



# **CE 208**

## **Quantity Surveying**



**Department of Civil Engineering**  
**Ahsanullah University of Science and Technology**

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## Preface

Quantity surveying refers to the estimation of materials as well as the final cost estimation for any project. Cost estimating is one of the most important steps in project management. Cost estimation establishes the baseline of the predicted project cost at different stages of development of the project. This lab manual intends to introduce the students with the estimation of moderate-size structures, i.e., residential building, culvert, underground water reservoir, retaining wall as well as estimation for excavation. The examples are imaginary structures, but the basic process of the calculations will pave the way to estimate real structures.

The authors are highly indebted to their colleagues for their constant support and guidance during the course of preparing this manual. In addition, estimation concepts were taken from Estimating Building Costs for the Residential and Light Commercial Construction Professional, by Wayne J. el. Pico, Estimating for Residential Construction by David Pratt. Besides, practical estimating aspects were studied from Consultants Estimating Manual, Division of Capital Asset Management, Commonwealth of Massachusetts (2006), while the pictures, where referenced, were collected from the internet.

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## Part 1: Introduction to Quantity Surveying

Quantity surveying is an assessment of the cost based on certain rates of materials and labour. An estimate should be realistic, and an assessment should be made on actual conditions of market. Estimation is undoubtedly one of the most important aspects of a construction project. A good estimation saves the expenditure to a great extent and ensures optimum use of materials. Estimation is very much technical. It requires good knowledge on structural design, engineering materials, and practical experience.

Essentials in a good Quantity Surveyor: What are the essentials in a good Quantity Surveyor? He must be able to clearly describe the requirement of the Architect in proper unambiguous language and arrange his bill of quantities (BoQ) so that the Builder can quickly, efficiently, and accurately arrive at the estimated cost of the work. The Quantity Surveyor must have a sound knowledge of building materials, construction, and customs prevailing in the trade. He must be accurate in his work and calculations.

### 1.1 Study of Drawings

It would be extremely premature if an attempt were to be made at the taking on: immediately on receipt of the drawings. Much has to be accomplished before proceeding to take out quantities from the drawings. Many errors can be avoided if the following steps are taken before entertaining any thought of taking off:

- (1) Look over the drawings and attempt to visualize the work entitled.
- (2) Study the contents that are in agreement with one another.
- (3) Check drawings carefully to see that plans, elevations, sections and details, if any the dimensions on the drawings to make sure that each overall dimension agrees with the total room dimensions. If serious errors are discovered, the architect should be informed; but if the discrepancy is due to the result of slight arithmetical error, the drawings should be corrected.
- (4) If the dimensions do not exist in some places, then it is always better to write them in. These missing dimensions should be worked out from other dimensions, as far as possible, scaling them from the drawing being the last resort.

### 1.2 Bill of Quantities (BoQ)

When one wants to buy a table, he asks the cabinet maker as to what it would cost. The cabinet maker before giving the cost would like to know the detailed specification of the table, i.e., its size length, breadth, height, design, type of timber and the finish required. Once the specification is known the cabinet maker will give the value of the table by working out cost of materials and labour required and adding his overhead and profit. Similarly, a prospective building owner wants to know, before placing the order, what the cost of his building would be. To work out the cost of a building, detailed quantities have to be worked out in accordance with the requirement of the Standard Method of measurement and price by the Builder. These quantities when collected



together into a bill, form a bill of quantities. The advantages of a bill of quantities are as follows:

- (1) It forms a common basis for competitive tendering which is necessary to obtain a reasonable value for consideration.
- (2) It forms in itself a basis of rates for measured work which can be used in the contract for valuation of variations and final account.
- (3) It is used in building operations for the completion of interim payments.

The following points are essential in the production of good bill of quantities:

- (1) A good knowledge of building construction, as without this, the correct interpretation of the drawings would not be possible.
- (2) Accuracy and neatness in measuring and setting out.
- (3) A thorough knowledge of writing descriptions in concise and clear language which will translate the drawings into words.

### **1.3 What is Specification?**

A specification is a special description of a particular subject. An engineering specification contains detailed description of all workmanship and materials which are required to complete an engineering project in accordance with its drawings and details. The technical drawings of a structure will show the proportions and relative positions of the various components of the structure. It is not often possible to furnish the information on the drawings, regarding the quality of materials to be used and the quality of workmanship to be achieved during construction, due to shortage of space. This data regarding the materials and workmanship is conveyed in a separate contract document, which is known as the "Specifications" for the work. Thus, the drawings with the specifications will completely define the structure. The "specification" is furnished separately along with the drawings and is an essential part of all engineering contracts.

### **1.4 Necessity of Specifications**

The necessities of specifications are as follows:

- (a) The cost of unit quantity of work is governed by its specification.
- (b) Specifications of a work are required to describe the quality and quantity of different materials required for a construction work and is one of the essential contract documents. Thus, a contractor can make a program to procure the materials required for a project and the owner can check the quality of materials conforming to the specification avoiding dispute with the contractor.
- (c) This also specifies the workmanship and the method of doing the work. Thus, specification of a work serves as a guide to the supervising staff of the contractor as well as to the owner to execute the work to their satisfaction.
- (d) A work is carried according to its specification and the contractor is paid for the same. Any change in specification changes the tendered rate.



- (e) As the rate of a work is based on specification, a contractor can calculate the rates of various items of works in a tender with his procurement rates of materials and labour. Thus, tender paper without specifications of works is baseless, incomplete, and invalid.
- (f) Specification is necessary to specify equipment, tools, and plants to be engaged for a work and thus enables to procure them beforehand.
- (g) The necessity of specification is to verify and check the strength of materials for a work involved in a project.
- (h) Specification is an essential contract document and required for arbitration of court cases.

### 1.5 Main Items of Works of Building:

As per ASTM Standard Classification for Building Elements and Related Sitework - UNIFORMAT II (ASTM E1557-09, 2015), the main items of works of building are:

1. **Earthwork:** Earthwork in excavation and earthwork taken out accurately under different items.
2. **Concrete in Foundation:** Foundation concrete consists of lime concrete or weak/lean cement concrete. The proportion of cement concrete in foundation may be 1:4:8 or 1:5:10.
3. **Brick Flat Soling:** When the soil is weak or bad, one layer of dry brick or stone soling is applied below the foundation concrete. This soling layer is computed in square units specifying the thickness.
4. **Damp Proof Course:** DPC usually of 2.5 cm (1 inch) thick rich cement concrete 1:1.5:3 or 2 cm (.75 inch) thick rich cement mortar 1:2, mixed with standard water proofing material, is provided at the plinth level to full width of plinth wall and the quantities are computed in square units. It is not provided at veranda openings.
5. **Masonry:** Foundation and plinth masonry is taken under one item, and masonry in superstructure is taken under a separate item. In storied building, the masonry in each storey is tabulated separately. Proper deductions are made for openings as doors, windows, lintels etc. Arch masonry work is taken out separately.
6. **Arch Masonry Works:** Masonry work in arches is calculated in cubic units separately by multiplying the mean length of the arch by the thickness of the arch and by the breadth of the wall.
7. **Lintels over Openings:** Length of lintel is equal to the clear span plus two bearings. If the dimension of bearing is not given, the bearing may be taken as same as the thickness of lintel with a minimum of 12 cm. (4.50 inch).
8. **RCC & RB Work:** The quantities in roof or floor slab, beams, lintels, columns, foundations are calculated in cubic units exclusive of steel reinforcements and its bending but inclusive of centering and shuttering and fixing and binding reinforcement in position. The reinforcement including its bending is taken up separately under steel works. For this purpose, 0.6 % to 1 % of RCC by volume may be taken for steel.
9. **Flooring and Roofing:**
  - (i) **Ground Floor:** The base lime concrete and floor finishing of CC or stone or marble or mosaic etc. are usually taken as one job or one item and the quantity is calculated in square





units. The length and breadth are the inside dimensions from wall to wall of superstructure.

(ii) **1st floor, 2nd floor etc.:** Supporting structure is taken separately in cubic units as RCC and the floor finishing is taken separately in sq units as 2.5 cm or 4 cm (1 inch or 1.5 inch) CC or marble, mosaic etc.

**10. Plastering and Pointing:** Plastering usually 0.5-inch-thick is calculated in square metres. While deducting, the following rules are generally followed:

(i) For small openings up to 0.5 sq. m (5 sq. ft) no deduction is made and at the same time no additions are made for jambs, soffits and of sills of these openings.

(ii) For opening exceeding 0.5 sq. m (5 sq. ft) but not exceeding 3 sq. m (30 sq. ft) deduction is made for one face only and the other face is allowed for jambs, soffits and sills which are not taken into account separately.

(iii) For opening above 3 sq. m (30 sq. ft) deduction is made for both faces of the opening, and the jambs, soffits and sills are taken into account and added.

Plastering in ceiling usually of 12 mm (1/2 inch) thick and is computed in sq. m units under a separate head.

**11. Doors and Windows:** (i) Frame

(ii) Door and Window Shutters

**12. Iron Work:** Computed in Kg. or Quintal

**13. White Washing or Colour Washing or Distemping:** The quantities are computed in square units and are usually same as for plastering. The inside is usually white-washed and the outside is usually color-washed. The number of coats should be mentioned in the item.

**14. Painting:** Painting or Varnishing of doors and windows are computed in square meters, the dimension should be taken for outer dimensions of the frame i.e., the outer dimensions of doors and windows. Painting is usually done in two or three coats, usually over a coat of priming.

Electrification, Sanitary and Water Supply Works: For Sanitary and Water Supply Works 8% and for electrification 8% of the estimated cost of the building works is usually provided in the estimate.

Rates: Rates of different items in the estimate are the current rates for the completion of the items of work which include supply of materials, transport, labour, scaffolding, overheads, contractor's profit, taxes, etc. The rates are usually taken from the PWD Schedule of Rates.

## 1.6 What is Analysis of Rate?

The basis of arriving at a correct and reasonable rate per unit work or supply, for a particular item following its specification and detailed survey of materials, labour, equipment, etc. as required for the unit work and their prevailing rates may be called as an analysis of rate.





## 1.7 Purpose of Rate Analysis

Main purposes of rate analysis are the following:

- (a) To determine the current rate per unit of an item at the locality.
- (b) To examine the viability of rates offered by contractors.
- (c) To calculate the quantity of materials and labour strength required for the project planning.
- (d) To fix up labour contracts rates.

The price of an item of work is made up of the following components and a summation of these is the rate per unit of an item.

- (a) Cost of Materials
- (b) Cost of Labour
- (c) Cost of Equipment or Tools and Plants
- (d) Cost of Overheads or Establishment Charges (including incidental)
- (e) Profit

## 1.8 Factors Affecting the Rate Analysis

The rate of an item of work mainly depends on the following factors:

- (1) Specification of the item which indicates the quality and proportion of materials, the method of construction and protection of work.
- (2) The present rate of materials for the item of work up to the worksite.
- (3) Daily wages of different categories of labourer at the locality with their respective outputs.
- (4) The range of lead and lift required for deposition of materials to carry out the item or work.
- (5) Percentage charge of overheads which includes insurance and the possibility of theft or loss, etc.
- (6) The range of profit and availability of water in connection with the construction work.

Besides these the site condition, site organization, and cost control during execution etc. should be considered as these factors affect the cost per unit of work done at site.

## Part 2: Reinforcement Estimation of a RCC Slab

### 2.1 Reinforcement used in the RCC

Two types of steel are used in RCC work. They are

1. Plain round mild steel bar
2. Deformed bar

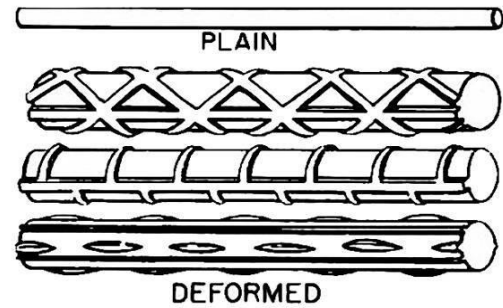


Figure 2.1: Typical Reinforcement

Designation and cross-sectional area of ASTM standard reinforcing bars are given below:

Table 2.1: Diameter and Nominal Cross-Section Area of ASTM Standard Reinforcing Bars

Bar No.	Diameter (in)	Nominal Area (in <sup>2</sup> )
#3	3/8	0.11
#4	4/8	0.20
#5	5/8	0.31
#6	6/8	0.44
#7	7/8	0.60
#8	8/8	0.79
#9	9/8	1.00
#10	10/8	1.27
#11	11/8	1.56

### 2.2 Cover and Clear Cover in RCC

**Cover:** Refers to the distance of outer concrete surface from C.G. of steel.

**Clear cover:** Refers to the distance of outer concrete surface from edge of steel.

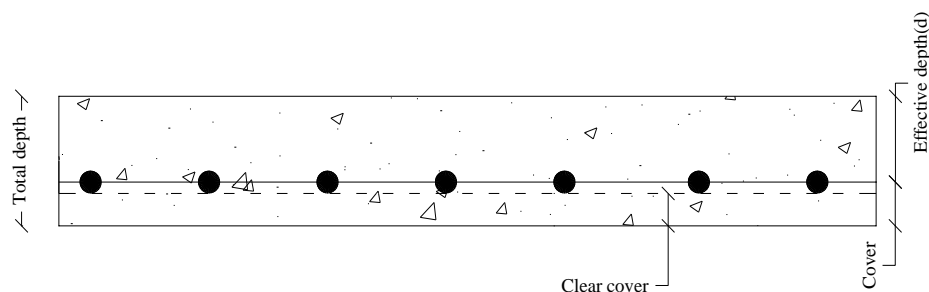


Figure 2.2: Cover and Clear cover in RCC

Reinforcement covering is necessary for the following reasons:

3. To protect reinforcement/steel from weathering effect i.e., corrosion.
4. To protect from fire.
5. The need for adequate adhesion between the steel and concrete.
6. The need to create cable and pipe channels without harming the reinforcement.

