld metal, in the case of welded steel structures. However, welding under stanchions (i.e., under the base) or steel grillage shall be described and enumerated.

Reinforcement in RCC work shall be measured by weight (kg) and shall include cutting to lengths, hooked ends, cranking or bending (straight or spiral). Designed overlaps, etc. shall be measured. Welding of joints (if any) shall be described. But welded joints shall be measured in numbers; and lap welded ones shall be measured in running metres of the length welded. Wire netting that may be used as an encasement shall be described, and shall be measured in m^2. Binding wire for reinforcement shall not be measured, but shall be included in the description of the item. Hoop iron shall be fully described and measured in running metre.

Bolts, nuts and washers, other than those described earlier, shall be specified and measured by weight (kg). Plain or barbed wire fencing shall be fully described and each line (or wire) shall be measured in running metres. Patent plain wire fencing shall be fully described and measured in m^2.

Collapsible gates shall be described and measured in m^2 as fixed, stating size of the gate opening, pickets, pivoted flat bars and size of meshes formed by them when fully extended. Top and bottom runners, pulleys, locking lugs and handles shall be described and included with the item – the description shall include erection in position and securing runners with hold fasts and brackets.

Steel rolling shutters/grills shall be described and measured in m^2. The width shall be measured as the width of the shutter which includes the portion that is hidden in the guide channels and the height shall be measured as the length of the shutter from the bottom of the locking plate to the top of the laths including the portion above the opening.

All steel doors, windows, ventilators and glazing frames shall be measured in m^2 (as fixed, stating the type).

Stanchions, columns, etc. shall be described and measured in numbers, specifying weight.

Cast iron work shall be measured by weight, classifying under the following headings :

Unmachined

These may include brackets, frames, gully traps, manhole covers, gratings, fire doors, soot doors; and frames, balls and stop cock boxes, etc.

Machine Turned

These may comprise pulleys, and the like.

Metal Sheet Roofing

It shall be described with its thickness stated. Also, side and end overlaps shall be stated. The item shall include all rolls, clips, etc. Measurements shall be made on the flat sheet; and not while bundled in round fashion.

7.3.1 Glazing

Glass whether included with the shutters or not shall be fully specified as to its kind, quality, shape and weight or thickness.

The method of glazing shall also be fully described whether front and back *puttied* and sprigged or fixed with beads and/or mouldings.

Measurement of various kinds of glass shall be separately taken – the work being paid per m^2 of superficial area.

Glazed shutters shall be similar to panelled shutters, except for the following features :

(a) Such parts as specially directed shall be glazed with sheet or ground glass of specified thickness and weight.

(b) Styles and rails shall be adequately rebated (at least 1.30 cm) to receive the glass.

(c) Sash bars shall be moulded and rebated and mitred on sides to receive the glass.

(d) Glass panes shall be fixed by means of putty, or by beading (wooden).

Glazed work shall be measured in the same way (m^2) as per panelled shutters. The rate shall include supply and fixing of glazing and beads.

Timber and Glazed Partitions

The partitions shall be partly panelled and partly glazed. The members of the partitions shall be as specified. These shall be fixed to the floor by means of iron clamps, rigidly fixed to the floor slab and wood work – or, may be detachable as per design. The lower portion upto a height of about 7.0 to 8.0 cm shall be either in panels (about 2 cm thick) 30 cm wide : or as per other design requirement. The upper portion shall be glazed as specified. The work shall be measured in m^2, and paid accordingly.

7.4 WOODEN FLOORING AND CEILING

Wooden flooring is in vogue in those areas where timber is abundantly available – particularly, in cold climates, as in our sub-Himalayan regions where wood borers and termites do not exist as such.

The flooring may rest on beams and joists that are of specified timber quality and section – these are fixed to the position of dead levels. The width of joists shall not be less than 50 mm. The arrangement and spacing of beams, joists, etc., is determined by the thickness of flooring (i.e., its dead load), and the live load coming on it. All the beams, joists, etc. shall be painted or treated with wood preservatives (as detailed in *general specifications*). The painting of beams, etc., shall be paid for separately unless otherwise specified.

Timber boards (i.e., flooring) shall be of the *quality* and *thickness* as per prescribed specifications. Generally only boards of uniform width (100 mm to 150 mm) shall be used. The selected width has to be altered to accommodate the situation where the width of the room is not an exact multiple of the board dimension. Obviously, in this case, the variations in the desired width shall be equally adjusted between the two end boards – adjacent to walls. The length of these boards shall not exceed 3.0 m – it being desired that the boards rest on at least three supports. The boards shall be planed true on the top face only. Wherever the bottom face is exposed and needs to be planed, such planing shall be paid for as an extra labour.

Longitudinal joints of boards (i.e., planks) must be *tongued and grooved* to a minimum depth of 12 mm while the *heading* joints shall be of *square butt type* which must occur over the centre line of the supporting beams. Heading joints of the adjacent boards shall not be placed over the same beam (joist). Iron screws used shall be of the slotted counter-sunk-head type – the length of a screw being not less than the thickness of planks (boards) plus 25 mm; and the minimum length shall be 40 mm. This type of screw is designated as No : 9 (as per IS 451-1961).

Joists (or beams) for the boards to rest on shall be laid correct to level. All the end boards shall be accurately fixed with sides parallel and close to the walls. For fixing the board onto the joists at least two screws shall be used at each end of the boards, and one screw at each of the intermediate joists – but in a zig-zag fashion; the screws shall be counter sunk, with all the screw holes being filled with approved stopping.

Any junction between timber flooring and adjacent flooring shall be inserted with a metal strip (aluminium or brass) to form a separator. This strip has to be fixed at the end of the planks by means of screws – its cost shall be paid extra to the flooring rate as such. Such joints shall be truly parallel and/or perpendicular to the walls. It is necessary that the floor shall be planed in both directions, and shall be even and smooth.

Finishing of the floor surface can be done by waxing or otherwise as per the design provisions. The lower surface of wooden flooring shall be painted, or treated with wood preservative as discussed in general specifications. Finishing is an item that is paid for separately in m^2 units.

Measurement of floor area shall be expressed as m^2 correct to two places of decimal – length and breadth of the superficial area of the finished work shall be measured correct to a cm. No deductions shall be made, nor any extra paid for any opening in the area of the floor up to 0.1 m^2.

In cold climates of our country, particularly in Kashmir region, the traditional flooring consisted of unplaned timber boards laid on wooden joists/beams. Over this boarding a thin layer of *birch* sheets separated the timber surface from lime concrete that was laid over it. Finally, over it tiling (or finishing) was done in concrete/mortar, or only a thin layer of CC was laid that was finished with cement mortar. In the case of ground floors, floor joists (bridging joists) will rest on pillars, dwarf walls, rails or beams as may be necessary. The plinth under the flooring shall be excavated to adequate depth, and dressed level and rammed. A layer of LC will be laid under CC, otherwise dwarf walls or pillars will be built on an LC foundation.

Insulating building boards shall be used as a ceiling material (IS 3348-1965) – tolerances, vis-à-vis, length and breadth shall be ± 3 mm up to a length of 120 cm; for greater lengths, tolerance limit shall be ± 6.0 mm. Timber frame (of specified section and timber quality) shall be used to sustain the boards. The width of the scantlings shall be enough to allow adequate nailing – providing a minimum nailing surface of 50.0 mm. Scantlings (both header and longitudinal) must be arranged so as to allow boards to be fixed in a pattern shown in the drawings – longitudinal scantling (to which the boards are mainly fixed) shall be spaced 30 to 45 cm c/c.

The wooden frame work shall be given two coats of a good preservative paint prior to commencing nailing the boards over it. Mild steel angles (or any other suitable section) shall be provided to suspend the frame work.

Ceiling boards shall be fixed to the framed scantling with galvanised iron (GI) lost head nails 2.24 mm in diameter when the joints are supposed to be left exposed. In case the joints are to be covered with beading, GI felt headed (clout) nails 2.5 mm are used. Length of the nails shall be equal to the thickness of the ceiling board plus 25.0 mm.

Ceiling boards shall be applied with length parallel to all the joints that are positioned over the framing members. The boards are, to begin with, nailed to the intermediate framing member, proceeding from the centre outwards.

The exposed face of the boards must be truly level without any local buldges or sags. All the joints shall be truly parallel and/or perpendicular to the walls. Width of joints shall be maintained uniform. Beading (if desired) shall be fixed with screws. Ceiling shall be treated with distemper (or paint).

7.5 GENERAL SPECIFICATIONS : JOINERY AND GLAZING

All timber shall be well cut and free from warp or any other deformation; it shall be free from signs of rot, worm and beetle, and shall not contain large, loose or dead knots, shakes or other defects to such an extent or so situated in the piece as to render it insufficient in strength or stiffness for the work to be done. No piece of exceptionally light weight shall be used.

Timber is graded as : Deodar, Kail, Dandeli Teak (or Burma Teak), Douglas fir (or long-leaved pitch pins), Shesham, Saal, etc.

Every piece shall have not less than four annual rings to a length of 2 to 3 cm (say, to an inch), and shall be free from spiral or diagonal grain with more than *one in ten* inclination to the direction of the length, except where it can be shown that the strength of the piece is not impaired by default of these requirements.

Knots shall be sound and free from rot. A sound knot (the smallest diameter on the face in which the area of the knot is greater) shall not measure more than one-fourth the greater transverse dimension of the piece, unless it is so situated that it will not impair the strength of the piece. A loose knot or knot hole shall be considered as a sound not of twice its width. A knot cluster or a knot hole cluster shall be measured as a single unit. Pitch pockets shall not exceed 20 cm in length, nor shall these exceed 3.0 mm in width. Sapwood shall be only slightly discoloured.

The single length of a *shake*, or the sum of the lengths of all the shakes in the end of a piece, shall not exceed the breadth of the piece.

If timbers are specified to be wrought (on one or both the opposite surfaces), the finished size shall not be more than 12.5 mm less than the nominal dimension unless designated as the *actual dimension*. It is emphasised that timber shall be taken as wrought (finished) if done by machine dressing.

The moisture content of timber (to be used for construction) shall not exceed 22% of its weight, in case it is to be used in sheltered (or enclosed) positions; and, the moisture content shall not be more than 25% in case to be used in damp environment. Thus, timber should be properly seasoned – air-seasoned or kiln-seasoned – and it shall be free of seasoning defects when used.

Ideally timber shall be from the heart of a sound tree, the sapwood being entirely removed. It shall be uniform in substance, straight in fibre. All scantlings, planks, etc. shall be sawn straight, and of uniform thickness and of full measurement from end to end, and, as mentioned above, shall be sawn in the direction of the grain. All planks and scantlings shall be sawn 1.5 to 1.6 mm (say, $\frac{1}{16}$th of an inch) in excess of the actual measurement (i.e., the finished product) to allow of planing.

As soon as the foundations of a building are laid, all necessary timber shall be brought to site, sawn to sections, and then carefully stacked under cover, and allowed to season till required – this would be a welcome measure. It has to be understood that the rate for timber work is for the scantlings or planks sawn to size. Thus, no allowance is to be made for wastage.

It is understood that all the wood work shall be neatly and truly planed to the required dimensions. Unless, specially specified, all the joints shall be simple tenon and mortise joints with the end of the tenon exposed to view. All mortise and tenon joints (or scarfs) shall fit truly and fully, without filling. Where specified, in the case of special high class joinery, the end of the tenon shall not show. Joints shall be painted with white or red lead before the frames are put together.

Holes of correct size shall be drilled before inserting screws; *driving in or starting in screws with a hammer shall not be done*. All screws shall be dipped in oil before being inserted in the wood. The heads of nails or screws shall be sunk and puttied or dealt with as designed.

All wood work shall be approved by the concerned authority before being finally fixed in position. Rejected timber shall at once be removed from the site of the work.

All portions of timber, built into or against or close to masonry or concrete, and all junctions of rafters, purlins, beams and wall plates shall be given two coats of hot *solignum*, *creosote* or other wood preservative that is approved.

All beams and girders shall be bedded, on plates, with not less than 23 cm bearing. All joists shall bear, not less than 11 to 12 cm on wall plates; and every purlin or batten supported on a wall, will have a bearing in the direction of its length equal to its own depth, subject to a minimum of 10 cm.

As a precaution against fire, no wood work shall be fixed within 30 cm of the interior face of a chimney flue.

Wood posts, in exposed position, must rest on a raised stone or cement concrete base, and be fixed by a holding down bolt. Tenons projecting into the stone or concrete base are not allowed. The holding down bolt shall be at least 1.5 to 1.7 cm in diameter and fixed to a washer embedded in the plinth at least 27 cm below the stone base. The bolt must pass through the base and project 23 cm through the bottom of the post, being secured to it by a nut let in through a side cavity, which must be subsequently plugged.

Wood work over 7.5 cm in width and 5.0 cm or less in thickness will be paid for as planking. The rate shall include the cost of planing on both sides and of *shooting or rebating* edges, and fixing in position with nails and screws. For floors and ceilings, and for shelves the rates may be different. The measurement of wood work in planking will be the net measurement after fixing, no allowance being made for waste, overlaps, rebates, or the like.

Doors and Windows

All *chowkhats* (frames), doors, and windows together with their fittings and furniture shall be as per specifications detailed in the drawing.

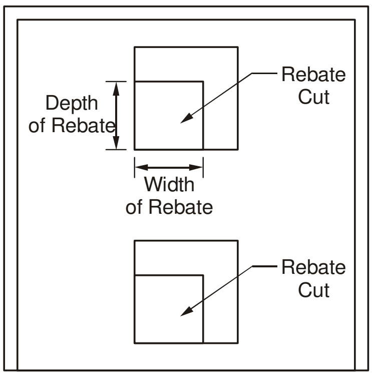
All the joints shall be of mortice and tenon type, neat, strong, and yet simple. Mortice and tenon joints shall fit in perfectly without filling or wedging. The joints shall be glued, framed, assembled and pinned with hardwood or bamboo pins – not less than 10 mm in diameter.

No wood work must be painted, oiled or given any other treatment before it is approved. All portions of timber abutting against concrete or masonry (as said above) or embedded in ground shall be painted with the approved wood primer *or boiling coal tar*. If doors and windows are to be subsequently painted, the *chowkhats* shall have the priming coat painted on before fixing.

Door *chowkhats* shall be with or without wooden sills as designed (in colder climates there is a tradition of 4-piece frame to shut out cold air). When no wooden sills have been specified, concrete floors in the door opening shall be so laid as to provide a concrete sill (if necessary) raised about 2.0 cm above the floor and sloping down to the door on either side. Wooden sills (which are also generally necessary for double hung doors and all outside doors provided with wire gauze shutters) shall be fixed so as to project about 3 cm above the floor level. Where no sill has been provided, the feet of the *chowkhat* shall rest on the damp-proof course or floor as the case may be (or there shall be left a clearance above the floor). An additional hold fast shall, in that case, be fixed near each foot. In the case of door frames without sills, the vertical members shall be embedded in the flooring to its full depth. When sills are provided, these shall be embedded (sunk) in the floor to its full depth. The door frames without sills, while being placed in position, shall be suitably strutted and wedged in order to prevent warping during construction. Similarly, window frames shall also be protected from damage, during construction.

Chowkhats shall be properly framed and mortised together. Doors and window frames (chowkhats) shall have 11 to 12 cm wide *horns* left on the heads (also on sills, where these are provided): or the corners of the chowkhats shall be bound with 5 to 6 cm × 1.5 mm iron strap bent into a right angle having legs of a length equal to the depth of the chowkhats, and fixed with four 5 cm screws. **The cost of horns or straps is included in the rate** – therefore, while taking measurements for frame pieces, only visible dimensions (while placed in final location) are recorded (as will be clear from the Solutions to Examples given in this Unit).

***Chowkhats* shall have a rebate cut to receive the leaves (shutters) – generally, the rebate shall be 12 to 13 mm deep, and of width equal to the thickness of the leaf.** Rebate in shutters for closing, in double leaved door shutters (or windows), shall not be less than 2.0 cm. The other side shall be finished with a bead and quirk, or some other simple moulding, unless wire gauze is to be fitted. Where the plaster butts against the *chowkhat* a 12 to 13 mm deep rebate (with a slight cut back) shall be given to serve as a key to the plaster.



Section of Top and Bottom Members of a Chowkhat

No *chowkhat* shall be painted or fixed before it is approved by the concerned authority. All *chowkhats* shall be ready before the work reaches sill level, so that these can be built in as the masonry proceeds.

When sill level is reached and damp proof course laid, *chowkhats* shall be erected, being placed truly level and plumb. These shall be securely strutted or lashed in position till built in – the frames shall be placed in proper position, and secured to walls or columns with metallic fastener, iron hold-fasts. These holdfasts shall be built into the masonry with 1 : 5 cement mortar. Hold-fasts shall be made from 4 cm × 6 mm steel bar bent over at both ends leaving 35 cm clear length between bends. One bend shall have a screwed hole to which the *chowkhat* is secured by a bolt, and the hole plugged with wood. Where the *chowkhat* is fixed at the extreme edges of the jambs, the holdfasts shall be forked or bent. Number of holdfasts to each *chowkhat* shall be specified – where no sill have been provided, an additional holdfast shall be given on each side.

Unless otherwise specified, doors and windows opening to another room, or to a corridor, or varandah, shall have the *chowkhats* so fixed that they project about 1.0 cm from the plastered face of the wall.

The plaster will stop against the *chowkhat* which will have the rebate (mentioned above) as a key for the plaster.

Other doors and windows will be set back about 11.50 cm from the face of the wall.

In the case of doors and windows in *dhujji* walls (combination of bricks and scantlings) the *depth* of the *chowkhat* (dimension perpendicular to the shutter when closed) shall be equal to the thickness of the wall, and the faces flush with the plaster. Where *architraves* (in classical architecture, a main beam resting across the tops of columns/or the frame around a doorway or window/or a moulding round the exterior of an arch) have been provided, *chowkhats* shall be fixed as per detailed drawing.

All the door and window leaves shall be cut out and framed together, as soon as possible after the commencement of the work, and stacked in the shade to season further on. They are, ideally, not to be wedged and glued for four months where possible – or are to be wedged and glued, just prior to be hung. All the contact surfaces of tenon and mortise joints shall be treated, before putting together, with bulk type synthetic resin adhesive. Immediately after glueing, the frames shall be tightly clamped and so left till the glue has set.

All styles and rails shall be properly and accurately mortised and tenoned. The thickness of the tenon shall not exceed one-fourth the thickness of the plank, and the width shall not exceed five times the thickness.

Leaves are to be hung on hinges of the specified size – and of best quality wrought iron, or brass. All hinges shall be counter sunk into the *chowkhat* as well as in the leaf.

Hinged *chocks* shall invariably be fitted to all doors and windows to keep these open when desired. Wooden *stops* of suitable size shall be fixed to the door/ window *chowkhats* to prevent the leaf from damaging the plaster of the jamb when fully opened.

Doors and windows shall be paid for by measuring the clear opening in the brickwork/or masonry – or the *chowkhats* and shutters (leaves) shall be paid separately (as explained in the solved Examples of this Unit). Circular or other similar joinery will either be paid for on the net area (at special rates), or on the basis of measurements taken as the least square/rectangle containing the item under consideration.

Panelled, Glazed or Panelled and Glazed Doors and Windows

The frames shall be wrought, framed and fixed in position as per detailed drawings. Panels shall be in one piece up to 30 cm clear in the case of *deodar wood*, and 45 cm clear in the case of teak. In larger sizes these may be jointed – the joint shall be glued and dowelled together to prevent all possibility of its opening out later on. Panels shall be planed absolutely smooth so that no marks are visible. Generally the panels shall be *splayed* and *fielded* on both sides and the *arrises* of the frame receiving the panels shall be finished with a simple mould.

Sash bars, shall be of the full thickness of the leaf, and from 2.5 cm to 3.0 cm in width according to the size of the doors.

The panels shall be framed into grooves to the full depth of the groove leaving an air space of 1.5 mm, and the faces shall be closely fitted to the sides of the groove.

Following types of panelling can be used for door/window shutters :

(a) hard board (b) block board (c) asbestos cement sheet

(d) sheet glass (e) particle-board (f) plywood

Corners and edges of the panels shall be finished as per drawings – these shall be feather tongued into styles and rails. Timber, plywood, hard board and particle board panels shall be fixed only with grooves, but additional beading may be provided either on one side or on both the sides. In case of glass and asbestos panels, beading shall always be provided without grooves; and where beading is provided without grooves, beading shall be only on one side – the other side being supported by rebate from the styles. For external doors and windows beading shall be fixed on the outside.

For glazing work, all glass shall be flattened sheet glass of fine quality with specified thickness (and weight per m^2). Glass shall be free from specks, bubbles, distortions and flaws of every kind, and shall be properly cut to fit the rebates, so as to leave a uniform space of 1.58 mm all round the panes between the edge of the glass and the rebate. Plate glass shall be 6.35 mm thick and of the usual light colour.

Putty shall be prepared from pure raw linseed oil and best whiting (of specified grain size) – the two shall be well mixed by hand and kneaded into a stiff paste. It shall then be left for 12 hours, and worked up in small pieces till quite smooth. If the putty becomes dry, it should be restored by heating and working it up again white hot. Where the rebate is small a little white lead should be added in making the putty. Putty required for glazing large panes or for bedding plate glass shall be made with a mixture of linseed oil and tallow with whiting to make it pliable and capable of standing expansion of the panes. Where required, putty shall be coloured to match the wood work. Doors and windows of bed rooms and bath rooms shall be glazed with blind glass (at least up to full eye level). If rebates have not been painted, these shall be well primed with boiled linseed oil to prevent the wood drawing the oil out of the putty. Putty shall be painted at the same time and the same number of coats, as wood work (or iron work).

Each pane of glass shall be bedded on a thin layer of putty called "*back putty*" and secured into position with proper glazing springs. "*Front putty*" shall then be applied chamfered and finished off neatly in such a manner that the depth of the putty is exactly equal to the rebate.

In the case of teak doors and windows, and in the case of all panes exceeding 30 cm in width, front putty shall not be used but the glass secured with fillets of wood. The glass shall be protected from contact with the wood by a piece of wash leather or by putty made with tallow to act as a cushion.

Blind (or frosted) glass shall be fixed where required – frosted face away from the putty.

No glazing shall be considered complete until all paint and other stains have been removed from the surface of the glass. Glass must be cleaned and polished with pads of damp news papers, and then with clean, dry soft cloth.

In measuring glazier's work all fractional parts under 12.70 mm will be omitted, and all above that, taken as 2.5 cm. Curved or irregular shaped pieces will be measured as the least rectangle from which these can be cut. Measurements shall be made net, from inside to inside of rebate.

The length and width of all the shutters (simple, glazed, or part glazed) shall be measured to the nearest cm in closed position covering the rebates of the frame but excluding the gap between the shutter and the frame. Overlap of two shutters shall not be measured. All works shall be measured net as fixed. No extra payment shall be made for shape, joints, etc., except for circular or segmental portions which shall be measured separately.

Framed and Braced, Ledged and Braced, Ledged, Ledged and Battened, Braced and Battened Doors and Window Shutters

Only specified timber shall be used that has been sawn in the direction of the grains. The thickness of the door shall be the thickness of the battens only and not the combination of battens and braces.

Planks for the battens shall be 20 mm thick (unless otherwise specified), and of 75 to 100 mm uniform width. Battens shall be planed and made smooth, and provided with minimum 12 mm rebated joints. Battens, when finished, shall have a tolerance of ± 1 mm in thickness, and ± 2 mm in width – and so will have ledges, etc. Battens and ledges shall be feather tongued into styles and rails, which shall have 12 mm groove for battens to fit in.