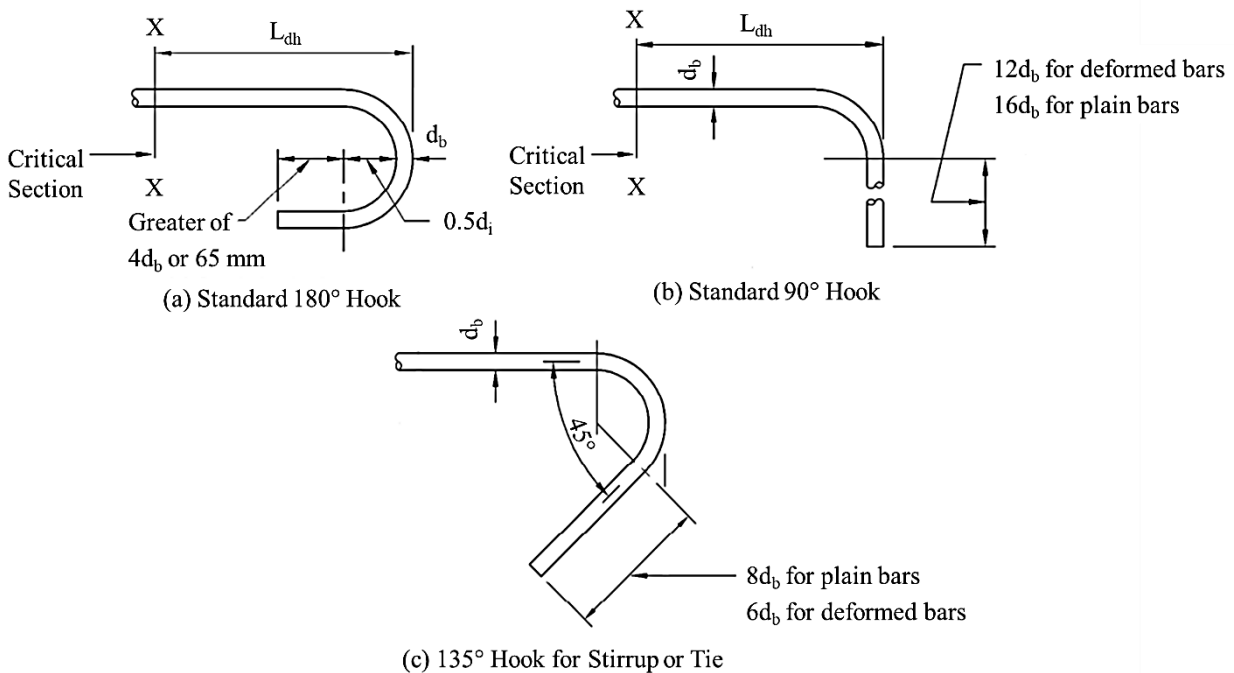
According to the ACI code minimum cover should be maintained in all kind of RCC works. ACI code provisions are given in the following table.

**Table 2.2: ACI Code Provisions for Minimum Cover and Clear Cover**

	<b>Beam/Column</b>	<b>Slab</b>
Clear cover	1.5 inch	0.75 inch
Cover	2.5 inch	1 inch

## 2.2 Reinforcement Hooks

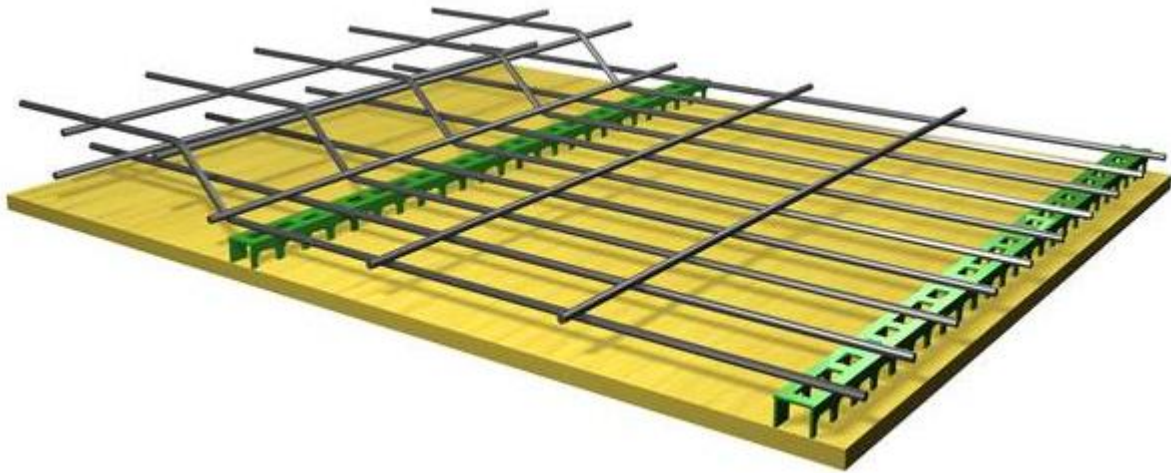
In RCC work, reinforcements are used in concrete to take tension. To achieve the good performance i.e., strong bond between concrete and steel, hooks are provided at the ends of the all reinforcing bars (especially in plain bars). Typical length of one hook is  $9d_b$  to  $12d_b$ , where  $d_b$  is the diameter of the hook bar.



**Figure 2.3: Standard Hooks**

### 2.3 Type of Reinforcement Used in Slab

1. Straight bar [lies at bottom]
2. Cranked bar [lies at top and bottom depending on cranking]
3. Extra top [lies at top]



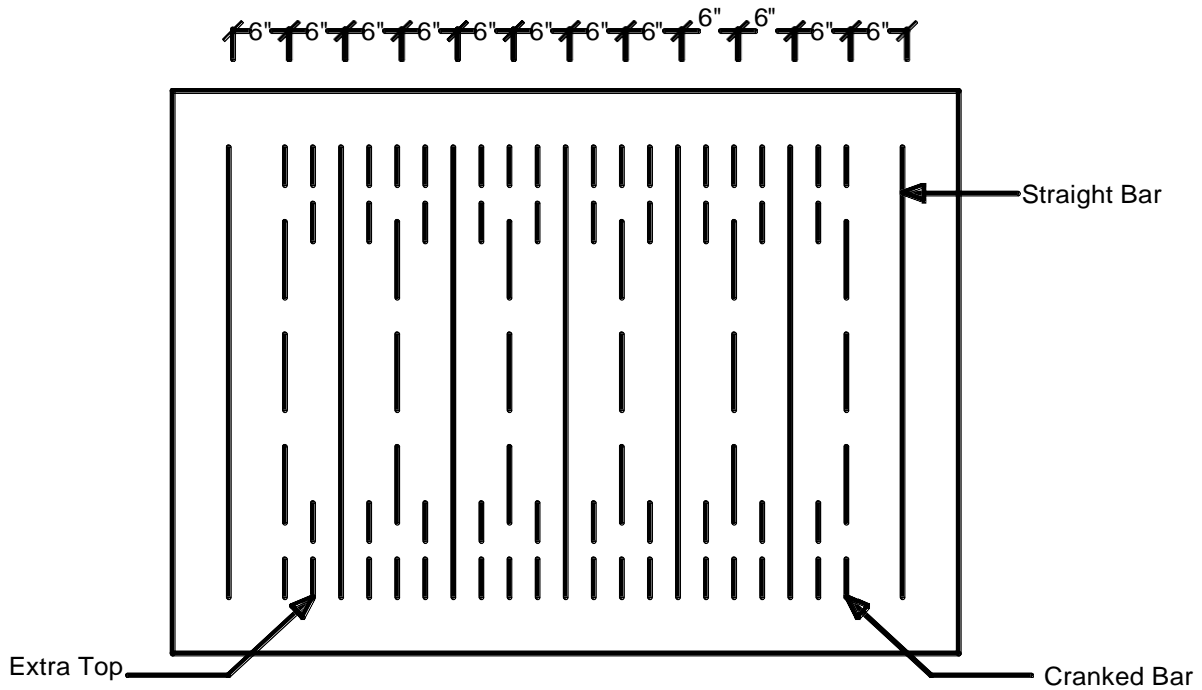
**Figure 2.4: Typical Slab Reinforcement Pattern (straight & cranked bar).**

### 2.4 Rules for Slab Reinforcement Distribution

1. Start with a straight bar and end with a straight bar
2. Cranked bars are in between straight bars.
3. Extra tops are in between cranked bar.

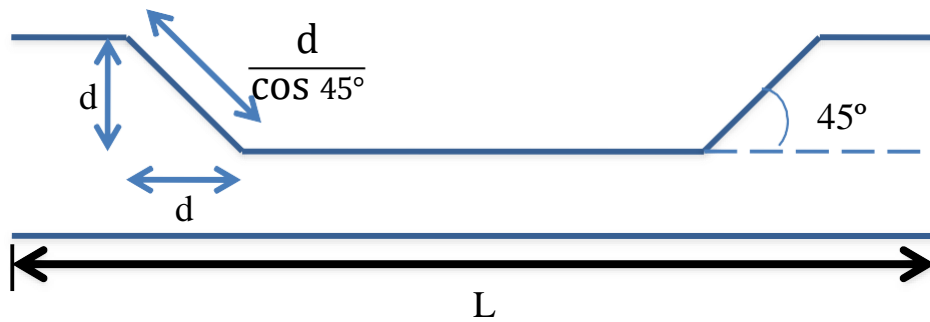
### 2.5 Meaning of Legends

- #3@ 6" c/c alternately cranked: #3 bars are distributed at bottom with a spacing 6". First bar should be straight and next bar should be cranked.
- 2#3 extra top in between cranked: 2#3 bars are placed in between cranked bars at top position on one side.



**Figure 2.5: Demonstration of Slab Reinforcement Pattern.**

**2.6 Length of a Cranked Bar**



**Figure 2.6: Length of a Cranked Bar**

Length of straight reinforcement = L

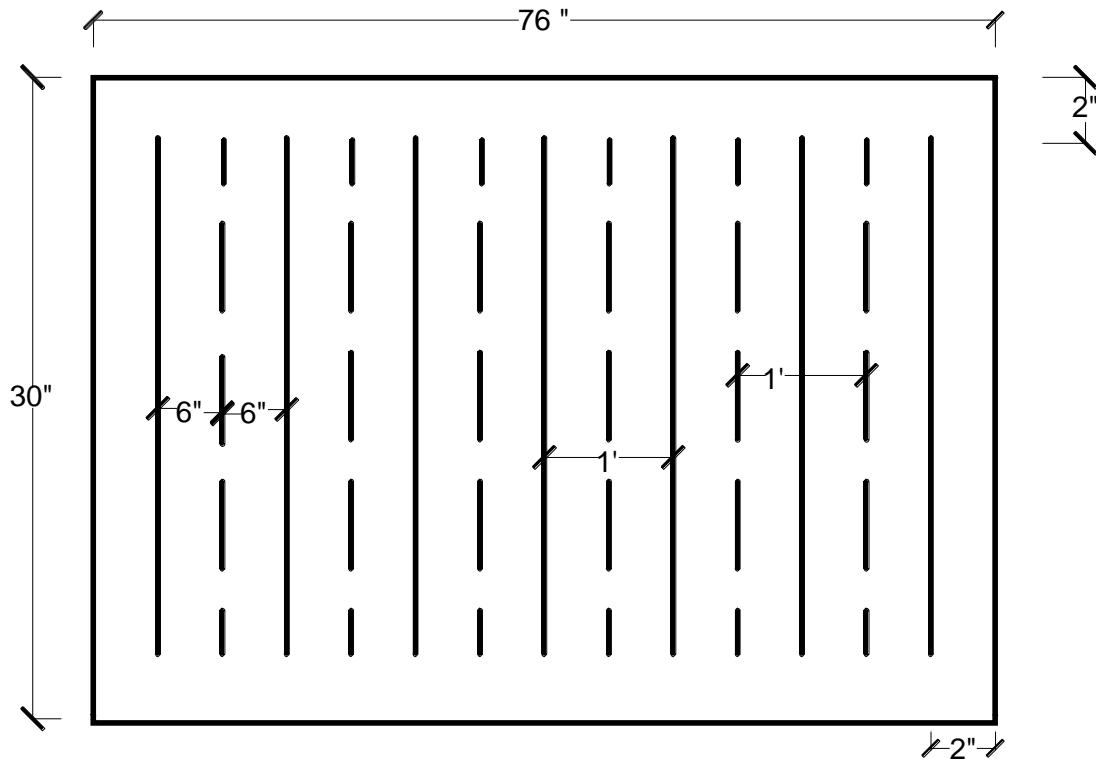
$$\begin{aligned} \text{Length of cranked reinforcement} &= (L - d - d) + d/\cos 45^\circ + d/\cos 45^\circ \\ &= (L - d - d) + 1.42d + 1.42d \\ &= L + 0.42d + 0.42d \end{aligned}$$

Length of cranked reinforcement = Length of straight bar + n (0.42d)

{Where, n= no. of cranked portion}

## 2.7 Number of Reinforcement (Alternately Cranked Distribution)

1. #3@ 6" c/c alt. ckd.