Framed and braced doors will consist of two styles, three rails and two braces forming the frame of each leaf to which the battens (planks) shall be fixed. Windows shall be as above, but will have two rails and one brace. In the case of certain outside doors, where it is necessary to admit light, a frieze rail shall be added, and the space between the frieze and top rail, shall be glazed. Framing shall be made with mortise and tenon joints (as discussed earlier). The top rail (or frieze rail when the door has been glazed) and the bottom rail as well as the styles shall be rebated to receive the battens. The battens will butt into rebates in the top rail (or frieze) and the bottom rail, and will pass over the braces and the lock rail. The joints shall be ploughed and tongued and finished with a V joints, or a bead and quirk, on the outside. Battens shall be secured with two screws at each end, and with one screw over each brace and the lock rail.

Ledged and braced door will be formed with battens secured to three ledges, with two braces between the ledges. Windows will have only two ledges and one brace. Battens shall be fixed together by 25 mm thick ledges and braces fixed to the inside face of door shutters by screws. The ledge shall be 175 mm wide and brace 125 mm wide unless otherwise specified. The braces shall incline downwards towards the side on which the door is hung. All the edges and braces shall be chamfered.

Wooden cleats, blocks, fittings and measurements shall be the same as for '*panelled, glazed or panelled and glazed shutters*' as mentioned above.

The battens shall have rebated joints, finished with a V on one side, and shall be of uniform width, not more than 12 to 13 cm.

In the case of a double door, a 76 mm × 25 mm cover bar shall be screwed on to the edge of one leaf so as to make it a master leaf.

The *chowkhats* shall be rebated to a depth equal to the full thickness of the door, i.e., the battens plus ledges. The doors shall be hung with the battens inside and the ledges outside. Hinges shall be fixed to the ledges.

Ledged doors and windows are also known as "country" doors and windows, and are formed by fixing battens on to three ledges. The battens shall be of uniform width (not more than 22-23 cm), and shall have rebated joints. Country doors shall have thickness of battens of the size of ledges specified. These shall be hung on pivots with battens outside and ledges inside. In other respects specifications for ledged, braced, battened doors shall be followed.

Painting with Wood Preservative

Oil type wood preservative of specified quality (IS : 218-1961) shall be used – usually it shall be creosote oil type-I or anthracene oil. Surface preparation shall be done only when the surface is perfectly dry to allow a good absorption. All dirt, dust or other foreign matter shall be removed from the surface to be painted. All roughness shall be sand papered and cleaned.

The preservative shall be applied liberally with a stout brush, using pencil brush at the joints of the wood work. It is only after the first coat has soaked in (say, for 24 hours) that the second coat (final coat) is applied.

Wire Gauzed Doors

Wire gauzed doors will normally be hung on the same *chowkhat* as other doors – the rate shall include the provision of extra depth in the *chowkhat* to take the rebate for the wire gauze leaf. Wire gauze shall be of the best quality uniformly woven wire webbing (as specified) – made from 22 gauge galvanised iron wire. All wire gauze panels shall be in one piece, no joints being allowed in the gauze. Wire gauze shall be fixed to the frame of the leaf after being stretched from out to out of rebate and nailed down taut, and then fixed by a fillet screwed into a rebate of that size. All exposed arrises of the fillet shall be finished with a small neat mould.

All wire gauze doors shall be hung on self-closing, spring hinges, which shall be of best quality iron, and black japanned.

All double leaf wire gauze doors shall close with the meeting styles butting against each other, a felt strip being fixed to one leaf to close the joint. The leaves must close to such an extent that the junction projects from the face of the *chowkhat*, the projection being 1 cm for each 12 cm width of leaf. The top of the *chowkhat* (and sill when this has been provided) shall be enlarged to a corresponding wedge shape, the cost of this arrangement being included in the rate. Generally, the width and position of lock and bottom rails on wire gauze doors shall be the same as those of the other leaves hung on the same *chowkhat*.

Where moveable wire gauze flaps (or leaves) are provided to windows, all specifications for wire gauze doors shall be followed with the following departures :

(a) wire gauze windows shall not be provided with springs or spring hinges,

(b) double hung wire gauze windows shall close flush with the *chowkhat* without the meeting styles projecting in any way, and

(c) wire gauzed windows shall open outwards and be provided with hinged chocks, to keep them in the open position; and with stops, to prevent damage to plaster.

In fixed wire gauze construction, all panels shall be in one piece, no joints being allowed in the gauze. Wire gauze shall be fixed to the outside of the *chowkhat* – this shall be drawn taut to the full width of the *chowkhat* and nailed down, and a cover strip (of the same width as the *chowkhat*), so as to seem part of the *chowkhat*, fixed all round with screws. Or, the wire gauze shall be fixed to the *chowkhat* by a fillet screwed into a rebate of the same size.

7.6 RATE ANALYSIS (BASICS) : DOORS, WINDOWS AND CEILINGS

Materials, and labour constitute the main components that make up the cost of a civil engineering item (as also of any other work). The composition of these components differ as per the specifications, and design of an item – like in wooden doors, windows, and wooden ceilings. Some of the works under these groupings are discussed in outline as under :

(a) **Wood work in CP teak wood one-door chowkhat, wrought, framed and fixed, including simple mouldings – door opening ⇒ 1.0 × 2.0 m; section of 3-piece chowkhat (i.e. chowkhat without sill) ⇒ 10 × 7 cm.**

Materials	**No.**	**L (m)**	**B (m)**	**Thickness (m)**	**Quantity/No.**
Timber for posts	2	2.0	0.1	0.07	0.028 m^3
Timber for head	1	1.0	0.1	0.07	0.007 m^3
				Total	0.035 m^3
				Add 5% wastage (= 0.00175 m^3)	0.002 m^3 (say)
				Grand Total	**0.037 m^3**

Labour	**No.**
Mistri	0.06
Carpenter	0.05

Helper (i.e. beldar) 0.25

Add T and P Sundries, etc. on LS basis

(b) **Wood work in a shutter ($b \times l$ m) of ledged and braced door (Figure 7.1) without a chowkhat, using country wood, including fixing on the chowkhat all fittings.**

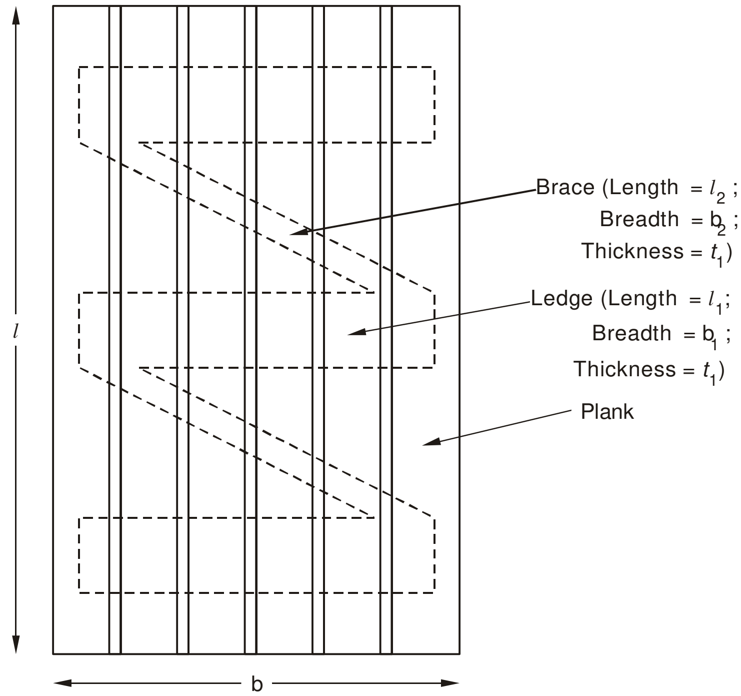


Figure 7.1 : Ledged and Braced Door

Materials

(i) ***Timber***	No.	L (m)	B (m)	H/D (m)	Quantity/No.
Timber for planks	1	ℓ	b	t (say)	$(1 \times \ell \times b \times t)$ m^3
Timber for ledges	3	ℓ_1	b_1	t_1	$(3 \times \ell_1 \times b_1 \times t_1)$ m^3
Timber for braces	2	ℓ_2	b_2	t_2	$(2 \times \ell_2 \times b_2 \times t_1)$ m^3
				Total	$= T$ m^3 (say)
Add 5% wastage, and 5% more for overlapping at joints $\left(= \frac{10}{100} \times T\right)$					$= \frac{1}{10}(T)$ m^3
				Grand Total =	$(1.1T)\,m^3$

(ii) ***Fittings***

Tower bolts (20 cm)	2 Nos.
Strap hinges	3 Nos.
Steel handles	2 Nos.
Wooden cleats	2 Nos.
Hinges 2.5 cm for cleats	2 Nos.
Screws 40 mm	30 Nos.
Screws 20 mm	50 Nos.
Nails, putty, etc. Add on LS basis	

Labour	
Mistri	0.1 No.
Carpenter	1.5 No.
Helper	1.5 No.
Glue, *T* and *P*, Sundries, etc. Add on LS basis	
Note: Similar analysis can be applied to other types of doors based on the detailed drawings of the item.	

(c) **Fixing 10.0 m^2 of 2.5 cm deodar-wood plank ceiling including 2.5 cm × 4.0 cm beading over plank joints – without ceiling frame work.**

Materials

Planks (including rebate overlap and wastage	0.34 m^3
Beading	0.06 m^3
Total timber	= 0.4 m^3
Nails 3 kg	
Screws 35 mm 300 Nos.	
Labour	
Mistri 2 Nos.	
Carpenter 2 Nos.	
Beldar (helper) 4 Nos.	
Add for scaffolding; and *T* and *P* and Sundries, etc. on LS basis	

7.7 CASE STUDIES : DOORS AND WINDOWS – ESTIMATION OF QUANTITIES

Analysis of data, as given in the relevant drawings is the best way to master the art/skill of estimating quantities in any item of work. Practice develops imagination, perfects concepts, and helps develop expertise and speeds up the task of estimation. A few solved examples as presented below should inculcate the ability to analyse doors/windows with a view to estimating the material quantities that go into the make-up of the particular item.

Example 7.1

A building has following doors, windows, and a ventilator fixed in the superstructure :

(a) Windows (W) – 10 Nos.; size : 2.0 (horizontal) × 1.3 m

(b) Four sizes of door :

- (i) D_1 – 3 Nos.; size : 1.5 × 2.0 m
- (ii) D_2 – 1 No.; size : 1.3 × 2.0 m
- (iii) D_3 – 4 Nos.; size : 1.0 × 2.0 m
- (iv) D_4 – 2 Nos.; size : 0.75 × 2.0 m

All are having 3-piece chowkhats (frames), except the ventilator and windows which have a 4-piece frame.

(c) Ventilator – 1 No.; size : 0.5 × 0.5 m

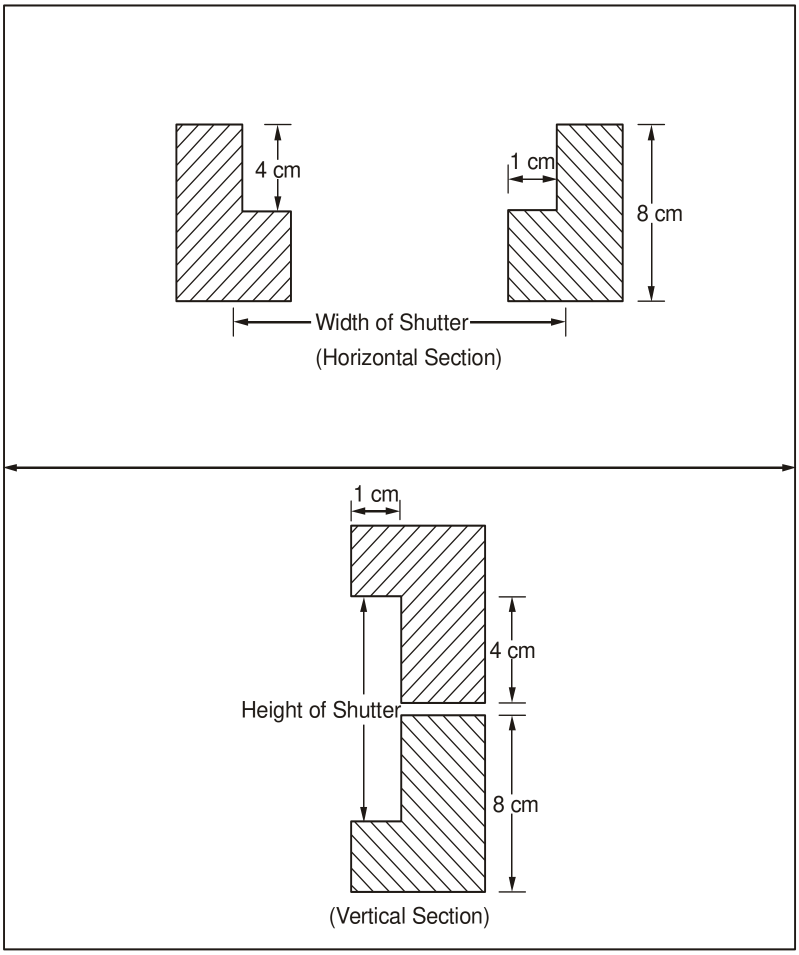
(d) Chowkhat-piece sizes :

(i) For D_1, D_2 and D_3 – 10 × 8 cm

(*It is to be understood that the greater dimension, viz., 10 cm, refers to the dimension perpendicular to the door shutter when in shut position*.)