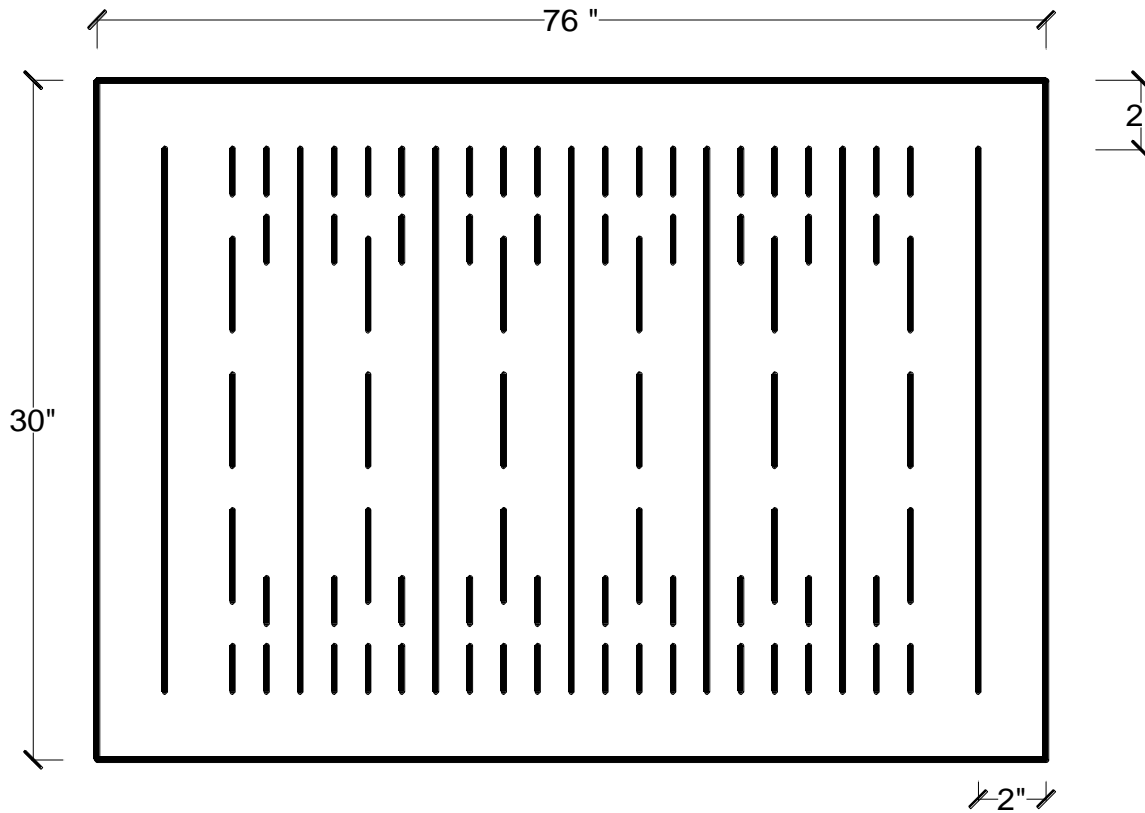


**Figure 2.7: Straight and Cranked Reinforcement Distribution**

No of straight bars =  $(76" - 2" - 2") / 12 + 1 = 6.16 \approx 7$  Nos. (Upper rounding)

No of cranked bars = No of straight bars - 1 = 7 - 1 = 6 Nos.

2. 2#3 extra top in between cranked



**Figure 2.8: Straight, Cranked and Extra Top Distribution**

No of extra top (one side) = Space available for extra top x No of extra top

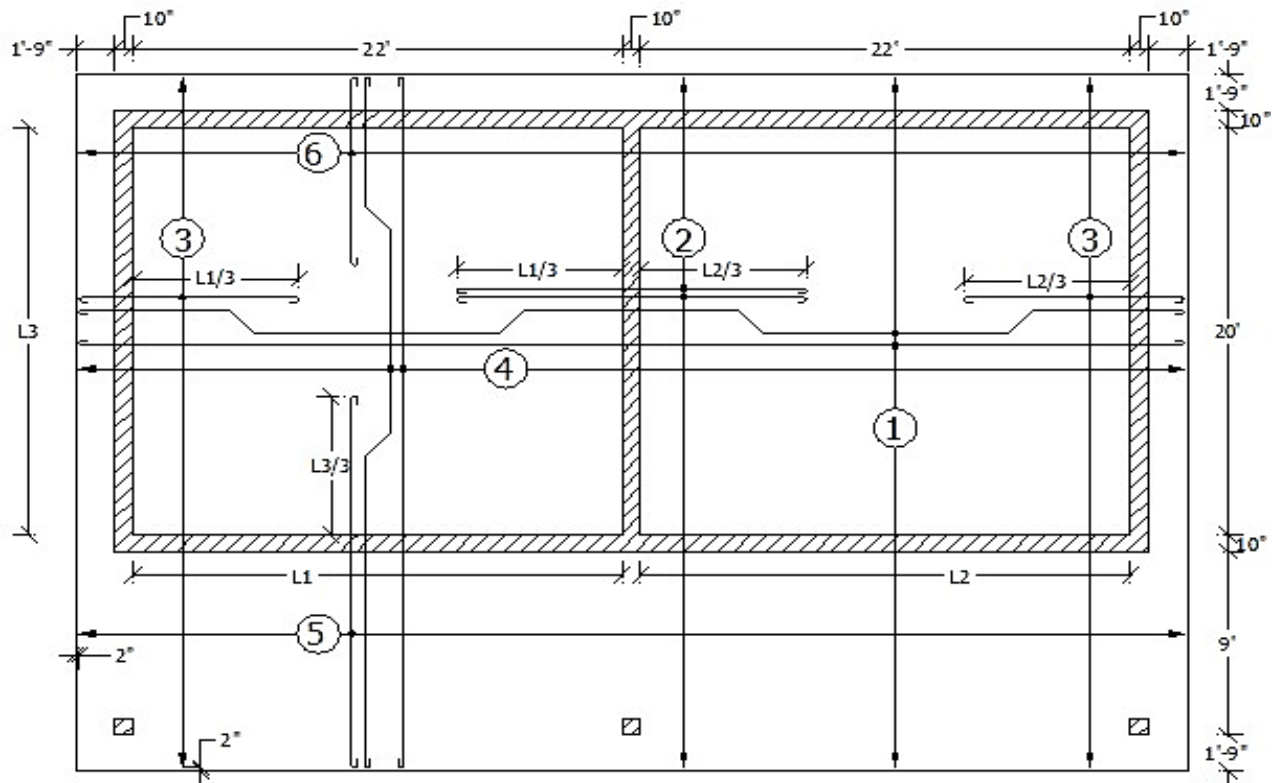
$$= (\text{No of cranked bar} - 1) \times 2 = (6 - 1) \times 2 = 10 \text{ Nos.}$$

**Table 2.3: Nominal Weight of the ASTM standard Reinforcing Bar**

U.S. rebar size chart			
Imperial Bar Size	Metric Size (mm)	Mass per unit length	
		lb/ft	(kg/m)
#3	10	0.376	0.561
#4	13	0.668	0.996
#5	16	1.043	1.556
#6	19	1.502	2.24
#7	22	2.044	3.049
#8	25	2.670	3.982
#9	29	3.400	5.071
#10	32	4.303	6.418
#11	36	5.313	7.924
#14	43	7.650	11.41
#18	57	13.60	20.284



## 2.8 Worked Out Problem



### Legends:

- (1) #4 @ 6" c/c alt. ckd
- (2) 2#4 extra top in between ckd. bars
- (3) 1#3 extra top in between ckd. bars
- (4) #3 @ 4" c/c alt. ckd
- (5) 1#4 extra top in between ckd. Bars
- (6) 1#3 extra top in between ckd. bars

Slab Thickness = 5"  
Cover = 1"

**Figure 2.9: Reinforcement Detailing for a 5-inch Slab Supported on Masonry Wall**



## Reinforcement Estimation

**Table 2.4: Calculation of Reinforcement Estimation for the Workout Problem**

Bar	Bar Designation	No. [rounded to upper 1]	Length (ft)	Total Length (ft)
Long Direction	#4 Straight	$\frac{34'2"-2"}{12} + 1 = 35$	$50' - 2-2 = 49.67'$	1738.33
	#4 Cranked	$35 - 1 = 34$	$49.67' + 4 \times 0.42 \times \left(\frac{4}{12}\right) = 50.23'$	1707.82
	#3 Extra top	$(34 - 1) \times 2 = 66$	$1'9" - 2"+10" + \frac{22'}{3} = 9.75'$	643.50
	#4 Extra top	$(34 - 1) \times 2 = 66$	$\frac{22'}{3} + 10" + \frac{22'}{3} = 15.5'$	1023
	#3 Hook	$66 \times 2 = 132$	$10 \times \frac{3}{8} \times \frac{1}{12} = 0.3125$	55.04
	#4 Hook	$(35 + 34 + 66) \times 2 = 270$	$10 \times \frac{4}{8} \times \frac{1}{12} = 0.417$	112.59
Short Direction	#3 Straight	$\frac{50' - 2" - 2"}{8} + 1 = 76$	$34'2" - 2" - 2" = 33.83'$	2571.33
	#3 Cranked	$76 - 1 = 75$	$33.83' + 2 \times 0.42 \times \left(\frac{4}{12}\right) = 34.11'$	2558.25
	#3 Extra top	$75 - 1 = 74$	$1'9" - 2"+10" + \frac{20'}{3} = 9.08'$	672.16
	#4 Extra top	$75 - 1 = 74$	$1'9" - 2"+9'+10" + \frac{20'}{3} = 18.08'$	1338.16
	#3 Hook	$(76 + 75 + 74) \times 2 = 450$	$10 \times \frac{3}{8} \times \frac{1}{12} = 0.3125$	140.62
	#4 Hook	$74 \times 2 = 148$	$10 \times \frac{4}{8} \times \frac{1}{12} = 0.417$	61.716

**Table 2.5: Calculation of Weight of Reinforcement Bars for the Workout Problem**

Bar Designation	Total Length (ft)	Weight per unit length (lb/ft)	Weight (lb)
#3	6641	0.376	2498
#4	5982	0.668	3996



## Part 3: Estimation of a Residential Building

### 3.1 Basic Calculation of Estimation of Construction Materials

- ❖ Find out the quantities in 100 cft cement concrete. Mix ratio (C: FA: CA= 1:2:4) and shrinkage factor 1.5.

➤ Volume of concrete (before mixing) =  $100 \times 1.5 = 150$  cft

Required materials:

$$\text{Cement} = \frac{1}{1+2+4} \times 150 = 21.428 \text{ cft} = \frac{21.428}{1.25} \text{ bags} = 17.142 \text{ bags} \approx 18 \text{ bags}$$

(1 bag cement = 1.25 cft = 50 kg)

$$\text{FA} = \frac{2}{1+2+4} \times 150 = 42.856 \text{ cft}$$

$$\text{CA} = \frac{4}{7} \times 150 = 85.712 \text{ cft}$$

- ❖ Find out the quantities in 100 cft brick masonry. Factor of safety = 1.2 for wastage. Mortar mix ratio (cement: sand) = 1:4 and shrinkage factor 1.5.

➤ Volume of brick masonry =  $100 \times 1.2 = 120$  cft

Nominal size of brick (with mortar) =  $10" \times 5" \times 3"$

$$\text{No. of Bricks required} = \frac{120}{\frac{10}{12} \times \frac{5}{12} \times \frac{3}{12}} = 1382.4 \approx 1383$$

$$\text{Volume of 1383 no. of bricks with mortar} = 1383 \times \frac{10}{12} \times \frac{5}{12} \times \frac{3}{12} = 120.052 \text{ cft}$$

Actual size of brick without mortar =  $9.5" \times 4.5" \times 2.75"$

$$\text{Volume of 1383 no. of bricks without mortar} = 1383 \times \frac{9.5}{12} \times \frac{4.5}{12} \times \frac{2.75}{12} = 94.091 \text{ cft}$$

Volume of mortar required =  $120.052 - 94.091 = 25.961$  cft

Calculate quantity of cement and sand like previous problem.



### 3.2 Unit Weight of Some Important Materials

**Table 3.1: Unit Weight of Some Important Materials**

Materials	Unit Wt. (lb/cft)
Brick work	120
Cement	90
RCC	150
Mild steel	490

### 3.3 Assignment

**Question (1):** Find out the ingredients required for making 20 ft x 18 ft concrete slab (thickness = 5 inch). Given, mix ratio = 1: 1.5: 3.

Answer (1): cement = 32.72727273 bags; sand (fine aggregate) = 61.36363636 cft & brick/stone chips (coarse aggregate) = 122.7272727 cft.

**Question (2):** Suppose, you have 50 bags of cement. What volume of concrete you can make from this 50 bags cement with a mix ratio of 1: 1.25: 2.50.

Answer (2): 197.9166667 cft dry concrete.

**Question (3):** Suppose, you have 5000 Nos. of full-size brick. You want to make a brick wall. What will be the volume of brickwork?

Answer (3): 434.0277778 cft.

**Question (4):** In question (3), determine the number of cement bags & volume of sand if mortar mix ratio is 1:4.

Answer (4): 22.52604167 bags of cement; 112.6302083 cft sand.

**Question (5):** Given a 10-inch-thick brick wall having a length of 30 feet and height of 10 feet. The wall contains two doors (7 feet height & 3.5 feet width) and two windows (4 feet height & 6 feet width) and a continuous lintel (25 feet length & 6 inch height). Using a factor of safety of 1.2 and cement : sand ratio in mortar = 1 : 4, Estimate the no. of bricks, no. of bags of cement & sand required for the construction of the wall.