(ii) For D_4 *W*, and *V* – 10 × 7 cm

(e) Rebate for chowkhats (all) : as shown in the sketch.



Compute *salwood* work in doors, windows and ventilator *chowkhats*; and wood work in 3 cm-thick panelled shutters of *shisham*.

Also estimate the quantity of 16 mm round bars as used in the grills of windows and the ventilator; and 3 cm-thick glazed ventilator shutters of *shisham wood*.

Two coats of painting (as per specifications) over one coat of priming on doors, windows, and ventilator are provided in addition to *solignum* two coats in the back of chowkhats – estimate all these quantities.

Present the results in a bill of quantities format.

Solution

Length of chowkhats to be paid for :

$D_1 = 2 \times 2 + 1.5 = 5.5$ m

$D_2 = 2 \times 2 + 1.3 = 5.3$ m

$D_3 = 2 \times 2 + 1.0 = 5.0$ m

$D_4 = 2 \times 2 + 0.75 = 4.75$ m

$W = 2 \times 2 + 2 \times 1.3 = 6.6$ m

$V = 2 \times 0.5 + 2 \times 0.5 = 2.0$ m

Shutter dimensions for the determination of areas for which payment is to be made :

D_1 (horizontal) = 1.5 – 2 × 0.08 (i.e., twice the *chowkhat* thickness)

+ 2 × 0.01 (i.e. twice the horizontal rebate)
= 1.5 – 0.16 + 0.02 = 1.36 m

D_1 (vertical) = 2.0 – 2 × 0.08 + 2* × 0.04

= 2 – 0.16 + 0.08 = 1.92 m

[* Taking twice the vertical rebate allows due clearance of the door shutter with respect to the flooring.]

Similarly, we have for other *D*s/*W*s :

Item	Horizontal Dimension (m)	Vertical Dimension (m)
D_2	1.3 – 0.16 + 0.02 = 1.16	1.92 (as shown above)
D_3	1.0 – 0.16 + 0.02 = 0.86	1.92
D_4	0.75 – 0.16 + 0.02 = 0.61	1.92
W	2.0 – 0.16 + 0.02 = 1.86	1.3 – 0.16 + 0.08 = 1.22
V	0.5 – 0.16 + 0.02 = 0.36	0.5 – 0.16 + 0.08 = 0.42

Bill of Quantities

Sl. No.	Description of Item	No.	Dimensions			Quantity	Remarks
			L (m)	B (m)	H/D (m)		
1.	*Salwood work in doors, windows and ventilator chowkhats*						
	D_1	3	5.5	0.1	0.08	0.132 m³	
	D_2	1	5.3	0.1	0.08	0.042 m³	
	D_3	4	5.0	0.1	0.08	0.16 m³	
	D_4	2	4.75	0.1	0.07	0.067 m³	
	W	10	6.6	0.1	0.07	0.462 m³	
	V	1	2.0	0.1	0.07	0.014 m³	
					Total	= 0.877 m³	
2.	*Shisham wood 3 cm-thick panelled shutters for doors, windows, and ventilator*						
	D_1	3	1.36	–	1.92	7.834 m²	
	D_2	1	1.16	–	1.92	2.227 m²	
	D_3	4	0.86	–	1.92	6.605 m²	
	D_4	2	0.61	–	1.92	2.342 m²	

	W	10	1.86	–	1.22	22.692 m^2	
					Total	41.70 m^2	
	(**Note :** *Ventilator size is 0.36 × 0.42 m – but its cost shall be paid under glazed item – see ahead*)						
3.	*3 cm-thick glazed shutter for ventilator* (*within shisham wood panel frame*)						
		1	0.36	–	0.42	0.15 m^2	
4.	*Mild steelwork in doors/windows/ventilator :*						
	(i) Hold fasts						6 Nos. hold fasts for each door; 4 Nos. for each window, and 2 Nos. for one ventilator
	Doors	10×6	–	–	–	60 Nos.	
	Window	10×4	–	–	–	40 Nos.	
	Ventilator	1×2	–	–	–	2 Nos.	
						Total 102 Nos.	
						@ 1.0 kg per piece	
						= 102 kg	
	(ii) (*a*) *16 mm round bars in window grating @ 1.58 kg/m*						19 Nos. bars in all – i.e., at 10 cm spacing
		10×19	1.3	–	–	247 m	
	(*b*) *16 mm round bars in ventilator grating @ 1.58 kg/m*						4 Nos. bars in all – i.e., at 10 cm spacing
		1×4	0.5	–	–	2.0 m	
					Total [(ii) (a) and (b)]	249×1.58 =393.42 kg	
					Grand Total	495.42 kg	
5.	*Solignum painting – 2 coats in the back of chowkhats*						
	D_1	3	5.5	0.1	–	1.65 m^2	
	D_2	1	5.3	0.1	–	0.53 m^2	
	D_3	4	5.0	0.1	–	2.0 m^2	
	D_4	2	4.75	0.1	–	0.95 m^2	
	W	10	6.6	0.1	–	6.60 m^2	
	V	1	2.0	0.1	–	0.20 m^2	
					Total	11.93 m^2	

6.	(*a*) *Painting* (*woodwork*) *doors, windows, ventilator – two coats over one coat of priming*						(i) 1.3 is a factor for each side – i.e., 2.6 for both sides – that takes care of chowkhat area, etc. (ii) For V (*glazed*) the factor is 1.0 for one side – i.e., 2 for two sides
	D_1	3×2.6	1.5	–	2	23.4 m^2	
	D_2	1×2.6	1.3	–	2	6.76 m^2	
	D_3	4×2.6	1	–	2	20.8 m^2	
	D_4	2×2.6	0.75	–	2	7.80 m^2	
	W	10×2.6	2	–	1.3	67.60 m^2	
	V	1×2	0.5	–	0.5	0.50 m^2	
	Sub-Total of (a)					126.86 m^2	
	(*b*) *Painting of mild steel bars*						We pay for one flat area, excluding chowkhats
	W	10	1.86	–	1.22	22.692 m^2	
	V	1	0.36	–	0.42	0.151 m^2	
	Sub-Total of (b)					22.84 m^2	
	Grand Total =					149.70 m^2	

Example 7.2

(a) A given structure has following doors, windows and ventilators :

Doors	*Size*	*No.*	*Remarks*
D_1	1.5 × 2.1 (vertical) m	2	with 3-piece frame
D_2	1.2 × 2.1 m	4	
D_3	0.9 × 2.1 m	5	
D_4	0.75 × 2.0 m	5	

(b)

Windows	*Size*	*No.*	*Remarks*
W	1.0 × 1.3 m	17	with 4-piece frame

(c)

Ventilators	*Size*	*No.*	*Remarks*
V	0.5 × 0.5 m	4	with 4-piece frame

Chowkhat size in each case is 10 × 8 cm; and rebate 4 cm in vertical direction, while in horizontal direction it is 1 cm – all around. However, for ventilators take vertical rebate also as 1 cm.

Take out the following quantities :

(a) Salwood work in frame of doors, windows and ventilators.

(b) 30-mm thick *deodar* wood in panelled shutters with block iron (ordinary) fittings in doors and windows.

(c) 30-mm thick deodar wood shutters (with wire mesh) for ventilators.

(d) Solignum painting, two coats in the back of chowkhats.

(e) Painting doors, windows, and ventilators – 2 coats over one coat of priming.

(f) 16 mm round bars in grills of windows and ventilators.

Solution

Length of chowkhats (frames) to be paid for :

Sl. No.	Item	Total Length = Verticals + Horizontals
1.	D_1 (3-piece)	1.5 + 2 (2.1) = 5.7 m
2.	D_2 (3-piece)	1.2 + 2 (2.1) = 5.4 m
3.	D_3 (3-piece)	0.9 + 2 (2.1) = 5.1 m
4.	D_4 (3-piece)	0.75 + 2 (2.0) = 4.75 m
5.	*W* (4-piece)	2 × 1.0 + 2 (1.3) = 4.60 m
6.	*V* (4-piece)	2 (0.5) + 2 (0.5) = 2.0 m

Dimensions for shutters are worked out as under :

Sl. No.	Item	Rebate (Single)		Horizontal Dimension (m)	Vertical Dimension (m)
		Vertical (cm)	Horizontal (cm)		
1.	D_1	4.0	1.0	1.5 – 2 (0.08) + 2 (0.01) = 1.36	2.1 – 2 (0.08) + 2 (0.04) = 2.02
2.	D_2	4.0	1.0	1.2 – 2 (0.08) + 2 (0.01) = 1.06	2.1 – 2 (0.08) + 2 (0.04) = 2.02
3.	D_3	4.0	1.0	0.9 – 2 (0.08) + 2 (0.01) = 0.76	2.1 – 2 (0.08) + 2 (0.04) = 2.02
4.	D_4	4.0	1.0	0.75 – 2 (0.08) + 2 (0.01) = 1.61	2.0 – 2 (0.08) + 2 (0.04) = 1.92
5.	*W*	4.0	1.0	1.0 – 2 (0.08) + 2 (0.01) = 0.86	1.3 – 2 (0.08) + 2 (0.04) = 1.22
6.	*V*	4.0	1.0	0.5 – 2 (0.08) + 2 (0.01) = 0.36	0.5 – 2 (0.08) + 2 (0.01) = 0.36

Note : (i) Rebate taken twice in vertical direction allows due clearance of the door shutter with respect to the flooring.