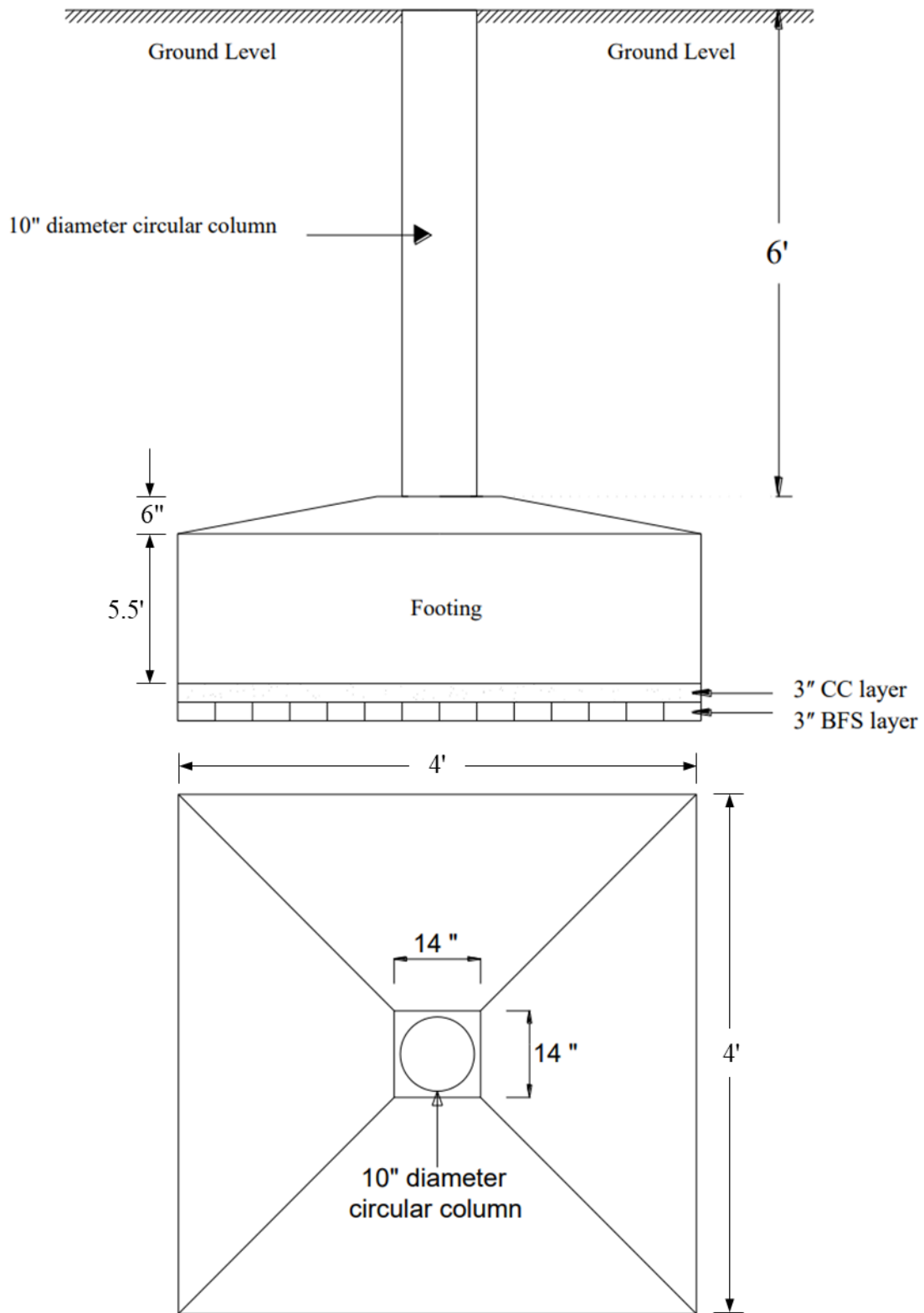
Answer (5): No. of bricks = 2195; cement = 9.88695 bags & sand co: 49.43475 cft.

**Question (6):** Lime concrete (3 inch thickness), casted over a RCC roof, has a plan area of 50 feet x 30 feet. Determine its ingredients (mix ratio = 2 : 2 : 7).

Answer (6): Lime = 102.2727 cft; surkhi = 102.2727 cft & brick chips = 357.9545 cft.

**Question (7):** Find out the ingredients required for the RCC foundation up to ground level (see Figure 4.1). Given, mix ratio = 1 : 2 : 4.

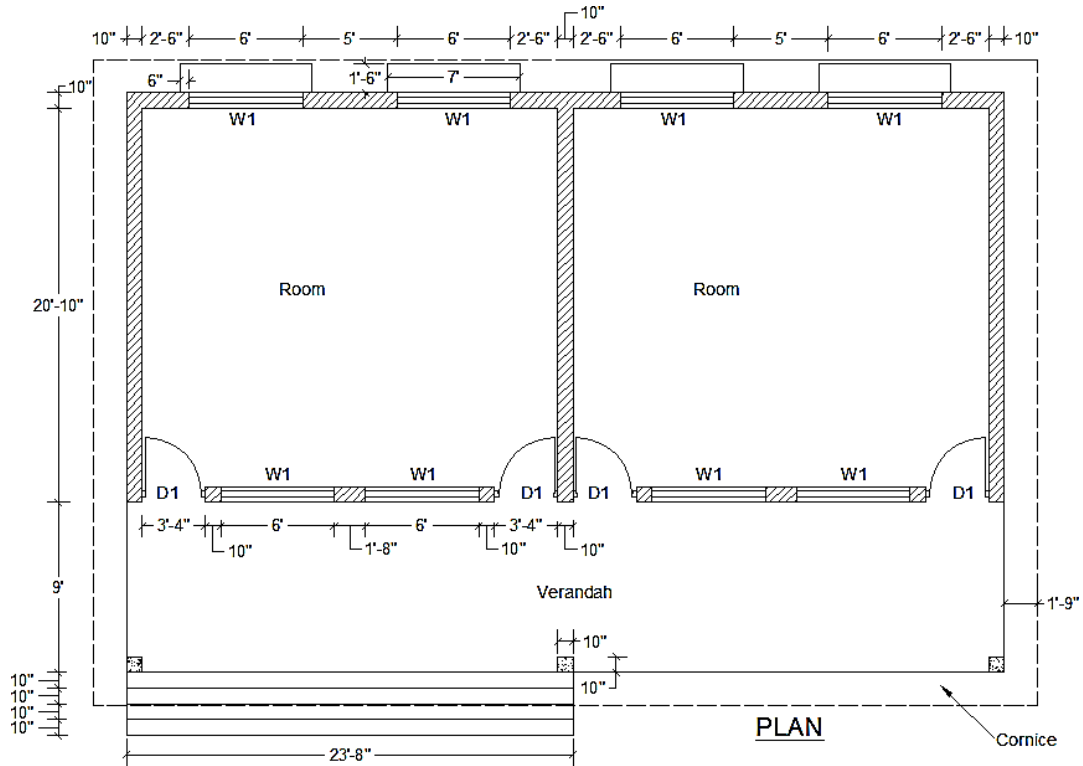
Answer (7): Do yourself



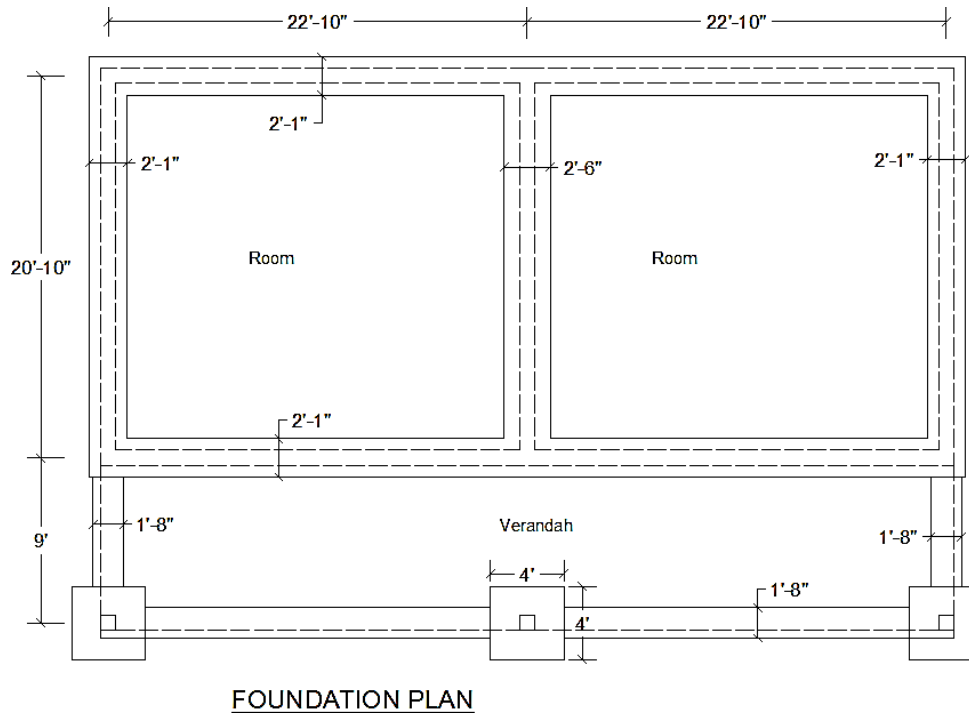
**Figure 3.1: Plan and Elevation of Foundation for Question 7 of Assignment**

### 3.4 Worked Out Problem

Estimate the materials required for the following residential building. Also find out the cost of all materials.

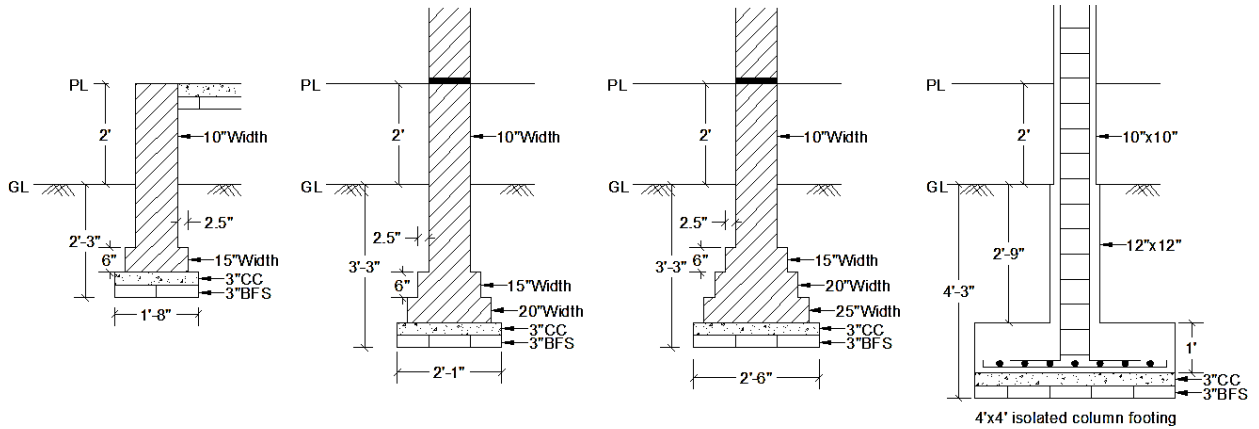


**Figure 3.2: Building Plan**

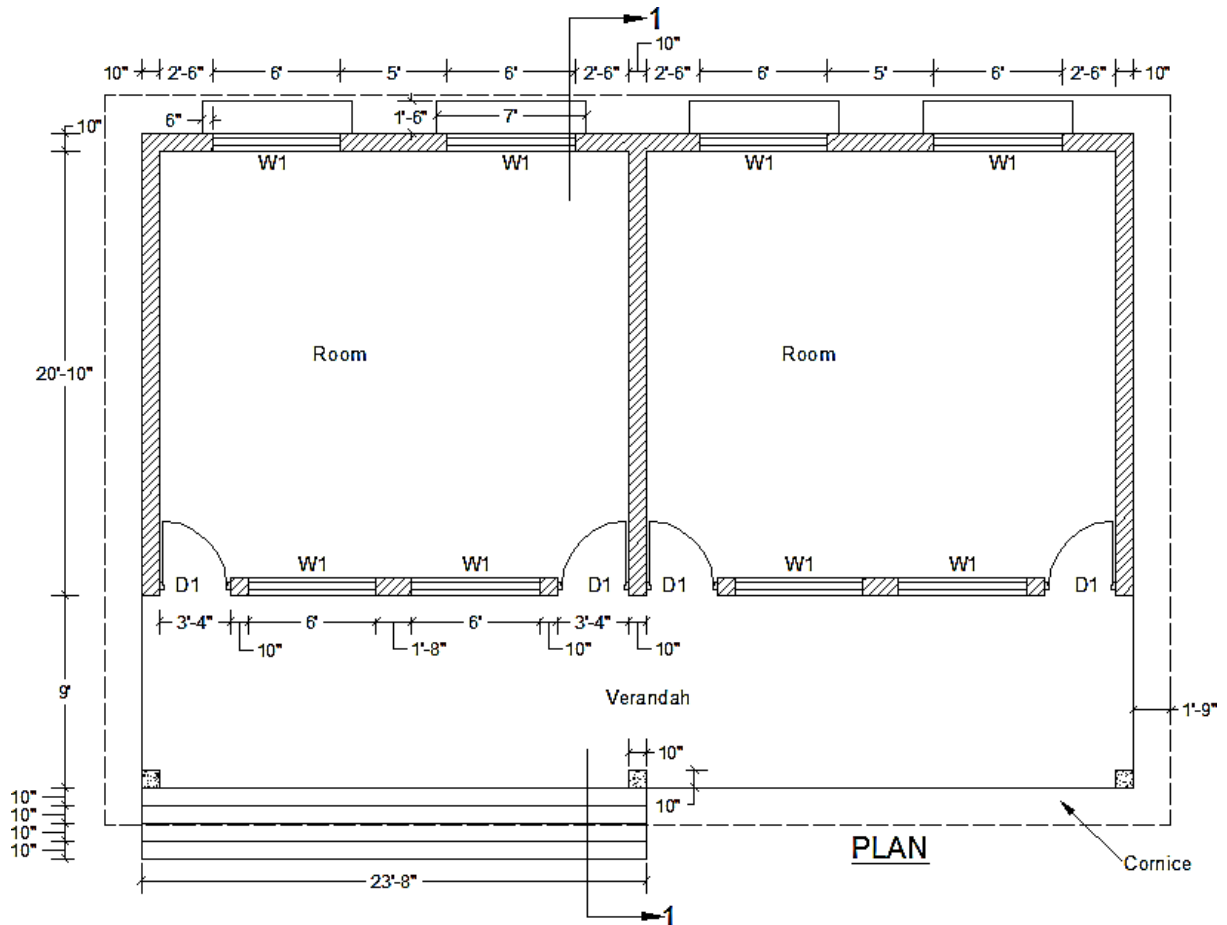


**FOUNDATION PLAN**

**Figure 3.3: Foundation Plan**



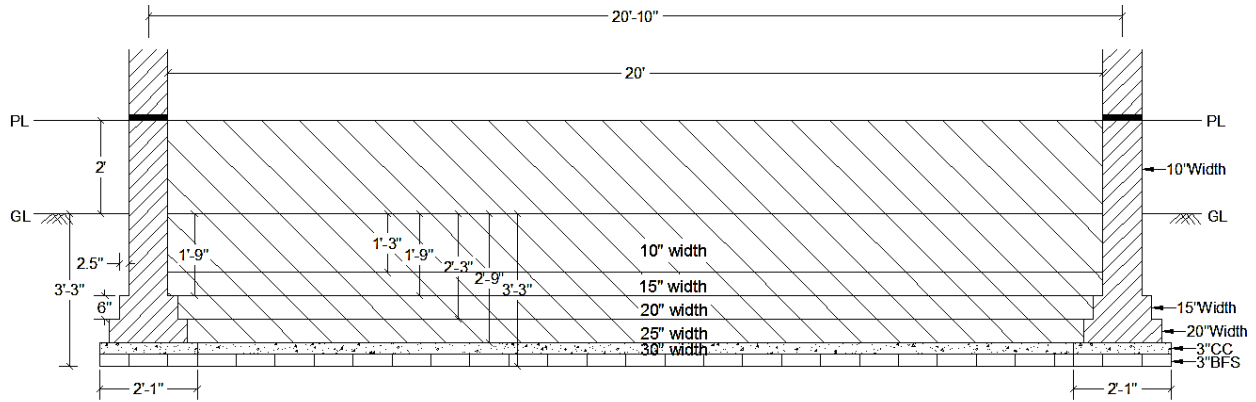
**Figure 3.4: Cross Sections of Foundations**