(ii) In case *rebates differ for small-sized items* (*in comparison to bigger-sized items*) *the basics of calculations would not change, though the final values of dimensions will vary, as can easily be understood.*

The bill of quantities can now be tabulated as shown below :

Bill of Quantities

Sl. No.	Description of Item	No.	Measurements L (m)	B (m)	H (m)	Quantity	Remarks
1.	*Salwood work in doors, windows and ventilator chowkhats*						
	D_1	2	5.7	0.1	0.08	0.091 m^3	
	D_2	4	5.4	0.1	0.08	0.173 m^3	
	D_3	5	5.1	0.1	0.08	0.204 m^3	
	D_4	5	4.75	0.1	0.08	0.190 m^3	
	W	17	4.6	0.1	0.08	0.626 m^3	
	V	4	2.0	0.1	0.08	0.064 m^3	
					Total	= 1.348 m^3	
2.	*30-mm thick deodar wood, panelled shutters with block iron (ordinary fittings)*						
	D_1	2	1.36	–	2.02	5.49 m^2	
	D_2	4	1.06	–	2.02	8.56 m^2	
	D_3	5	0.76	–	2.02	7.68 m^2	
	D_4	5	0.61	–	1.92	5.86 m^2	
	W	17	0.86	–	1.22	17.84 m^2	
					Total	45.43 m^2	
3.	*30-mm thick wire meshed deodar wood shutter for ventilators*						
	V	4	0.36	–	0.36	0.52 m^2	
					Total	0.52 m^2	
4.	*Solignum painting, two coats in the back of chowkhats*						
	D_1	2	5.7	0.1	–	1.14 m^2	
	D_2	4	5.4	0.1	–	2.16 m^2	
	D_3	5	5.1	0.1	–	2.55 m^2	
	D_4	5	4.75	0.1	–	2.38 m^2	
	W	17	4.6	0.1	–	7.82 m^2	
	V	4	2.0	0.1	–	0.8 m^2	
					Total	16.85 m^2	
5.	*Painting of doors, windows and ventilators, two coats over one coat of priming coat*						
	D_1	2 × 2.6	1.5	–	2.1	16.38 m^2	1.3 times for each side, i.e. 2 × 1.3 = 2.6 for both sides.
	D_2	4 × 2.6	1.2	–	2.1	26.21 m^2	
	D_3	5 × 2.6	0.9	–	2.1	24.57 m^2	
	D_4	5 × 2.6	0.75	–	2.0	19.5 m^2	1 for each side, i.e. 2 × 1 = 2 for both sides.
	W	17 × 2.6	1.00	–	1.3	57.46 m^2	
	V	4 × 2	0.5	–	0.5	2.0 m^2	One flat area for overall, i.e. excluding frames.
	Window bars						
		17	0.86	–	1.22	17.84 m^2	

					Total =	163.96 m^2	
6.	*Iron and steel items – hold fasts, and grating of windows and ventilators*						
	Hold fasts :						
	D_1	2 × 6				12	(i) Providing 6 Nos. in each door
	D_2	4 × 6				24	
	D_3	5 × 6				30	(ii) Providing 4 Nos. in each window
	D_4	5 × 6				30	
	W	17 × 4				68	(iii) Providing 2 Nos. in each ventilator
	V	4 × 2				8	
					Total which, @ 1 kg each =	172 Nos. 172 kg	
	16 mm round bars:						
	W	17 × 9	–	–	1.3	198.9 m	Providing (at 10 cm distances) 9 bars in each window and 4 bars in each ventilator
	V	4 × 4	–	–	0.5	8.0 m	
					Total	206.9 m @1.58 kg/m = 326.90 kg	
					Grand Total	= 498.90 kg	

[**Note :** As has been stressed earlier, exercising one's mind solving problems, as many as possible, is the most effective way to master any procedure, and more so in the case of estimating quantities in civil engineering works. Some SAQs are given below for students to try their hands on – and, it is advised that the solutions worked out individually must be compared with the solutions given in Section 7.9.]

SAQ 1

(a) The ground floor of a building has following openings in its superstructure :

Item	*Size*	*No.*	*Remarks*	
Doors				
D_1	1.3 × 2 m	5	Ht. of door = 2 m	All doors have 3-piece frames
D_2	1 × 2 m	2	Ht. of door = 2 m	
D_3	0.8 × 2 m	1	Ht. of door = 2 m	
Windows				
W	2 × 1.3 m	6	Ht. of window = 1.3 m	
Glazed Ventilator				
V	0.5 × 0.5 m	1		

Windows, each have two bays with two vertical posts in the middle (one bay has two shutters; and the other has only one shutter) – each piece of the frame (vertical or horizontal) of *D*s, *W*s, or *V* has a 12 × 7 cm sectional area.

Rebate in chowkhats for shutters to be received in appropriately is detailed below :

D_1; D_2; D_3 ⇒ 1 cm in horizontal direction; and 3.5 cm in vertical direction.

W ⇒ 1 cm in horizontal direction; and 1 cm in vertical direction.

V ⇒ 1 cm all around.

Compute the following quantities, presenting the results as a *bill of quantities :*

(i) Salwood work in chowkhats.

(ii) 30 mm thick deodar panelled shutters (with ordinary steel fittings) in doors and windows (including hold fasts, etc.)

(iii) 30 mm thick deodar wood glazed shutter in the ventilator.

(iv) Painting two coats over one coat of priming coat on doors, windows, and ventilator.

(v) Solignum painting, two coats in the back of chowkhats.

(vi) Grating (grill) – 16 mm mild steel round bars in windows and ventilator.

(b) A structure has doors windows, and ventilators in its superstructure as detailed below :

Sl. No.	**Item**	**No.**	**Size (horz. × vertical)**	**Chowkhat Size**	**Rebate**	
					Vertical	**Horizontal**
1.	D_1	5	1.2 × 2 m	10 × 8 cm	5 cm	2 cm
2.	D_2	1	1 × 2 m	10 × 8 cm	5 cm	2 cm
3.	D_3	2	0.8 × 2 m	10 × 8 cm	5 cm	2 cm
4.	W	4	1.5 × 1.2 m	10 × 8 cm	5 cm	2 cm
5.	V	2	0.6 × 0.6 m	10 × 8 cm	2 cm	2 cm

All doors have 3-piece frames, while windows and ventilators have 4-piece frames.

Take out the following quantities in the form of a *bill of quantities :*

(i) Kail woodwork in chowkhats.

(ii) Deodar woodwork in 3 cm-thick panelled shutters for all *D*s, *W*s and *V*s.

(iii) Two coats painting over one coat of priming on *D*s, *W*s, and *V*s.

(iv) Solignum painting (2 coats) in the back of chowkhats.

(v) Mild steel in hold fasts for windows and ventilators; and 16 mm round bars in *W* and *V* grills – 13 bars in *W*s; and 4 bars in *V*s.

[**Note :** Taking twice the vertical rebate into account for 3-piece doors allows the due clearance of the shutter with respect to the flooring.]

7.8 SUMMARY

Doors, windows and ventilators are an inseparable feature of a superstructure of a building. These items of work comprise frames (chowkhats), shutters, and MS fittings. Doors can have 4- or 3-piece frames, and all the frames have appropriate rebates in their section to accommodate shutters snugly. While thinking of doors and windows, one has to understand the need for the associated hardware which is generally paid for separately.

Flooring and ceiling can also be built of timber, and have their own specifications.

Every item of these works need material and labour to make it upto specifications – and, these factors, as usual, determine the cost (or rate, after the contractors profit is added) of the item.

Every door/window/ventilator/flooring/or ceiling is classified as per the specifications that have been followed to make the final product – and is paid for accordingly.

7.9 ANSWERS TO SAQs

SAQ 1

(a) *Chowkhat Lengths :*

$D_1 = 1.3 + (2 \times 2) = 5.3$ m

$D_2 = 1 + (2 \times 2) = 5.0$ m

$D_3 = 0.8 + (2 \times 2) = 4.8$ m

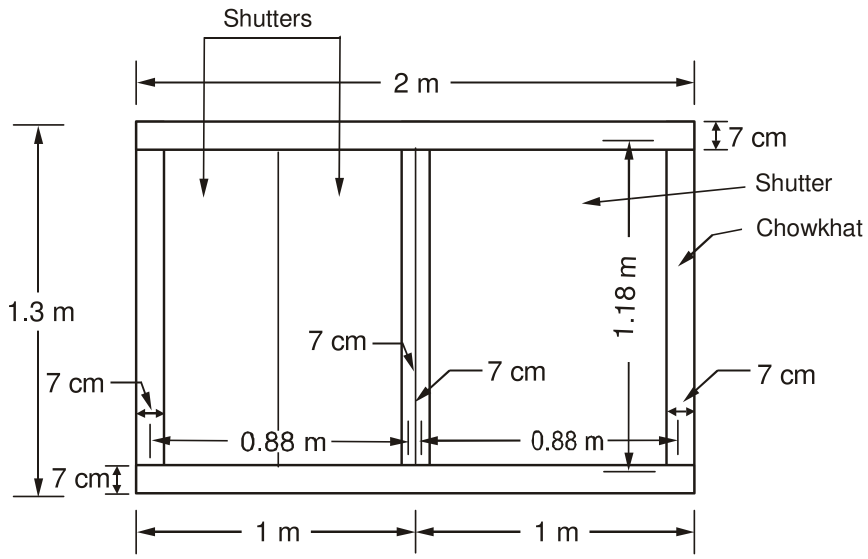
$W = (2 \times 2) + 2\,(1.3) +$ [Two posts in the middle)

$= 6.6 + [2 \times 1.3]$

$= 9.2$ m

$V = 2 \times 0.5 + (2 \times 0.5)$

$= 2.0$ m



Sketch of Window, *W*

Shutter Dimensions :

$D_1 \Rightarrow 1.3 - 2 \times (0.07) + 2\ (0.01) = 1.18$ m; and

$2 - 2 \times (0.07) + 2\ (0.035) = 1.93$ m

$D_2 \Rightarrow 1.0 - 2 \times (0.07) + 2\ (0.01) = 0.88$ m; and

$2 - 2\ (0.07) + 2\ (0.035) = 1.93$ m

$D_3 \Rightarrow 0.8 - 2 \times (0.07) + 2\ (0.01) = 0.68$ m; and

$2 - 2\ (0.07) + 2\ (0.035) = 1.93$ m

[**Note :** Vertical rebate taken twice gives the required clearance to the door shutter from the floor.]

$W \Rightarrow$ (a) Two-shutter bay :

$[1 - 2\ (0.07) + 2\ (0.01)] \div 2 = 0.44$ m; and

$1.3 - 2\ (0.07) + 2\ (0.01) = 1.18$ m

One-shutter Bay

$[1 - 2\ (0.07) + 2\ (0.01)] = 0.88$ m; and

$1.3 - 2\ (0.07) + 2\ (0.01) = 1.18$ m

$V \Rightarrow 0.5 - 2\ (0.07) + 2\ (0.01) = 0.38$ m; and

$0.5 - 2\ (0.07) + 2\ (0.01) = 0.38$ m

(i) *Salwood work in chowkhats*

	No.	**L (m)**	**B (m)**	**H m)**
D_1	5	5.3	0.12	0.07
D_2	2	5.0	0.12	0.07
D_3	1	4.8	0.12	0.07
W	6	9.2	0.12	0.07
V	1	2.0	0.12	0.07

(ii) *30 mm-thick deodar wood D and W shutters* (*including ordinary mild steel fittings – i.e. here included in the shutter rates*).

	No.	**L (m)**	**B (m)**	**H m)**
D_1	5	1.18	–	1.93
D_2	2	0.88	–	1.93
D_3	1	0.68	–	1.93
W : (i)	6 × 2	0.44	–	1.18 – two shutters in one bay
(ii)	6 × 1	0.88	–	1.18 – one shutter in other bay

(iii) *30 mm-thick glazed shutter*

V	1	0.38	–	0.38

(iv) *Painting, two coats, of D_s, W_s and V over one coat of priming*

D_1	5 × 2.6	1.3	–	2
D_2	2 × 2.6	1.0	–	2
D_3	1 × 2.6	0.8	–	2
W	6 × 2.6	2.0	–	1.3
V	1 × 2	0.5	–	0.5

Mild steel bars (grating)

W	6 × 2	0.44	–	1.18
	6 × 1	0.88	–	1.18

16 mm-round bars in grating

W	6×9	2	–	– Taking spacing of bars as 20 cm

(Assume wt. of bars @1.58 kg/m)

V	1 × 2	0.5	–	–

(v) *Solignum painting, two coats, in the back of chowkhats*

D_1	5	5.3	0.12	–
D_2	2	5.0	0.12	–
D_3	1	4.8	0.12	–
W	6	6.6	0.12	–

(**Note :** Central two posts are not to be painted, as these are not in contact with the masonry.)

V	1	2.0	0.12	–

SAQ 2

(i) *Chowkhat lengths*

$D_1 \Rightarrow 1.2 + 2\ (2) = 5.2$ m

$D_2 \Rightarrow 1 + 2\ (2) = 5.0$ m

$D_3 \Rightarrow 0.8 + 2\ (2) = 4.8$ m

$W \Rightarrow 2 \times 1.5 + 2\ (1.2) = 5.4$ m

$V \Rightarrow 2 \times 0.6 + 2\ (0.6) = 2.4$ m

(ii) *Shutter dimensions* (*length × breadth*)

$D_1 \Rightarrow 1.8 \times 1.94$ m

$D_2 \Rightarrow 0.88 \times 1.94$ m

$D_3 \Rightarrow 0.68 \times 1.94$ m

$W \Rightarrow 1.38 \times 1.14$ m

$V \Rightarrow 0.48 \times 0.48$ m

} Work out these quantities yourself

Note : The shutter of V is unglazed thus the multiplying factor is 2.6.