**Figure 3.5: Building Plan with Section Lines**

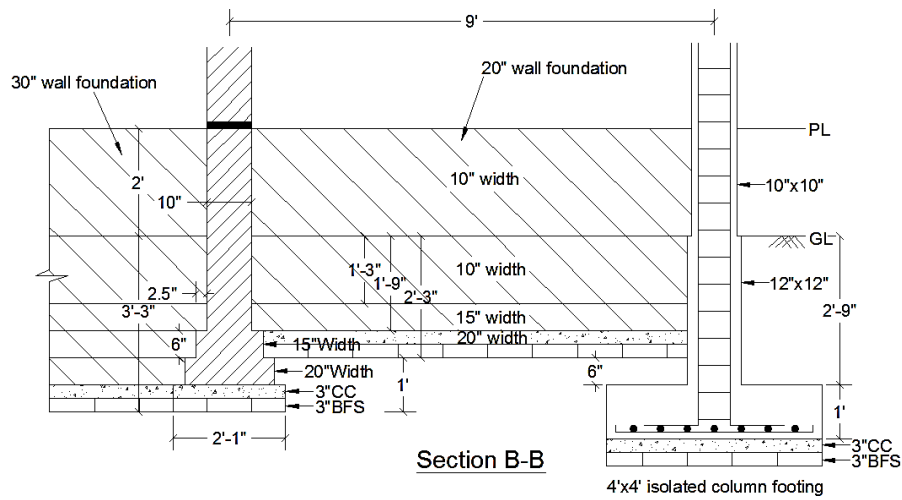






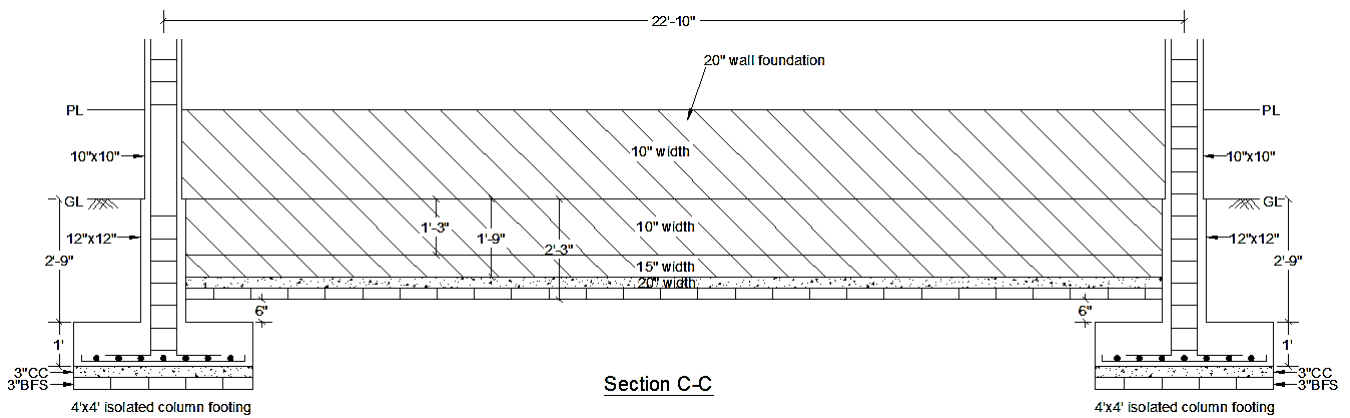
Section A-A

Figure 3.9: Elevation at Section A-A



Section B-B

Figure 3.10: Elevation at Section B-B



Section C-C

Figure 3.11: Elevation at Section C-C



Here,

V= Volume

L= Length along center line

B= Thickness/ Width

H= Height

**Earthwork Excavation: (Volume)**

For 25" wall foundation-

$$\text{Length} = 20'10'' \times 2 + 22'10'' \times 4 = 133'$$

$$\text{Width} = 2'1'' + 3'' \times 2 \text{ (extra in both side)} = 31''$$

$$\text{Height} = 3'3''$$

$$\text{Volume} = L \times W \times H = 1116.65 \text{ ft}^3$$

For 30" wall foundation-

$$\text{Length} = 20'10'' - 31'' = 18'3''$$

$$\text{Width} = 2'6'' + 3'' \times 2 \text{ (extra in both side)} = 36''$$

$$\text{Height} = 3'3''$$

$$\text{Volume} = L \times W \times H = 177.94 \text{ ft}^3$$

Column foundation-

$$\text{Volume} = L \times W \times H = (4'6'' \times 4'6'' \times 4'3'') \times 3 = 258.19 \text{ ft}^3$$

For 20" wall foundation-

$$\text{Length} = (9' - 31'' / 2 - 4'6'' / 2 \text{ (column footing)}) \times 2 + (22'10'' - 4'6'') \times 2 = 47'7''$$

$$\text{Width} = 20'' + 3'' \times 2 \text{ (extra in both side)} = 26''$$

$$\text{Height} = 2'3''$$

$$\text{Volume} = L \times W \times H = 231.97 \text{ ft}^3$$

$$\text{Total volume} = (1116.65 + 177.94 + 258.19 + 231.97) = 1784.75 \text{ ft}^3$$



**BFS (one layer below foundation): (Area)**

For 25" wall foundation-

$$\text{Length} = 20'10'' \times 2 + 22'10'' \times 4 = 133'$$

$$\text{Width} = 2'1'' = 25''$$

$$\text{Area} = L \times W = 277.08 \text{ ft}^2$$

For 30" wall foundation-

$$\text{Length} = 20'10'' - 2'1'' = 18'9''$$

$$\text{Width} = 2'6'' = 30''$$

$$\text{Area} = L \times W = 46.875 \text{ ft}^2$$

For column foundation-

$$\text{Length} = 4'$$

$$\text{Width} = 4'$$

$$\text{Area} = L \times W = 3 \times (4' \times 4') = 48 \text{ ft}^2$$

For 20" wall foundation-

$$\text{Length} = (9' - 1'3''/2 \text{ (due to 25" wall foundation)} - 1'/2 \text{ (due to column footing)}) \times 2 + (22'10'' - 1'/2 - 1'/2) \times 2 = 59'5''$$

$$\text{Width} = 1'8'' = 20''$$

$$\text{Area} = L \times W = 99.03 \text{ ft}^2$$

$$\text{Total Area of BFS} = (277.08 + 46.875 + 48 + 99.03) = 470.985 \text{ ft}^2$$

**Cement Concrete in Foundation: (Volume)**

To find volume of CC, multiply by the total area of BFS with thickness (3").

$$\text{Total volume of CC} = 470.985 \text{ ft}^2 \times 3''/12 = 117.75 \text{ ft}^3$$



**Brickwork in Foundation (up to GL): (Volume)**

For 25" wall foundation-

$$20'' \text{ width: } 133' \times 20'' / 12 \times 6'' / 12 = 110.83 \text{ ft}^3$$

$$15'' \text{ width: } 133' \times 15'' / 12 \times 6'' / 12 = 83.12 \text{ ft}^3$$

$$10'' \text{ width: } 133' \times 10'' / 12 \times 21'' / 12 = 193.95 \text{ ft}^3$$

$$\text{Total} = 387.9 \text{ ft}^3$$

For 30" wall foundation-

$$25'' \text{ width: } (18'9'' + 2.5'' \times 2) \times 25'' / 12 \times 6'' / 12 = 19.97 \text{ ft}^3$$

$$20'' \text{ width: } (19'2'' + 2.5'' \times 2) \times 20'' / 12 \times 6'' / 12 = 16.32 \text{ ft}^3$$

$$15'' \text{ width: } (19'7'' + 2.5'' \times 2) \times 15'' / 12 \times 6'' / 12 = 12.5 \text{ ft}^3$$

$$10'' \text{ width: } (19'7'' + 2.5'' \times 2) \times 10'' / 12 \times 15'' / 12 = 20.83 \text{ ft}^3$$

$$\text{Total} = 69.62 \text{ ft}^3$$

For 20" wall foundation-

$$15'' \text{ width: } (59'5'' + 2.5'' \times 2) \times 15'' / 12 \times 6'' / 12 = 37.4 \text{ ft}^3$$

$$10'' \text{ width: } (59'5'' + 2.5'' \times 2) \times 10'' / 12 \times 15'' / 12 = 62.33 \text{ ft}^3$$

$$\text{Total} = 99.73 \text{ ft}^3$$

**Brickwork in Foundation from GL to PL: (volume)**

$$25'' \text{ wall foundation} = 133' \times 10'' \times 2' = 221.67 \text{ ft}^3$$

$$30'' \text{ wall foundation} = 20' \times 10'' \times 2' = 33.33 \text{ ft}^3$$

$$20'' \text{ wall foundation} = ((9' - 5'' - 5'' + 22' 10'' - 5'' - 5'') \times 2) \times 10'' \times 2' = 100.56 \text{ ft}^3$$

$$\text{Total} = 355.56 \text{ ft}^3$$

**RCC in Footing up to GL: (Volume)**

$$\text{Base slab of footing} = 3 \times (4' \times 4' \times 1') = 48 \text{ ft}^3$$

$$\text{Column up to GL} = 3 \times (1' \times 1' \times 2'9'') = 8.25 \text{ ft}^3$$

$$\text{Total} = 56.25 \text{ ft}^3$$



**RCC in Column from GL to PL: (Volume)**

$$\text{Concrete volume} = 3 \times 10'' \times 10'' \times 2' = 4.167 \text{ ft}^3$$

**DPC (Damp Proof Course): (Volume)**

$$\text{Thickness} = 1.5''$$

$$25'' \text{ foundation} = 133' \times 10'' / 12 \times 1.5'' / 12 = 13.6 \text{ ft}^3$$

$$30'' \text{ foundation} = 20' \times 10'' / 12 \times 1.5'' / 12 = 2.1 \text{ ft}^3$$

$$\text{Deduct (door strip)} = 4' \times 3'4'' \times 10'' \times 1.5'' = 1.39 \text{ ft}^3$$

**BFS (one layer) in Floors: (Area)**

$$\text{Main room} = 2 \times (22' \times 20') = 880 \text{ ft}^2$$

$$\text{Verandah} = (46'6'' - 20'' \text{ (due to foundation below)}) \times (9' - 10'') = 366.1 \text{ ft}^2$$

$$\text{Total} = 1246.1 \text{ ft}^2$$

**CC (cement concrete) in Floors: (Volume)**

To find volume of CC, multiply by the total area of BFS with thickness (3'').

$$\text{Total volume} = 1246.1 \text{ ft}^2 \times 3'' / 12 = 311.53 \text{ ft}^3$$

**Floor Finish (thickness 1/4''): (Volume)**

$$1. \text{ Main room} = 2 \times 22' \times 20' \times 0.25'' / 12 = 18.33 \text{ ft}^3$$

$$2. \text{ Door} = 4 \times 3'4'' \times 10'' / 12 \times 0.25'' / 12 = 0.23 \text{ ft}^3$$

$$3. \text{ Verandah} = 46'6'' \times 9' \times 0.25'' / 12 = 8.72 \text{ ft}^3$$

$$\text{Deduct (due to column)} = 3 \times 10'' \times 10'' \times 0.25'' = 0.043 \text{ ft}^3$$

$$4. \text{ Stair steps} = 4 \times 23'8'' \times 1'4'' \times 0.25'' / 12 = 2.63 \text{ ft}^3$$

$$\text{Total} = 29.87 \text{ ft}^3$$



**Brick Wall in Superstructure: (Volume)**

$$\text{Wall} = (133' + 20') \times 10'' \times 10'7'' = 1349.375 \text{ ft}^3$$

Deduct:

1. Door (D1) =  $4 \times 3'4'' \times 10'' \times 7' = 77.78 \text{ ft}^3$

2. Window (W1) =  $8 \times 6' \times 10'' \times 4'6'' = 180 \text{ ft}^3$

3. Lintel over W1 =  $4 \times (6' + 2 \times 6'') \times 10'' \times 6'' = 11.67 \text{ ft}^3$

4. Lintel over D1+W1 =  $(22' \times 2 + 10'' + 2 \times 6'') \times 10'' \times 6'' = 19.1 \text{ ft}^3$

$$\text{Total} = 1060.825 \text{ ft}^3$$

**RCC in Column: (Volume)**

$$\text{RCC volume} = 3 \times 10'' \times 10'' \times 10'7'' = 22.05 \text{ ft}^3$$

**RCC in Lintel: (Volume)**

$$\text{Lintel over W1} = 4 \times 7' \times 10'' \times 6'' = 11.67 \text{ ft}^3$$

$$\text{Lintel over D1+W1} = 45'10'' \times 10'' \times 6'' = 19.1 \text{ ft}^3; \text{ Total} = 30.77 \text{ ft}^3$$

**RCC in Roof: (Volume)**

$$\text{RCC volume} = (46'6'' + 2 \times 1'9'') \times (30'8'' + 2 \times 1'9'') \times 5'' = 711.81 \text{ ft}^3$$

**LC (Lime concrete) in Roof: (Volume)**

$$\text{LC volume} = (50' - 10'') \times (34'2'' - 10'') \times 3'' = 409.72 \text{ ft}^3$$

**Bricks in Parapet: (Volume)**

$$\text{Brick} = (2 \times (50' - 5'' + 34'2'' - 5'')) \times 5'' \times 2' = 138.89 \text{ ft}^3$$





**Brick Work in Stair: (Volume)**

1. 1st step:  $23'8'' \times 10'' \times 6'' = 9.86 \text{ ft}^3$
  2. 2nd step:  $23'8'' \times 20'' \times 6'' = 19.72 \text{ ft}^3$
  3. 3rd step:  $23'8'' \times 30'' \times 6'' = 29.58 \text{ ft}^3$
  4. 4th step:  $23'8'' \times 40'' \times 6'' = 39.44 \text{ ft}^3$
- Total=  $98.6 \text{ ft}^3$

**R.C.C. in Drop Wall: (Volume)**

Length=  $(9'-10'') \times 2 + (22'10''-10'') \times 2 = 60'4''$   
 Width=  $5''$   
 Height=  $2'6''$   
 Volume=  $62.85 \text{ ft}^3$

**R.C.C. in Sunshade: (Volume)**

RCC Volume=  $4 \times ((3'' \times 6'') + (0.5 \times (3''+4'') \times 15'')) \times 7' = 13.71 \text{ ft}^3$

**Inside Plastering (thickness 0.25''): (Volume) Mix ratio- C:S= 1:6**

**1. Inside wall**

- a) Main room=  $2 \times 84' \times (10'7''-10''\text{skirting}) \times 0.25'' = 34.125 \text{ ft}^3$   
 Deduct, Door=  $4 \times 3'4'' \times (7'-10''\text{skirting}) \times 0.25'' = 2.18 \text{ ft}^3$   
 Window=  $8 \times 6' \times 4'6'' \times 0.25'' = 4.5 \text{ ft}^3$   
 Total=  $27.45 \text{ ft}^3$
- b) Verandah=  $(22'10'' \times 2 + 10'') \times (10'7''-10''\text{skirting}) \times 0.25'' = 9.45 \text{ ft}^3$   
 Deduct, Door=  $4 \times 3'4'' \times (7'-10''\text{skirting}) \times 0.25'' = 2.18 \text{ ft}^3$   
 Window=  $4 \times 6' \times 4'6'' \times 0.25'' = 2.25 \text{ ft}^3$   
 Droop wall=  $2 \times 5'' \times 2'6'' \times 0.25'' = 0.043 \text{ ft}^3$   
 Total=  $4.98 \text{ ft}^3$



## 2. Ceiling

a) Main room=  $2 \times 22' \times 20' \times 0.25'' = 18.33 \text{ ft}^3$

b) Verandah=  $46'6'' \times 9' \times 0.25'' = 8.72 \text{ ft}^3$

Deduct, Column=  $3 \times 10'' \times 10'' \times 0.25'' = 0.0434 \text{ ft}^3$

Drop wall=  $60'4'' \times 5'' \times 0.25'' = 0.524 \text{ ft}^3$

Total=  $26.48 \text{ ft}^3$

## 3. Edges

a) Door edges=  $4 \times (6'2'' + 3'4'' + 6'2'') \times 10'' \times 0.25'' = 1.09 \text{ ft}^3$

b) Window edges=  $8 \times (6' \times 2 + 4'6'' \times 2) \times 10'' \times 0.25'' = 2.92 \text{ ft}^3$

Total=  $4.01 \text{ ft}^3$

## 4. Drop Wall (inside face)

a) Inside face=  $60'4'' \times 2'6'' \times 0.25'' = 3.14 \text{ ft}^3$

b) Bottom edge=  $60'4'' \times 5'' \times 0.25'' = 0.524 \text{ ft}^3$

Total=  $3.66 \text{ ft}^3$

Total volume of inside plastering=  $66.58 \text{ ft}^3$

## Outside Plastering (thickness 0.5''): (Volume) Mix ratio- C:S= 1:4

1. GL to PL=  $(46'6'' \times 2 + 30'8'' \times 2) \times 2' \times 0.5'' = 12.86 \text{ ft}^3$

Deduct, Stair=  $23'8'' \times 2' \times 0.5'' = 1.97 \text{ ft}^3$

Total=  $10.89 \text{ ft}^3$

2. Outside Wall=  $(46'6'' + 21'8'' \times 2) \times 10'7'' \times 0.5'' = 39.61 \text{ ft}^3$

Deduct, Window=  $4 \times 6' \times 4'6'' \times 0.5'' = 4.5 \text{ ft}^3$

Sunshade=  $4 \times 7' \times 4'' \times 0.5'' = 0.39 \text{ ft}^3$

Total=  $34.72 \text{ ft}^3$

3. Columns=  $3 \times (10'' \times 4) \times (10'7'' - 10'') \times 0.5'' = 4.06 \text{ ft}^3$

Deduct, Drop wall=  $6 \times (2'6'' \times 5'' \times 0.5'') = 0.26 \text{ ft}^3$

Total=  $3.8 \text{ ft}^3$



#### 4. Stairs

$$1\text{st step} = 2 \times 10'' \times 6'' \times 0.5'' = 60 \text{ in}^3 = 0.035 \text{ ft}^3, 2\text{nd step} = 2 \times 60 \text{ in}^3 = 0.07 \text{ ft}^3$$

$$3\text{rd step} = 3 \times 60 \text{ in}^3 = 0.1 \text{ ft}^3, 4\text{th step} = 4 \times 60 \text{ in}^3 = 0.14 \text{ ft}^3$$

$$\text{Total} = 0.345 \text{ ft}^3$$

#### 5. Parapet

$$\text{a) Inside} = (49'2'' \times 2 + 33'4'' \times 2) \times 2' \times 0.5'' = 13.75 \text{ ft}^3$$

$$\text{b) Outside} = (50' \times 2 + 34'2'' \times 2) \times 2' \times 0.5'' = 14.03 \text{ ft}^3$$

$$\text{c) Top} = (49'7'' \times 2 + 33'9'' \times 2) \times 5'' \times 0.5'' = 2.9 \text{ ft}^3$$

$$\text{Total} = 30.68 \text{ ft}^3$$

#### 6. Sunshade

$$\text{a) Bottom face} = 4 \times (7' \times 1'6'' \times 0.5'') = 1.75 \text{ ft}^3$$

$$\text{b) Side edge} = 4 \times \{ \{ (6'' \times 3'' + 0.5 \times (3'' + 4'')) \times 15'' \} \times 2 \times 0.5'' \} = 0.16 \text{ ft}^3$$

$$\text{c) Front face} = 4 \times (7' \times 6'' \times 0.5'') = 0.58 \text{ ft}^3$$

$$\text{d) Top face} = 4 \times \{ 7' \times (3'' + 3'' + 15.04'') \times 0.5'' \} = 2.05 \text{ ft}^3$$

$$\text{e) Inside face} = 4 \times (3'' \times 7' \times 0.5'') = 0.29 \text{ ft}^3$$

$$\text{Total} = 4.83 \text{ ft}^3$$

#### 7. Cornice

$$\text{a) Side edge} = (50' \times 2 + 34'2'' \times 2) \times 5'' \times 0.5'' = 2.92 \text{ ft}^3$$

$$\text{b) Bottom edge} = \{ (30'8'' + 1'9'') \times 2 + (46'6'' + 1'9'') \times 2 \} \times 1'9'' \times 0.5'' = 11.76 \text{ ft}^3$$

$$\text{Total} = 14.68 \text{ ft}^3$$

#### 8. Drop Wall

$$\text{Outside face} = 60'4'' \times 2'6'' \times 0.5'' = 6.28 \text{ ft}^3$$

$$\text{Total volume} = 106.23 \text{ ft}^3$$



**Skirting (Thickness 0.75"): (Volume)**

1. Main room=  $(20' \times 2 + 22' \times 2) \times 10'' \times 0.75'' = 4.38 \text{ ft}^3$

Deduct, Door=  $4 \times 3'4'' \times 10'' \times 0.75'' = 0.69 \text{ ft}^3$

2. Verandah=  $46'6'' \times 10'' \times 0.75'' = 2.42 \text{ ft}^3$

Deduct, Door=  $4 \times 3'4'' \times 10'' \times 0.75'' = 0.69 \text{ ft}^3$

3. Columns=  $3 \times (10'' \times 4) \times 10'' \times 0.75'' = 0.52 \text{ ft}^3$

Total volume=  $5.94 \text{ ft}^3$

**Costing of a Residential Building**

Example:

**Table 3.2: Calculation of Costing of a Residential Building**

Item No.	Item Description	Quantity	Price Per Quantity	Total Cost
01	Earthwork Excavation	1784.75 cft	2.13 tk/cft	3802 tk

Total Cost =  $X_1$  tk

Electrification= 8% of total cost =  $X_2$

Sanitary and water supply = 8% of total cost =  $X_3$

Estimated cost=  $(X_1 + X_2 + X_3)$  tk

## Part 4: Estimation of RCC Slab Culvert

### 4.1 Culvert

Culvert is a small bridge used to carry water from one side to other. It should be covered with embankment and composed of structural material around the entire perimeter. In general culverts are of maximum 3 spans. Maximum span is limited to 5~6 meter. But long span culvert (>40 feet span) was introduced in 1960's.

### 4.2 Use of Culvert

1. Where natural streams intersect the roadway.
2. For passing surface drainage.
3. Bottom of depression where no natural water course.



Figure 4.1: Various Types of Culverts



### 4.3 Different Types of Culverts

1. **Arch Culvert:** An arch culvert is normally a low-profile culvert. It can be installed without disturbing the causeway as it will span over the entire drainage width. They are normally made of metal, stone masonry or RCC. They are installed easily, and you don't need to use expensive water diversion structures to install it. Common shapes include semicircular arch, elliptical arch, and concrete box culverts. Another benefit of these type of structure is that the installation process will not take a lot of time, compared to traditional box culverts.



**Figure 4.2: Arch Culverts**

2. **Slab Culvert:** A slab culvert is made of RCC slab. Masonry arches in culverts have numerous problems, including difficulty in centering, shuttering, less life, more chance of cracks and more dead load. Thus, they have been replaced by simple RCC slab construction. Slab in these culverts may be RCC or stone.



**Figure 4.3: Slab Culverts**

3. **Pipe culvert:** Pipes culverts are available in different shapes such as circular, elliptical and pipe arches. Although circular pipes are the most common, other shapes might be used depending on site conditions and constraints at the job site. Their prices are very competitive, and they are very easy to install. As with other culvert types, the selection of the culvert will depend on hydraulic design and other factors that might affect their performance and suitability. It is the preferred one on urbanized areas and is the one usually used to manage storm sewer systems.



**Figure 4.4: Pipe Culverts**

- 4. Box culvert:** Box culverts have a concrete (sometimes other materials can be used too) floor allowing the water to flow smoothly through it. Box culverts are usually made up of Reinforced Concrete (RCC). Some box culverts can be built using composite structures and are great when water needs to change direction or when a large flow of water is expected. Box culverts can also be installed in such way that the top of the culvert is also the roadway surface.



**Figure 4.5: Box Culverts**

- 5. Steel girder culvert:** A steel girder culvert has two (2) steel girders running side-by-side to support the main rail path. This type of culvert can only be seen in railways. Two main girders are laid just below the rails. Wooden sleepers are provided between these girders and the rails. Therefore, sometimes these culverts are also called open deck culverts.





**Figure 4.6: Steel Girder Culverts**

6. **Scupper:** A scupper is an opening in the side walls of an open-air structure, for purposes of draining water. They are usually placed at or near ground level, and allow rain or liquids to flow off the side of the open-air structure, instead of pooling within the walls.



**Figure 4.7: Scuppers**

#### 4.4 Slab Culvert

Slab culvert is one of the most commonly used culverts in Bangladesh. A total of 18257 culverts have been constructed in Bangladesh until 2017 out of which 3991 culverts (22%) are box culverts ([http://www.rthd.gov.bd/bridge\\_maintenance.php](http://www.rthd.gov.bd/bridge_maintenance.php)).

#### Advantages of Slab Culvert

- a) Simple in construction
- b) Suitable for weak sub grade.
- c) Uniform load distribution over a wide area.

#### 4.5 Components of a Typical RCC Slab Culvert

##### 1. Abutment

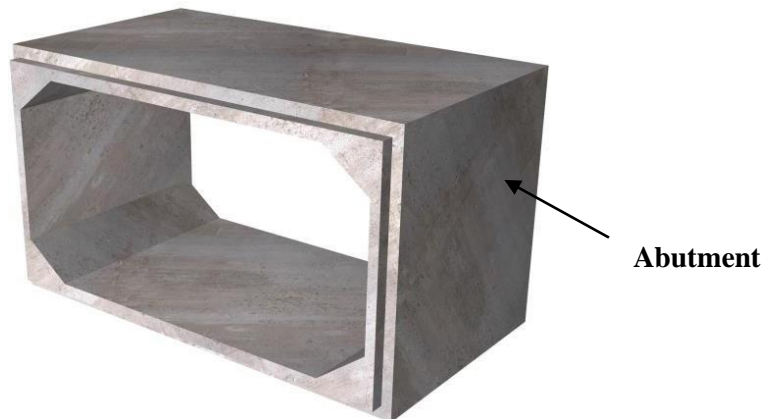
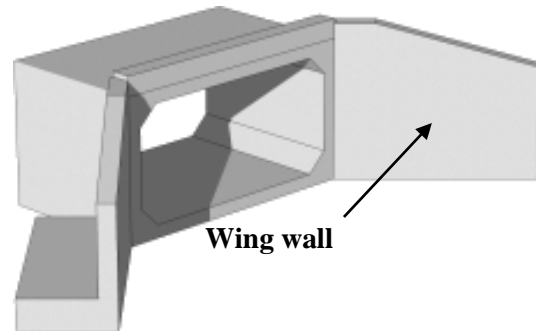
- a) Support bridge deck.
- b) Retain embankment.
- c) Connect approach road to bridge deck.