(iii) (a) *Two-coat painting*

$D_1 \Rightarrow 5 \times (2.6) \times [1.2 \times 2 \text{ m}]$

$D_2 \Rightarrow 1 \times (2.6) [1 \times 2 \text{ m}]$

$D_3 \Rightarrow 2 \times (2.6) [0.8 \times 2 \text{ m}]$

$W \Rightarrow 4 \times (2.6) [1.5 \times 1.2 \text{ m}]$

$V \Rightarrow 2 \times (2.6) [0.6 \times 0.6 \text{ m}]$

(b) *Window grills*

$\Rightarrow 4 \times (1) [1.36 \times 1.06 \text{ m}]$ – multiplying factor is 1.

[where, $1.2 - 2 \times 0.08 + 2 \times 0.01$ (i.e., each rod goes 1 cm into the chowkhat at two points vertically)

$= 1.06$ m;

$1.5 - 2 \times 0.08 + 2 \times 0.01 = 1.36$ m]

[**Note :** In this way too we can estimate the grill area to be painted after fixing the spacing (c/c) of the bars for the fixation of rate of payment.]

(c) *Ventilator grills*

$\Rightarrow 2 \times (1) [0.46 \times 0.46 \text{ m}]$

[where, $0.6 - 2 \times 0.08 + 2 \times 0.01 = 0.46$ m].

(iv) *Solignum painting, two coats in the back of chowkhats*

	No.	**L (m)**	**B (m)**	**H m)**
D_1	5	5.2	0.1	–
D_2	1	5.0	0.1	–
D_3	2	4.8	0.1	–
W	4	5.4	0.1	–
V	2	2.4	0.1	–

(v) *Mild steel* (*16 mm round bars, and hold fasts*)

(a) Hold fasts

	No.	**Quantity**	
D_1	5 × 6	30 Nos.	Taking 6 hold fasts for each door
D_2	1 × 6	6 Nos.	
D_3	2 × 6	12 Nos.	
W	4 × 4	16 Nos.	Taking 4 Nos. for each window
V	2 × 2	4 Nos.	Taking 2 Nos. for each ventilator

[**Note :** Calculate the weight @ 1 kg/each.]

(b) 16 mm round bars for grills @ 1.58 kg/m

Item	**No.**	**L**	**Quantity**

W	4 × 13	1.5	78 m @ 1.58 kg = 123.24 kg
V	2 × 4	0.6	4.8 m × 1.58 kg = 7.58 kg.

UNIT 8 PROCEDURE OF WORKS AND MAINTENANCE OF ACCOUNTS IN PWD CONTRACTS

Structure

8.1 Introduction

Objectives

8.2 Classification of Works

8.3 Approval and Sanction of Works

8.4 Contract System

8.5 Tender and Tender Documents

8.6 Contract Documents

8.7 Conditions of Contract

8.8 Departmental Methods of Maintaining Public Works Accounts

8.9 Miscellaneous Notes

8.10 Summary

8.11 Answers to SAQs

8.1 INTRODUCTION

Procedure of works, and maintenance of accounts in Public Works Department (PWD) contract works is a specialised job which may be differing in details for different organizations. However, primarily the basis followed is similar.

A work is proposed to be done to meet a certain need. Its drawings and specifications are prepared, quantities of items worked out, and costs estimated. The extract of this data is used to advertise the work, i.e. tenders being invited from approved persons who are interested in doing and completing the job.

The lowest bidder is offered the chance to come forward and, after completing some formalities, is allotted the work on terms and conditions that have already been standardised.

The owner (PWD/private owner) tries to get the job done as per specifications, and any disputes that may arise are subject to executive/legal remedies, or acts of arbitration.

Payments are made from time to time as the work proceeds.

A beginner in the profession has to gain proficiency in the niceties of the procedure of work.

Objectives

After studying this unit, you should be able to

- aquaint yourself with the basics of the PWD procedures for executing contract jobs, and
- form an idea about the fundamental accounting documents that form the foundation of assessing a work financially.

8.2 CLASSIFICATION OF WORKS

Public Works Department (PWD) – as various other government agencies – have been classifying its works under various heads with a view to reduce delays in sanctioning the execution of works, and avoid unnecessary confusion, thus enhancing efficiency and smooth functioning. This classification is fundamentally related to the estimated cost of a piece of work; and every authority (at different rungs of the set-up) has apportioned to itself the powers to sanction works up to the designated amounts.

The works, in general, can be categorised as outlined below :

(a) Petty works

(b) Minor works (usual, or original)

(c) Special repairs

(d) Maintenance and Repair works (M and R) – or Current Repairs (CR)

(e) Major works

(f) Deposit works (Original)

Minor works (original) comprise those small works that are generally extensions, and alterations (including additions) to an existing work. Also these works include new works, like, outhouses sheds, and servants' quarters up to the designated cost.

Special repair works refer to repairs carried out to the existing works – may have been damaged due to unforeseen causes, like fire, heavy rains, floods. However, *special repairs* do not refer to the envisaged repairs to address sub-standard workmanship, etc., that may cause the building (or any other structure) to collapse.

Maintenance and Repair jobs are the usual jobs done to help maintain the works in a good condition. Thus, this class of work is an annual feature of government buildings maintained by PWD. Annual grants (as per prior estimation) are earmarked for this purpose.

Major works are new works that have been proposed as a measure to augment the given facilities, or add as further assets to the infrastructure.

Deposit works are in a way a special category of works. The works can encompass a new construction or a repair to the existing work – however, the difference being that the cost involved is not met out of the PWD funds, but out of the funds that are made available by the client agency (wanting the job executed on its behalf). The amount (once estimated by the staff of the PWD) is deposited with the PWD/or placed at its disposal.

8.3 APPROVAL AND SANCTION OF WORKS

The hierarchy of authority in the set-up of the working machinery of PWD implies various stages and modes of approving a work, allocating funds, and executing the proposed work. Thus, before a work is commenced, it has got to be approved *administratively* as well as technically by the competent authorities. Following levels of action, in this regard, are to be gone through :

(a) Administrative approval

(b) Expenditure approval (or sanction)

(c) Technical sanction (or approval)

(d) Appropriation (or re-appropriation) of funds

Administrative approval implies the formal acceptance, by one that has the administrative control over the proposed works, to be executed. Approximate estimate, and preliminary designs and drawings (i.e., plans) form the grounds on which administrative approval is granted. Administrative approval has also to be sought if the original proposal is revised/modified even if the cost remains unchanged, or the modifications could be executed by debit to the savings effected in some items of the work.

Moreover, when the cost (expenditure) is likely to exceed (or has exceeded), due to extraneous causes (inflation, etc.), say by more than 10% of the amount already approved, a fresh administrative approval is called for.

Once the administrative approval is granted, the work is taken in hand, and side by side, detailed drawings, estimates, etc., are prepared with a view to execute the work according to specifications.

Approximate estimates (as mentioned above), incorporate a complete site plan that shows the area of the land (if) to be acquired, structure to be built, and the necessary roads (if required to be constructed, in some projects).

On the basis of this site plan, the required approximate estimate is prepared regarding all the main items of work – adding a contingency amount of 10% to the total approximate cost. In the case of buildings, the approximate cost is worked out on the basis of plinth area or, sometimes, on the cubical contents of the structure. As mentioned in previous units, plinth-area rates are derived from the costs of buildings of similar specifications, and number of floors, and considering the locality involved.

Expenditure sanction, that is sought, is granted as a token of approval (concurrence) of the government (centre of power political – administrative, and financial) to the proposed expenditure. This sanctions is necessary for works requiring larger sums of money.

Further, when funds are re-appropriated (diverted from one head to the other by the government, or any subordinate authority competent to do so), it is considered to be equivalent to the expenditure sanction.

A revised expenditure sanction is also needed in cases where the expenditure exceeds, or may exceed the original cost by more than 10%. These norms are liable to change from time to time, and may be variously applicable to different slabs of expenditure.

Technical Sanctions

It is an order/sanction by the competent authority that approves the detailed estimate of the cost of a given work (original, repair, etc.). This sanction is taken as a token of testifying that the proposed work is structurally sound and the detailed estimates reflect accuracy, detailings and complete description of the work. Thus, this sanction is a verification of the technical details of the work.

Any modifications to the original proposal (if circumstanced to happened), also needs a revised technical sanction.

It is obvious that the technical sanction follows the administrative approval. Without technical sanction, in fact, no work can be taken in hand. The detailed estimate shall, as usual, consists of bill of quantities, and an abstract of cost, and complete, detailed specifications. However, when there is any ambiguity about the rate of payment of an item, lump sum earmarking has to be made : subject to the final revision on the basis of actual analysis of rates; and, large lump sum provisions in the detailed estimate are not admissible.

Contingencies of 5% shall be added to the net total cost to address any minor error or omission.

Factors Affecting Costs

As is evident, the factors that influence the cost are mainly : material, labour, transport (cartage), overhead charges, including work charged establishment, and incidentals.

Rates should be based on actual conditions at the site of work : location, soil characteristics, best location for any plant that is an essential part of the effort, location of the yard to store materials, availability of power and water, locally applicable rules and regulations, availability of banking facilities, distances to railway yards and dealers in materials, prevailing conditions regarding wages of labour, supply and efficiency of local workmen, and facilities that can be mustered for positioning labour at site.

Material Estimates

Preparation of a list of required materials (known as the "*take-off*") is a helpful exercise. An estimator takes off the necessary materials with the help of drawings and specifications. The results are tabulated on "*quantity sheets*" giving number, size, weight, volume, etc. For a large job, many quantity sheets are needed – and, then "*summary*" sheets are prepared. This information helps in appropriate planning and accurate estimation.

For obtaining material costs, the cost of all the materials at the site are to be considered. This cost has, in general, the following components :

(a) First cost

(b) Freight

(c) Unloading

(d) Cartage

(e) Storage

(f) Inspection

(g) Testing

(h) Insurance

Estimates of Labour and Wages

While working out labour estimates, appropriate space shall be given to the inevitable variations in wages, variations in the time span (hours) to complete one and various items of work, variations in working conditions, and above all variations in the availability of skilled and unskilled men power – and, the influence of interplay between supply and demand of labour. Also, a prudent manager of works (as every civil engineer should be) should, as far as possible, foresees the affect of union politics on the daily output of a worker.

Estimating Infrastructure and Main Costs of a Plant

This includes setting up of temporary buildings and structures, machinery and tools, etc. – particularly, for handling reinforced cement concrete works.

Plant costs shall include costs, vis-à-vis, transportation, installation and repair, operation, dismantling, interest on investment, and depreciation – depreciation being accounted for as a fraction (percentage) of the first cost.

Estimation of Overhead Charges

These charges cover general office running costs, and all such costs that are not directly productive, such as :

(a) Rentals

(b) General insurance

(c) Compensatory insurance for labour

(d) Special security

(e) Office equipment, and stationery

(f) Communication – postage, telephone, telegraph etc.

(g) Interest and taxes

(h) Legal expenses (an inevitable expense)

(i) Travelling expenses

(j) Preparation of plans, drawings, and specifications, and other sundries

(k) Salaries, chargeable to the work

Sometimes these expenses are categorised as general overheads (say, office and site costs), and job overheads.

Appropriation/Re-appropriation of Funds

Sometimes it becomes necessary to divert funds for a particular work. It is an allotment of a certain sum of money, within the grants of a year, at anytime before the end of the financial year.

An appropriate authority (say, the chief engineer) can appropriate/ re-appropriate money. It is a mechanism to also liquidate the past liabilities. However, any unspent amount lapses by the end of the year.

8.4 CONTRACT SYSTEM

"*Contract*" – as implied in the PWD code – connotes an undertaking by a *person* (not being a government servant), a Syndicate, or a firm for constructing, maintaining and repairing of a work/or a group of works. These projected activities include supply of materials, labour etc. Herein a "*Contractor*" is a person, Syndicate, or a firm that gives the undertaking.