## 2. Wing wall

- a) Acts as an anchor.
- b) Provide smooth movement of water.
- c) Prevent spilling of earthen embankment

## 3. Slab/deck

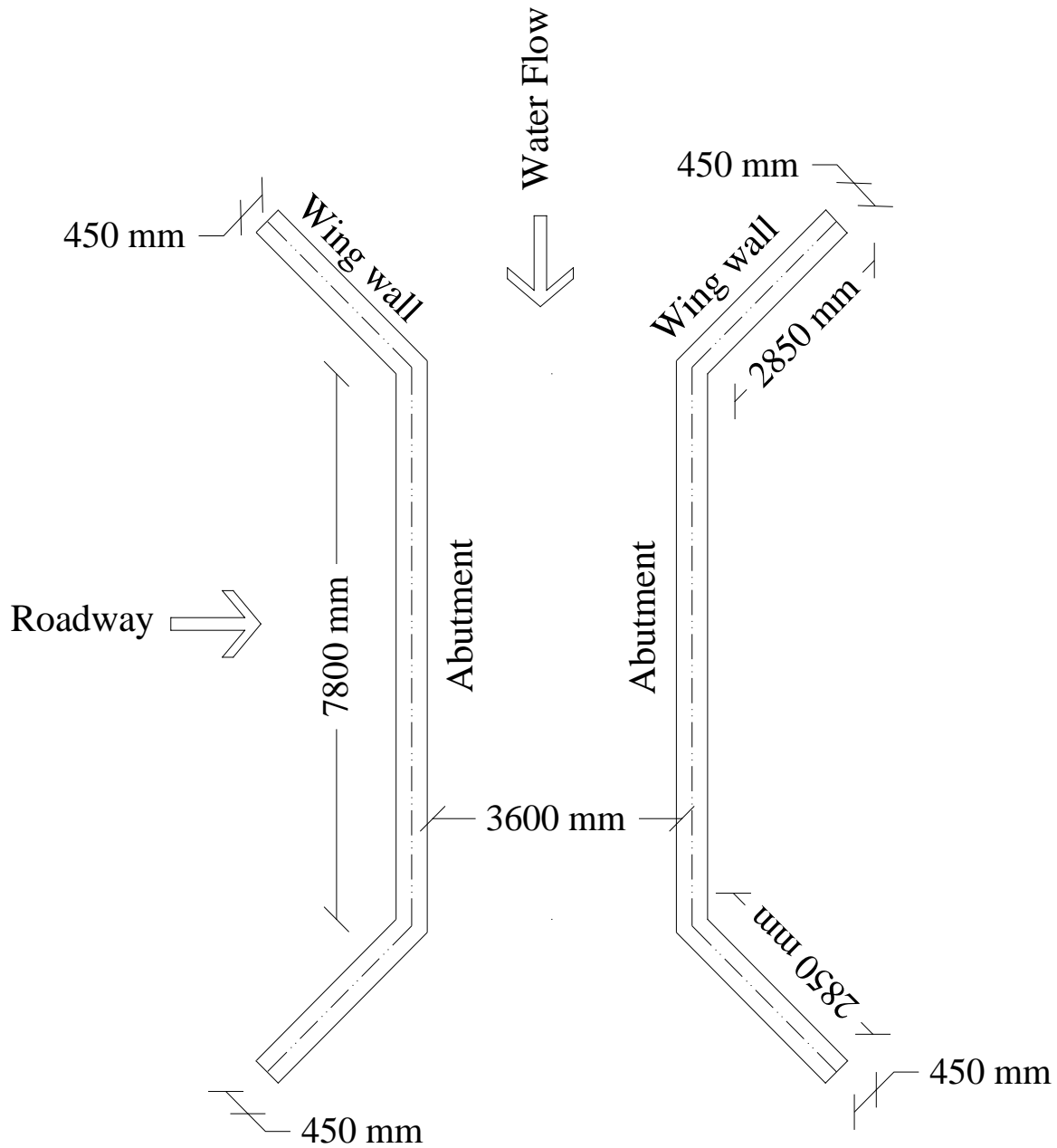
- a) Carries the load of vehicles.



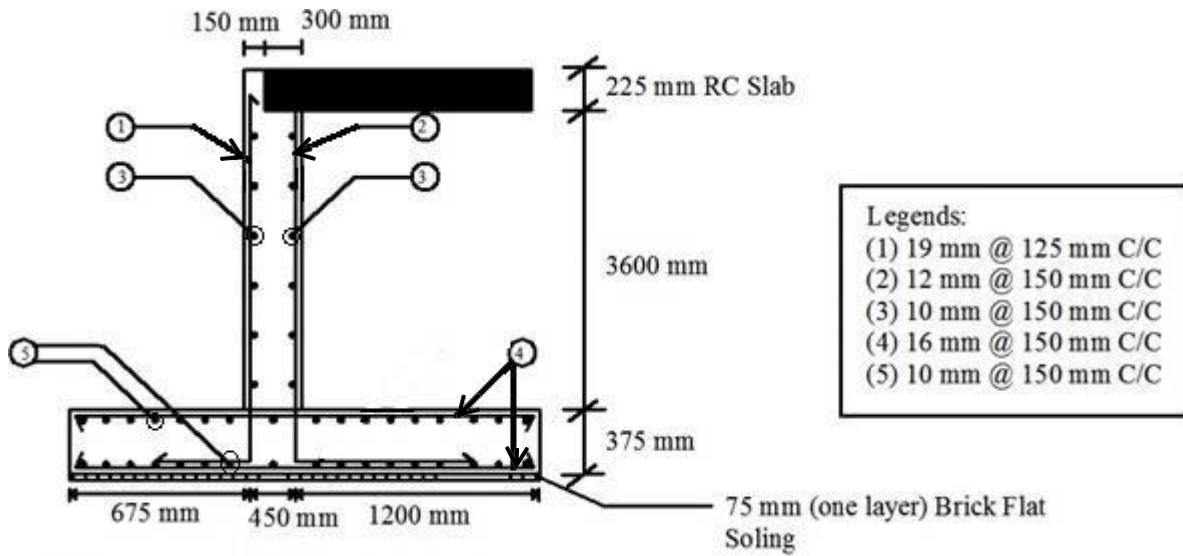
**Figure 4.8: Abutment and Wing wall**

#### 4.6 Worked Out Problem

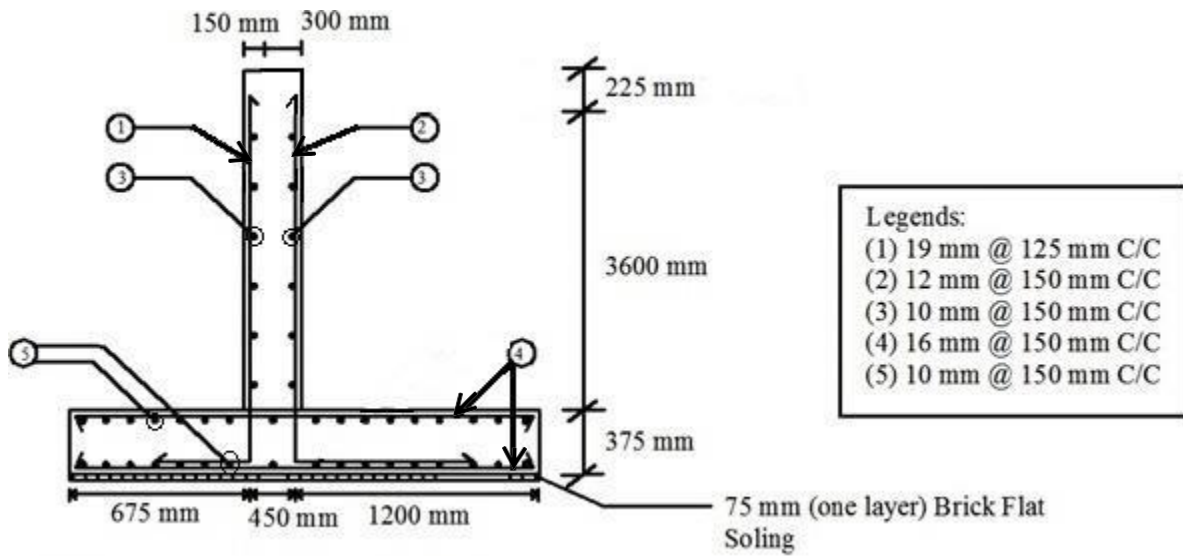
Calculate the quantity of the materials required for the construction of the following RCC slab culvert.



**Figure 4.9: Plan of the Culvert.**



**Figure 4.10: Sectional Elevation through Abutment**



**Figure 4.11: Sectional Elevation through Wing Wall**



## Concrete Estimation

**Table 4.1: Calculation of Estimation of Concrete for the Workout Problem of Slab Culvert**

Item Description	No	Length(m)	Width (m)	Height/ thickness (m)	Area (m <sup>2</sup> )	Volume (m <sup>3</sup> )	Remarks
(1)75mm brick flat soling in foundation							
Abutment	2	7.80	2.325	---	36.27	---	
Wing wall	4	2.85	2.325	---	26.51	---	
				Total =	62.78		
(2) Reinforced cement concrete in foundation (including reinforcement); 1:2:4							
Abutment	2	7.80	2.325	0.375	---	13.60	
Wing wall	4	2.85	2.325	0.375	---	9.94	
					Total =	23.54	
(3) Reinforced cement concrete in superstructure (including reinforcement); 1:2:4							
Abutment	2	7.80	0.45	3.825	---	26.852	
Deduction due to slab bearing	2	7.80	0.30	0.225	---	-1.053	
Wing wall	4	2.85	0.45	3.825	---	19.622	
					Total =	45.421	
(4) RCC in slab; 1:1.5:3	1	7.80	3.60	0.225	---	6.318	
					Total =	6.318	



### 1. 75mm BFS [one layer]

Size of one brick = 240 mm × 115 mm × 70 mm

Area of one brick = 0.24 m × 0.115 m = 0.0276 sqm

No of bricks =  $\frac{62.78}{0.0276} = 2275$  Nos.

Sand volume required per 10 sqm area of BFS = 0.1 cum

Volume of sand =  $0.1 \times \frac{62.78}{10} = 0.628$  cum

### 2. Reinforced cement concrete in Foundation (1:2:4)

Final volume (hard concrete) = 23.54 cum

Initial volume (before mixing) = 23.54 × 1.5 = 35.31 cum

Mix ratio = 1:2:4

Cement =  $35.31 \times \frac{1}{7} = 5.044$  cum = 143 bags

[One bag cement = 50 kg = 112 lb. = 1.25 cft = 0.035423256 cum]

Sand =  $35.31 \times \frac{2}{7} = 10.1$  cum

Brick chips/ Khoa =  $35.31 \times \frac{4}{7} = 20.2$  cum

No. of bricks = 20.2 × 300 = 6060 Nos.

[One cum brick chips required 300 Nos. of full-size brick]

### 3. Reinforced Cement Concrete in Superstructure (1:2: 4)

Final volume (hard concrete) = 45.42 cum

Initial volume (before mixing) = 45.42 × 1.5 = 68.13 cum

Mix ratio = 1:2:4

Cement =  $68.13 \times \frac{1}{7} = 9.7$  cum = 275 bags

[One bag cement = 50 kg = 112 lb. = 1.25 cft = 0.035423256 cum]

Sand =  $68.13 \times \frac{2}{7} = 19.5$  cum

Brick chips/ Khoa =  $68.13 \times \frac{4}{7} = 38.93$  cum

No. of bricks = 38.93 × 300 = 11680 Nos.

[One cum brick chips required 300 Nos. of full-size brick]





#### 4. RCC in Slab (1:1.5:3)

Final volume (hard concrete) = 6.32 cum

Initial volume (before mixing) =  $6.32 \times 1.5 = 9.48$  cum

Mix ratio = 1:1.5:3

Cement =  $9.48 \times \frac{1}{5.5} = 1.72$  cum = 49 bags

[One bag cement = 50 kg = 112 lb. = 1.25 cft = 0.035423256 cum]

Sand =  $9.48 \times \frac{1.5}{5.5} = 2.58$  cum

Brick chips/ Khoa =  $9.48 \times \frac{3}{5.5} = 5.17$  cum

No. of bricks =  $5.17 \times 300 = 1551$  Nos.

[One cum brick chips required 300 Nos. of full-size brick]

Total volume of cement = [143 + 275 + 49] = 467 bags

Total volume of sand = [0.628 + 10.3 + 19.5 + 2.58] = 33 cum

Total number of bricks = [2275 + 6060 + 11680 + 1551] = 21566 Nos.

The summary of quantity of materials is provided below:

**Table 4.2: Summary of Quantity of Materials:**

Materials	Quantity
Cement	467 bags
Sand	33 cum
Brick	21566 Nos.



**Reinforcement estimation:**

Deformed bar is used; each bar is hooked in each end.