A piece of work can either be executed departmentally – employing labour on daily wages – or by other means, such as through :

(a) Piece-work (also known as *Rate List* work), and/or

(b) Contract work.

Piece-work mode of execution allows an agency to do the work on an agreed rate of payment, with no commitment about the total quantity of work to be done, or about the time period within which it is to be completed. This mode of work is often employed for maintenance and repair work – like white washing, distempering, supplying materials like, sand, metal, etc.

Contract Work implies work that is done under an agreement – that defines the total quantity of work/works that is stipulated to be done within a defined time period. A contract is an agreement that has the sanction and backing (i.e., is enforceable) of law. Laws of contract, as prevailing in India at anytime, are applicable to this contract also. In a contract system of work, the department gets the work done through a contractor/contractors who arranges labour, material, and tools – occasionally, the department enters into a contract for the supply of only labour by the contractor. For common/usual works on roads or canals *stage contractors* are generally employed, on yearly basis, to execute works whenever asked for on approved rates of payment for different items of work.

Types of Contract

Various types of contracts in vogue in PWD are :

(a) Lump-sum contract,

(b) Item rate contract, and

(c) Percentage contract.

In a *Lump-sum contract*, the contractor undertakes to execute a piece of work complete in all respects (with all the contingencies that may arise) as per drawings and specification – all for a *fixed sum* of money. However, the following conditions do apply on this type of contract :

(a) A schedule of rates is specified that shall regulate the amount to be added or deducted from the contract sum (fixed sum as mentioned above) in the case of any alterations done in the work not covered by this contract.

(b) Detailed measurements of the work done in the case of alterations carried out shall be done.

This type of contract, it is easy to envisage, is fraught with the possibility of litigations that may ensue between the parties.

It is the characteristic of a lump-sum contract that the quantities of different items of work are not defined – however, the contractor shall have to complete the work as per drawings and specifications within the stipulated time. On the completion of this work, no detailed measurements of various items are made – and, the payment is made after the work is seen to have been done according to plan and specifications.

This type of contract is commonly adopted for works where the number of items are limited – e.g., a compound wall, a one-room structure, septic tank, man hole, etc.

Item Rate contract is also known as unit price contract. Item-rate works are carried out on the basis of scheduled rates for various items (sometimes with appreciation on the departmental rates). Payments are made on the basis of quantities of items done – hence, detailed measurements shall be done for the purpose; but for the purposes of inviting tenders from the prospective bidders, approximate quantity of the items involved in a piece of work is given.

Generally, contractors quote the rates as some percentage above (or below – a practice to grab the contract and indulge, later on, in corrupt practices) the scheduled rates of the PWD.

As the rates are quoted item-wise, any uncertainties in design and specifications are no cause for disputes.

Percentage contract is also known as cost-plus contract. In this form of arrangement for executing the work, the bidder works on the basis of a fixed percentage over the total cost of construction (as worked out earlier by the department). This type of contract comes into play when other two types are not workable due to fluctuating rates of men and materials – or the owner maintains the record of actual expenditure incurred, and makes the payment to the contractor at the agreed percentage over and above the total cost incurred. Usually, architects/chartered engineers undertake works in this mode – charging 5 to 10 percent of the total cost towards supervision, and preparation of technical documents, etc.

Note : (a) One more method of work, known as Work-Order method, is in vogue for executing small works up to a limited amount. In this type of contract no quotations are called. Work-Order books detail out the terms and conditions of contract. A sort of agreement is entered into by the parties concerned.

(b) *Negotiated contracts* are based on the negotiated rates (in special cases of work) and can form the basis of any type of contract discussed so far.

8.5 TENDER AND TENDER DOCUMENTS

Tenders (bids) are invited publicly, and in a transparent manner for a specified work to be executed, or even to supply some specified materials/articles. The notice inviting tenders asks for rates for the items of work/articles to be completed/supplied within the specified time period, and according to the laid down conditions. Every contractor (bidder) putting in a tender is given a set of documents – conditions of contract, specifications, and a bill of quantities; thus, there being left in scope for confusion as to the expected obligations and rights of the contractor once his/her tender is accepted.

Tenders that are submitted (for acceptance) shall invariably be sealed. These tenders are submitted in response to the *tender notice* published in the Government Gazette/newspapers/notices posted at public places. A sample tender notice is presented as under :

Upper Sindh, Hydel Project, J & K Department of Irrigation, Srinagar (Kashmir)

TENDER NOTICE NO. 1234/1903-1904

Sealed tenders (one for each item of work) for the following items of work, to be executed over the Project Site, District Baramulla, are invited in the office of the undersigned from “A” class Contractors of J & K Government, up to 12 : 00 hours on the date shown against each work. The tenders shall be opened publicly on the same day, in the same office, at 17 : 00 hours, by the undersigned or his duly authorised representative/(s) in the presence of the tenderers (whoever is present) or their representatives.

Sl. No.	Name of Work	Approximate Value of the Work	Earnest Money*	Cost of Tender Form	Time of Completion	Date of Opening of the Tender
1.	Construction of Roads in the Project Area (in all 20 km)	50.0 lacs	30,000/-	200/-	6 months	20-01-04
2.	Construction of Residential Blocks (single storey) – 3 blocks	80.0 lacs	35,000/-	200/-	12 months	04-01-04
3.	Construction of Mazdoor Hutments – 20 nos.	10.0 lacs	10,000/-	100/-	4 months	06-01-04

* It is about 1% to 2% of the total estimated cost of the work. *Earnest money* discourages unnecessary competition among the intending contractors; acts as a tool for punishment in case unnecessarily low rates (without seriousness to do work) are quoted; and as a compensation to the department in case the contractor does not take up the work.

All the tender documents along with the detailed specifications can be had from the office of the undersigned on any working day from 10.30 am to 3.30 pm on 02-01-04 on the payment of the cost of the tender form as indicated above – the cost is not returnable.

Tenders deposited without the accompanying earnest money will be rejected – their-in quoted rates will not to be declared.

Earnest money will be deposited in the form of a bank draft pledged (A/c payee) in favour of the undersigned – the draft being drawn at any SBI branch.

Tender documents can also be had by post on payment of Rs. 25/- extra per set of these documents.

Envelope carrying the tender shall bear the proper name (in capital letter) of the concerned work at the left top corner.

Dated S/d

01-12-03

Executive Engineer
Upper Sindh Hydel Project
Division – I
Ganderbal, Srinagar
(Kashmir).

Opening (Scrutiny) of Tenders

Once the sealed tenders are duly opened, a complete perusal of these documents is done. Every tender has to bear the signature of the tenderer (prospective contractor) before it is fit to be considered. The tenderer should have given his address very clearly and complete in form. Contract conditions accompanying the tender should exactly be the original conditions laid down by the department. It is to be checked that the rates quoted are written both in figures and words without any ambiguity. All other necessary checks shall be carried out.

Lastly, a duly signed comparative statement is prepared, presenting the data neatly – the least total cost being placed first in the statement followed by progressively increasing amounts.

The competent authority accepts the lowest amount tender unless valid reasons do not allow so, and then the next higher tender can be accepted (or recommended for acceptance).

The persons(s) (or firm) whose tender is accepted (herein after known/called the "contractor", the expression that includes his heirs, executors, administrators, and assignee) shall :

(a) duly, as required, deposit with the Executive Engineer, in cash (or by other means), a sufficient sum (as required) which will make up the full security specified in the tender, or

(b) permit the authorities to deduct from the payments due to him (later on) the agreed – upon amount towards security.

Any security deposit paid in to the government is returnable to the contractor on the expiry of the period of guarantee after some deductions towards the cost of expenses, incurred by the government. This amount is a security for the due fulfilment of the contract obligations.

8.6 CONTRACT DOCUMENTS

Prior to any work being given out on contract, an Executive Engineer shall prepare the following *contract documents* :

(a) A full, complete set of plans, drawings outlining the general dimensions of the proposed works; and the necessary details of the various elements.

(b) A complete set of specifications regarding the work; and the names and quantity of various materials that are needed, or reference may be made to available standard specifications.

(c) A set of *conditions of contract* to be followed/complied with by the contractor who is asked to undertake the work on the basis of the least tendered amount.

(d) A copy of *tender notice*.

(e) A copy of tender form that incorporates the contractor's rate, total cost involved, stipulated time of completion, security money, penalty clause (in case of default by the contractor) etc.

(f) A list of materials that is to be issued by the department (steel, bitumen, cement) with rates and place of issue.

8.7 CONDITIONS OF CONTRACT

The conditions of contract cover the clauses in the agreement (entered into between the department and the contractor – after the allotment of work to the party) that govern the obligations and rights of the parties. These conditions help in avoiding any dispute that may arise between the two parties. These conditions are framed after the due deliberations with the expert lawyers. For important, elaborate and complicated contracts, to avoid unnecessary bickering and delays in the execution of works, a thorough consideration is called for while framing these conditions.

These conditions must, in all cases, cover the following aspects of a work :

(a) Specifications, drawings, schedule of rates, notices on either side, arbitration, etc.,

(b) Labour welfare – concerning aspects like accidents, labour claims, labour amenities, labour safety, etc.,

(c) Defects, quality of materials, standards of workmanship, alterations and shortcomings in the works, damages to the works.

(d) Measurements, mode and timing of payments, extension of the time limit as laid down in the contract,

(e) Defaults, non-completion of work in time, punishments, penalties, etc.

(f) Pollution caused by the contract activities, royalties and taxes to be paid, etc.

The time limit specified for the completion of work has to be monitored strictly, and intensely – time is the essence of any contract. Department is generally empowered to re-tender the work or carry out the work departmentally in case of default on the part of the contractor.

Material used, when supplied by the contractor (as mostly is the case), shall be seen to be of the specified quality as certified by the Executive Engineer.

The quantity of work done shall be measured from time to time (as per the terms of the agreement) and on-account payments made accordingly. Supply of material at site (say, metal, bricks, steel, etc.) itself entitles the contractor for an on-account payment.

On the satisfactory completion of work, the concerned Executive Engineer shall furnish a *certificate of completion* – but no work is practically deemed complete until the contractor has removed from the site all scaffolding, surplus materials, and riff raff, cleaned off all the items of work, and settled all the labour claims (as per prevailing labour laws).

Termination of Contract

The concerned authority (say, Executive Engineer) may terminate the contract in the event of breach of the conditions of the agreement (similar right vests with contractor, after due legal procedure is gone through). The aggrieved party can always stake its claim for compensation.

Contract can also be terminated by mutual agreement under certain circumstances. Moreover, when it is impossible to complete the work – say, due to land dispute (on which the work is executed); acquisition of land by the government for some other purpose (a rare happening); and, in case of the flooding of the site, etc. – the work contract can be legally terminated.

Wherever, either part is declared a bankrupt (mostly, the contractor, if the other party is the government), a contract can always be terminated.

8.8 DEPARTMENTAL METHODS OF MAINTAINING PUBLIC WORKS ACCOUNTS

The basic (initial) records that form the foundation stone of PWD accounts are *Muster Roll* (Form 21); and *Measurement Book*.

Muster Roll

Muster Roll (also known as Nominal Muster Roll) is the record of daily labour employed on each day on a work constructed/maintained by the department. This daily labour can either be unskilled (male/female, mazdoors/coolies, bullock pairs, Bhisties (water men), etc.), or skilled labour, like masons, carpenters, fitters, blacksmiths, and other types of artisans.

While any piece of work is being executed directly by the department itself, it employs its own daily labour for the job. The system is known as *muster roll system*, or *daily labour system*. In fact, it is the records of attendance of labour – and, it is on this basis that the payment of wages is made to the labour; either weekly, fortnightly, or monthly, or at the time of completion of the work as per requirement. In its essentials the muster roll format is as shown in Page No. 242.

Either on the same page, or at the back of the muster roll, progress of the work achieved during these days shall be entered and signed, and countersigned by the concerned staff.

Measurement Book

Measurement Book is the PWD Accounts Form No. 23, and is the most important record book of quantities of different items of a work (or materials) needed to be paid for either by muster roll or any type of contract arrangement. All the measurement books concerning a Division of the department are serially numbered by machine – a register is kept in the Division office that indicates serial number of each book, to whom issued (sub-divisional office or a staff member), date of issue and date of its return. A typical format of the Book (same as for a bill of quantities) is presented as under :

Measurement Book

Name of Work______________ Debited to________ Agency _____________________

Name of Contractor_________________ etc.

Sl. No/ and Date	Particulars (Full Specifications)	Details of Measurement				Contents/ Area/No.
		No	L	B	H/D	

8.9 MISCELLANEOUS NOTES

Contractor shall be held responsible for all the damages that occur, through his labour/workers, or even to the labour itself while the work is under execution. The contractor shall be required to provide protection to work and labour against inclement weather. He is bound to take off all the accumulated water, by pumping, in order to maintain the works clean and dry.

The contractor shall be obliged to repair all the damages and distortions inflicted on all the surfaces of roads, streets, private lands, crops, etc., while executing the contract works. Generally, the relevant clause in the agreement clearly expresses the duty of the contractor to maintain the surface in good conditions.

In the event of the contractor not completing the work in the scheduled time (or also within the extended time, if allowed by the authorities on valid grounds) due charge is levied on him. Such sum is usually a specified sum per day for each day of delay – this sum is termed *ascertained or liquidated damages*, and not as a penalty. This charge can also be deducted from the amount falling due to the contractor.

All engineering contracts carry an important clause that deals with the *bankruptcy* of the contractor or *liquidation* of a Company. In case the party, while the work is under progress, commits any act as if it is bankrupt (or has entered into a liquidation) – whether voluntarily or otherwise – or do some similar acts, the department (Employer herein) is empowered (without affecting the contractor's liabilities) to employ any other contractor/contractors with a view to completing the incompletely – left work. In such a case, the department has full liberty to use the tools and plants and materials of the contractor. Any expenses/costs that may be incurred by the department shall be recovered from the contractor.

A common method of settling disputes between the contractor and the department (or a private owner) is *arbitration*. It is a process which is preferred in settling disputes that involve technical points/questions. An arbitrator can be a person having an expert knowledge of the matters, vis-à-vis, the dispute. He may inspect the work in order to save time and effort spent over hearings, etc. Arbitration involves less legal expenses compared to the action of law – and, is binding on the parties. An arbitrator shall have the power to reopen the earlier decisions of the department, review and revise any earlier actions done by the parties.

As mentioned earlier, the contractor shall be paid by the Employer from time to time (i.e., by instalments) under *on-account* (or *running-account*) mode of payment, for the works executed till date. Whenever such a type of payment is proposed to be made, it is imperative to ensure that the value of the work done is not less than the specified amount that is being paid in conformity with the contract agreement, and that the work has been done according to the relevant drawings and specifications.

Contract drawings, as stressed earlier also, have to be accurate and complete – its importance is highlighted every time it is stated that : the work shall be carried out in accordance with the signed drawings, and in accordance with any further drawings, and details as may be issued from time to time (of course, in accordance with the terms of the agreement).

It has to be understood here that a set of specifications coupled with detailed drawings is indeed a complete guide that can lead to a piece of good work. Drawing is the language of engineering, and thus the following rules shall be followed for this language to be comprehensively articulate :

(a) All the drawings should be drawn true to scale, and exhaustively but carefully dimensioned.

(b) Dimensions for openings shall be clear of all finishing.

(c) Room heights (from top of floor to the underside of the next floor/or to its top) should be indicated.

(d) It is useful to distinguish different kinds of floors (timber, RCC, etc.) by different colours.

(e) Rooms/bedrooms/hotel rooms, etc., should be numbered consecutively – avoiding the use of the same sets of numbers in one building.

(f) All the main dimensions must be given on each floor of a building – care being taken that these do agree in all respects.

(g) It is helpful to indicate all the floor levels on the elevation of the building by distinctive colours.

(h) All the sectional elevations should give the required dimensions clearly. Staircases should be detailed out by taking sections through them – and, it is advantageous to show them by bold colour.

(i) Those parts of brickwork which are to be built in different mortars (cement, line, mud) should be given different colours.

(j) It is appropriate to draw all the drawings (as far as feasible) to a uniform scale – say, 0.5 m = 1 cm, or 1.0 m = 1 cm.

Stores

Departmental stores have stocks of the following materials :

(a) Materials charged direct to works like, cement, bitumen, steel, etc.

(b) Tools and plant.

(c) Other necessary items.

Every staff member of the department is obliged to take up the duties of a storekeeper – departmental stores may be left at or near the station (with appropriate protection) where the staff member is located; but, in general, proper structures are available to function as stores.

General administration of all the stores of a Division (including those at the level of Sub-Divisions) is the responsibility of the Executive Engineer – being charged with the task of acquisition and custody and distribution (according to needs) of stores.

Stores are procured by floating tenders for the supply of materials – on the same pattern as for the execution of all the construction works. Detailed specifications and descriptions, quantities, location to be supplied at, time period given for the supply to be made (and the rate of supply with respect to time), etc., are to be included in the tender notice/agreement, as the case may be.

The staff concerned to look after the store is responsible for maintaining correct and up-to-date records and returns of the materials.

The head "*Stock*" is opened in every Division – under this head all the stocks are maintained; there always being a limit on the amount of money for which *stock reserves* can be kept. The account head " Stock" is charged with all the expenditure, vis-à-vis, the acquisitions of stocks, and with all *manufacturing operations*. The sub-heads of the stock account can be :

(a) small stores,

(b) building materials,

(c) timber,

(d) cement,

(e) metals,

(f) fuel (petrol, kerosene oil, diesel, etc.), and

(g) other such items.

When any serviceable stores, that are not returnable to the original source, are there, these are to be declared surplus, and notified accordingly by the competent authority. And, if these items cannot be sold to public, or transferred to other departments (who have to approach the Executive Engineer for the purpose) within the specified time, these *surplus* stores shall be survey-reported and disposed off as per the prevailing procedure.

SAQ 1

(a) Obtain information about a piece of work from your nearest PWD office (Division or Sub-Division), and study the various stages of approval and sanction through which the work proposal has gone. Summarise your observations in your notebook.

(b) On the lines indicated for (a) above write a report on the system of contract followed in a given work – draft the report in 200 words.

(c) On the lines indicated for (a) above note down (and explain) the contracting process of a piece of work – from issuance of tender notice, acceptance of the bid (give the sample of the lowest tender), agreement between the contracting parties, specimen of measurement-book filling, and all the related procedures.

8.10 SUMMARY

The working of Indian PWD is as old as the advent of British control over the subcontinent. Classification of work is based on the type of work as well as the total cost of the job.

A procedure, peculiar to PWD (and also in many respects to Military Engineering Service), of proposing a work to be done, its approval, and allocation of funds has been developed that is being followed upto these modern time – though thoughtful alterations/changes would be welcome in the interest of speed of execution and lessening the scope of corruption and undesirable practices.

Various cost factors – from first cost to overhead charges – make up the total cost of a project : big or small, or medium sized.

A gamut of systems is in vogue in the procedure of contracting the works to various agencies – particularly to a contractor or a firm; all depending on the importance, complication, and the length of time that is available to complete the job. Hence, various types of contracts are available for adoption.

The most common first step towards allotting the work on contract is to advertise the job (floating tenders) and then accepting the lowest bidder, entering into an agreement with the person, and getting on with the execution of work. However, the run of execution is not as simple an activity as it may seem. Legal aspects sometimes engage the two parties – owner and contractor – in a battle of wits through legal procedures. Conditions of contract (enshrined in the agreement) govern the rights and obligations of the parties concerned.

A practising engineer should also be familiar with the essential accounting documents – muster roll and measurement book – over and above other accounting modes.

Special attention has to be given to the preparation of drawings and clearly stating the desired specifications to avoid unnecessary pit-falls in this specialised work procedure.

8.11 ANSWERS TO SAQs

Refer to relevant preceding text in the Unit or other useful books listed in section 'Further Reading' to get answers to SAQs.

FURTHER READING

Birdie, G. S., *Text Book of Estimating and Costing* (*Civil Engineering*), Dhanpat Rai and Sons, Nai Sarak, Delhi.

Dutta, B. N. (1996), *Estimating and Costing in Civil Engineering : Theory and Practice*, UBS Publishers' Distributions Ltd., New Delhi.

IS 1200-1974, Part 1 to 25, *Methods of Measurement of Building and Civil Engineering Works*, Bureau of Indian Standards, New Delhi.

Majgaonkar,V. K., *Quantity Surveying and Costing*, Allies Book Stall, Poona.

ESTIMATING AND QUANTITY SURVEYING-I

Preparation of bill of quantities and, thereby, estimating the cost are the basic requirement of preparation of any engineering project. Apart from the functional and technical feasibility of constructing a building, the costing of project is essential for budgeting, approving and providing the funds for a project. This forms the subject matter for this course. The course has been designed to make you understand the methods of estimating the quantities of materials, labour and equipment and, thereby, estimating the cost of various operations required in building project. The bill of quantities and cost estimates also serve as important tool of cost management of the project.

The building project can be considered as a system consisting of various components, e.g. excavation and earthwork, concrete works, brick or stone masonry, RCC frames, formwork, trusses, iron and steel components including reinforcement, joinery, glazing, hardware, interior and exterior finishing, etc.

The course is structured into easy-to-grasp 8 units.

Unit 1 describes various commonly used types of earthwork, e.g. cutting and filling for roads, rails and canals and building foundations, etc. Estimation of earthwork involved in cutting and filling, their volumes, is explained with the help of solved examples. The specifications of earthwork in various projects of roads, canals and buildings are also discussed.

Unit 2 deals with building concrete work including lime concrete, formwork involved with concreting specifications and general considerations of quantity calculations.

Brick and stone masonries, their different types of classification and specification along with methods of quantity estimation and rate analysis are detailed in Unit 3.

Unit 4 discusses the specifications for steel and timber trusses. Formworks and their quantification has also been covered in the unit.

Steel is used in general building work for various purposes, e.g. beams, trusses, collapsible gates, shutters and reinforcement in RCC members. Their general specifications, rate analysis, quantity calculations and preparing bar-bending schedules are given in Unit 5 along with general specifications of RCC works and case studies.

Finishing items of interior and exterior finishing, e.g. plastering, pointing, white and colour washing, distempering, etc. are described in Unit 6 with rate analysis and case studies.

Unit 7 gives the fundamental principles regarding joinery – work estimation, builder's hardware, etc. It also deals with doors, windows, glazing, their specifications, types, classifications and rate analysis.

Finally, the work procedures and methods of accounting commonly used in government construction agencies are discussed in Unit 8. The classification of works, procedures of administrative approval and technical sanction, tendering procedures, contracting documents and conditions of contracts are described in detail along with departmental methods of maintaining the accounts.

Throughout the course development, emphasis is given on solved examples and real life case studies to help you grasp the basic concepts and procedures.

At the end, we wish you all the best for your all educational endeavours.

The course material comprises Estimating and Quantity Surveying-I is structured into easy-to-grasp 8 units. It lays the foundation for understanding the *basics* ***of estimation*** of quantities in civil engineering projects so that a keen student can later on take off into intricate quantity surveying exercises.

Unit 1 outlines the estimation of first item of work – earthwork – encountered in the construction of buildings, roads and canals.

Unit 2 discusses the quantification of concrete – lime and plain cement concrete – in buildings, such as in foundations, floors or on roof slabs.

Next common item of work, namely, brick work in foundations and superstructure is dealt in Unit 3; and identifies deductions that are to be made from the gross quantity – doors, windows, and lintels, beams etc.

Unit 4, explains the basics of estimating timber in RCC from work (a very common item in civil engineering projects), timber in trusses, and steel in steal trusses.

Unit 5 deals with bar bending schedules (in RCC items), placement of reinforcement, and other related items.

Unit 6 introduces estimation of plastering, painting, white washing, etc. in buildings.

Unit 7 gives the fundamental principles regarding joinery – work estimation, builder's hardware etc.

Unit 8 briefly introduces procedures of work, maintenance of accounts in Public Works projects – as essential concomitant technical skill that a civil engineer should have.