Hook length = nine times bar diameter =  $9d_b$

Cover = 75 mm = 3 inch

Development length for vertical reinforcement in abutment and wing wall = 12 inch =  $(12 \times 25)$  mm

**Reinforcement in one wing wall:**

(1) Vertical rod in wall (outside face)

19 mm dia @ 125 mm c/c

$$= \left[ \frac{2850 - 75}{125} \right] \times [3600 + 225 - 75 + 375 - 75 + (12 \times 25) + (10 \times 19 \times 2)]$$

(2) Vertical rod in wall (inside face)

12 mm dia @ 150 mm c/c

$$= \left[ \frac{2850 - 75}{150} \right] \times [3600 + 225 - 75 + 375 - 75 + (12 \times 25) + (10 \times 12 \times 2)]$$

(3) Horizontal rod in wall (both face)

10 mm dia @ 150 mm c/c

$$= \left[ \frac{3825 - 75}{150} + 1 \right] \times [2850 - 75 + (10 \times 10)] \times 2 \text{ (Two Face)}$$

(4) Horizontal rod in footing (both layer)

16 mm dia @ 150 mm c/c

$$= \left[ \frac{2850 - 75}{150} \right] \times [675 + 450 + 1200 - 75 - 75 + (10 \times 16 \times 2)] \times 2 \text{ (Two Layer)}$$

(5) Horizontal rod in footing (both face)

10 mm dia @ 150 mm c/c

$$= \left[ \frac{675 + 450 + 1200 - 75 - 75}{150} + 1 \right] \times [2850 - 75 + (10 \times 10)] \times 2 \text{ (Two Face)}$$





**Reinforcement in one abutment:**

(1) Vertical rod in wall (outside face)

19 mm dia @ 125 mm c/c

$$= \left[ \frac{7800}{125} + 1 \right] \times [3600 + 225 + 375 - 75 - 75 + (12 \times 25) + (10 \times 19 \times 2)]$$

(2) Vertical rod in wall (inside face)

12 mm dia @ 150 mm c/c

$$= \left[ \frac{7800}{150} + 1 \right] \times [3600 + 375 - 75 - 75 + (12 \times 25) + (10 \times 12 \times 2)]$$

(3a) Horizontal rod in wall (outside face)

10 mm dia @ 150 mm c/c

$$= \left[ \frac{3600 + 225 - 75}{150} + 1 \right] \times [7800]$$

(3b) Horizontal rod in wall (inside face)

10 mm dia @ 150 mm c/c

$$= \left[ \frac{3600 - 75}{150} + 1 \right] \times [7800]$$

(4) Horizontal rod in footing (both layer)

16 mm dia @ 150 mm c/c

$$= \left[ \frac{7800}{150} + 1 \right] \times [675 + 450 + 1200 - 75 - 75 + (10 \times 16 \times 2)] \times 2 \text{ (Two Layer)}$$

(5) Horizontal rod in footing (both face)

10 mm dia @ 150 mm c/c

$$= \left[ \frac{675 + 450 + 1200 - 75 - 75}{150} + 1 \right] \times [7800] \times 2 \text{ (Two Face)}$$



**Table 4.3: Calculation of Reinforcement in Two Abutments**

Bar	No.	Total Length [For one abutment] (m)	Weight per meter (kg/m)	Weight (kg)
19mm	2			
16mm	2			
12mm	2			
10mm	2			

**Table 4.4: Calculation of Reinforcement in Four Wing Walls**

Bar	No.	Total Length [For one Wing Wall] (m)	Weight per meter (kg/m)	Weight (kg)
19mm	4			
16mm	4			
12mm	4			
10mm	4			

**Table 4.5: Calculation of Reinforcement in two Abutments and Four Wing Walls**

Bar	Reinforcement		Total (kg)
	Two abutments (kg)	Four wing walls (kg)	
19mm			
16mm			
12mm			
10mm			

## Part 5: Estimation of an Underground Water Reservoir

### 5.1 Worked Out Problem

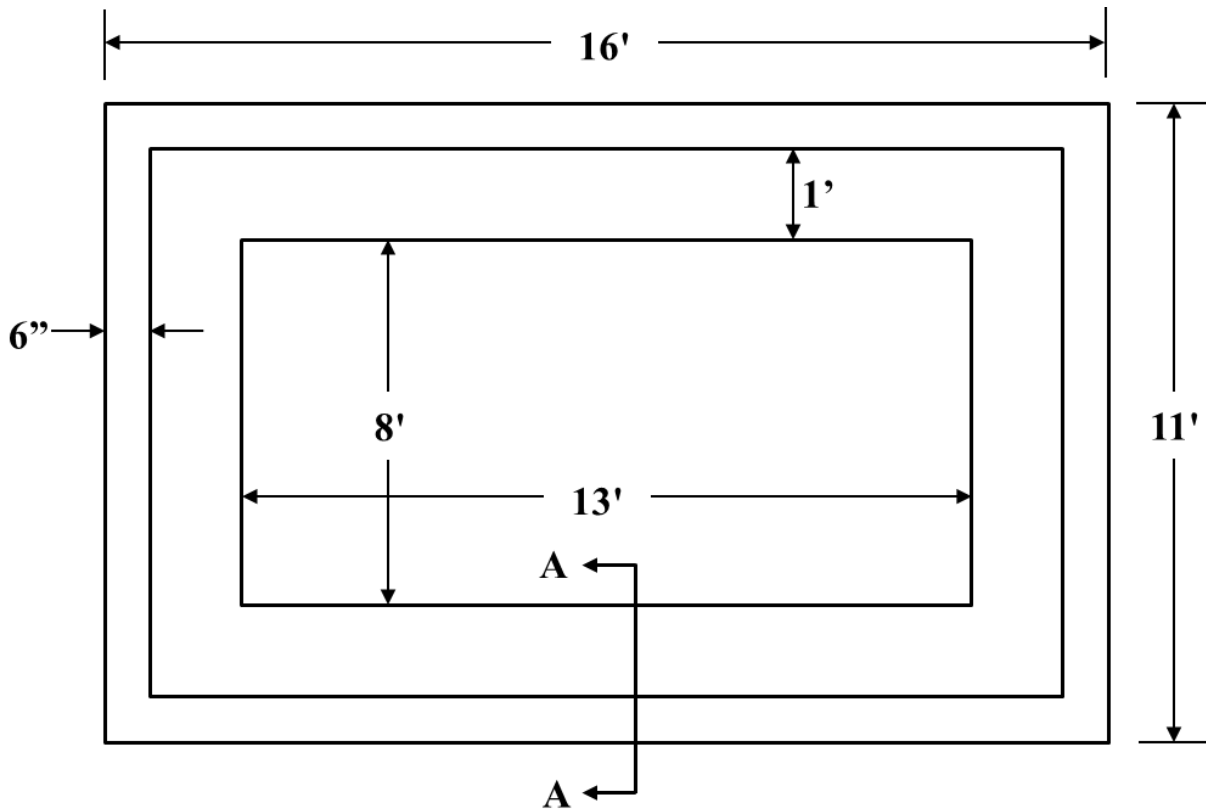


Figure 5.1: Plan of the Underground Water Reservoir

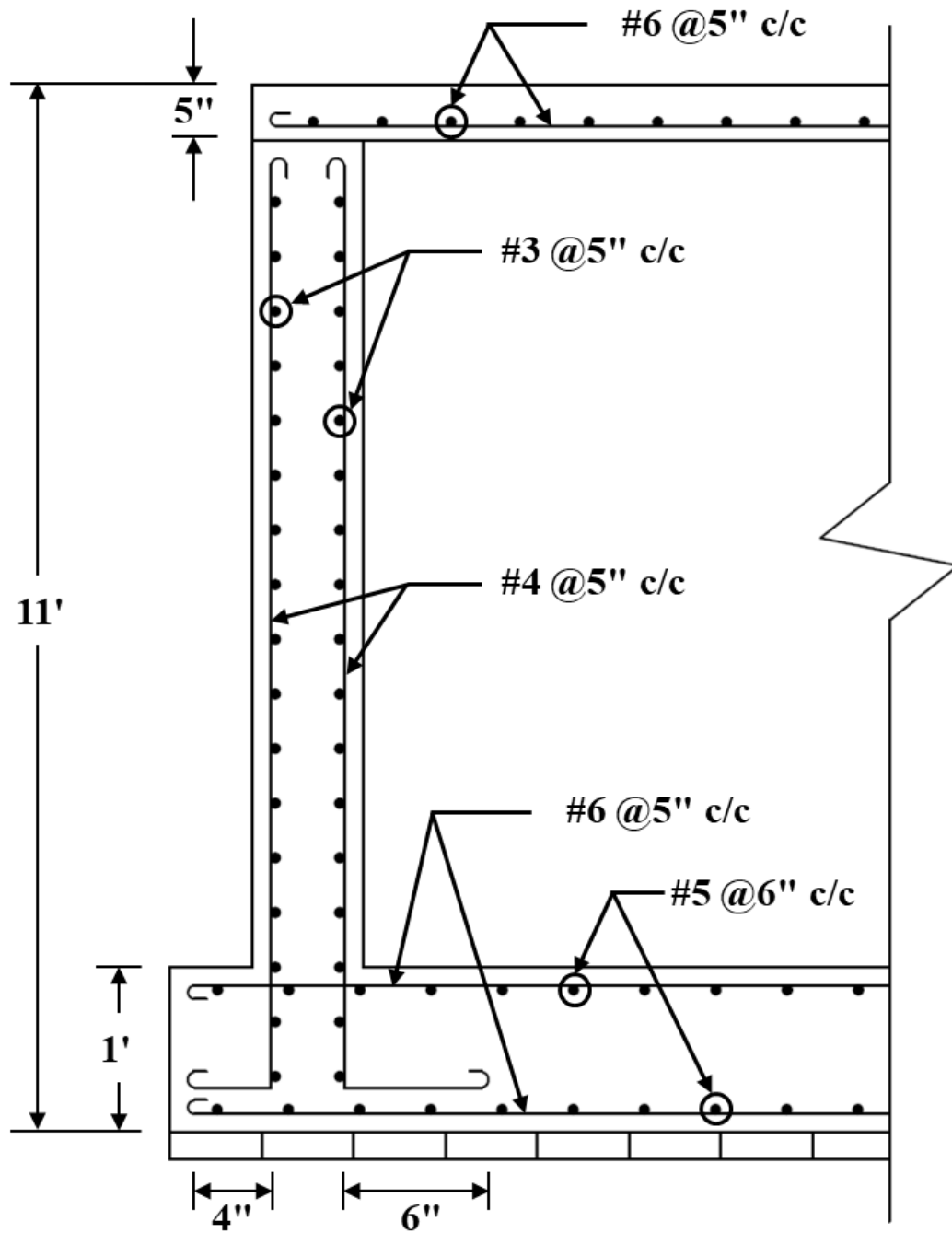


Figure 5.2: Section A-A



**Concrete Estimation:**

**Table 5.1: Calculation of Concrete Estimation for the Workout Problem on Retaining Wall**

Item	Length (ft)	Width (ft)	Height/ Thickness (ft)	Area (ft <sup>2</sup> )	Volume (ft <sup>3</sup> )
3" BFS	16	11	-	176	-
Base Slab	16	11	1	-	176
Wall	$2 \times (9+14) = 46$	1	$11-1- (5/12) = 9.583$	-	440.83
Cover Slab	15	10	$5/12 = 0.4167$	-	62.5

**Quantity of materials:**

**1. BFS**

Size of one brick = 9.5 in × 4.5 in × 2.75 in

Area of one brick = 9.5 in × 4.5 in = 42.75 in<sup>2</sup>

No of bricks =  $\frac{176 \times 144}{42.75} = 593$  Nos.

Sand volume required per 10 sqm area of BFS = 0.1 cum

Volume of sand =  $\frac{0.1 \times 176 \times 0.3048^2}{10} = 0.1635 \text{ m}^3 = 5.77 \text{ ft}^3$

**2. RCC (1:2:4)**

Final volume (hard concrete) = 176 + 440.83 + 62.5 = 679.33 ft<sup>3</sup>

Initial volume (before mixing) = 679.33 × 1.5 = 1018.995 cft

Mix ratio = 1:2:4

Cement =  $1018.995 \times \frac{1}{7} = 145.57 \text{ cft} = 117 \text{ bags}$

[One bag cement = 50 kg = 1.25 cft]

Sand =  $1018.995 \times \frac{2}{7} = 291.14 \text{ cft}$

Brick chips/ Khoa =  $1018.995 \times \frac{4}{7} = 582.28 \text{ cft}$

No. of bricks =  $\frac{300 \times 582.28}{35.315} = 4947$  Nos.

[1m<sup>3</sup> = 35.315 ft<sup>3</sup> brick chips required 300 Nos. of full-size brick]

**Table 5.2: Summary of Materials**

Material	Quantity
Cement	117 bags
Sand	$5.77 + 291.14 = 297 \text{ ft}^3$
Brick	$593 + 4947 = 5314$ Nos.


**Reinforcement Estimation:**
**Table 5.3: Calculation for Reinforcement Estimation**

Item	Bar Designation	No.	Length (ft)	Total Length (ft)
Base Slab	#6 @5" c/c	$2 \times \left[ \frac{16' \times 12 - 3'' - 3''}{5} + 1 \right] = 78$	$11' - \frac{3''}{12} - \frac{3''}{12} + \left( 2 \times 10.5 \times \frac{6}{8 \times 12} \right) = 11.813$	921.414
	#5 @6" c/c	$2 \times \left[ \frac{11' \times 12 - 3'' - 3''}{6} + 1 \right] = 44$	$16' - \frac{3''}{12} - \frac{3''}{12} + \left( 2 \times 10.5 \times \frac{5}{8 \times 12} \right) = 16.594$	730.136
Wall	#3 @5" c/c	$2 \times \left[ \frac{11' \times 12 - 5'' - 3'' - 3''}{5} + 1 \right] = 52$	46	2392
	#4 @5" c/c (Outside)	$\left[ \frac{46' \times 12}{5} + 1 \right] = 112$	$11' - \frac{5''}{12} - \frac{3''}{12} - \frac{3''}{12} + \frac{4''}{12} + \left( 2 \times 10.5 \times \frac{4}{8 \times 12} \right) = 11.292$	1264.704
	#4 @5" c/c (Inside)	$\left[ \frac{46' \times 12}{5} + 1 \right] = 112$	$11' - \frac{5''}{12} - \frac{3''}{12} - \frac{3''}{12} + \frac{6''}{12} + \left( 2 \times 10.5 \times \frac{4}{8 \times 12} \right) = 11.458$	1283.296
Cover Slab	#6 @5" c/c (Bottom)	$\left[ \frac{15' \times 12 - 3'' - 3''}{5} + 1 \right] = 36$	$10' - \frac{3''}{12} - \frac{3''}{12} + \left( 2 \times 10.5 \times \frac{6}{8 \times 12} \right) = 10.813$	389.268
	#6 @5" c/c (Top)	$\left[ \frac{10' \times 12 - 3'' - 3''}{5} + 1 \right] = 24$	$15' - \frac{3''}{12} - \frac{3''}{12} + \left( 2 \times 10.5 \times \frac{6}{8 \times 12} \right) = 15.813$	379.512

**Table 5.4: Calculation for Weight of Reinforcement**

Bar	Length (ft)	Additional (2%)	Final Length (ft)	Weight/Length (lb/ft)	Weight (lb)
#3 bar	2392	47.840	2439.84	0.376	918
#4 bar	2548	50.960	2598.96	0.668	1737
#5 bar	730.136	14.603	744.739	1.043	777
#6 bar	1690.194	33.804	1724.00	1.502	2590

## Part 6: Estimation of a Retaining Wall

### 6.1 Retaining Wall

A retaining wall is a structure designed and constructed to resist the lateral pressure of soil. Generally used to protect embankments of roads, hills etc.

### 6.2 Types of Retaining Wall

- (a) Gravity
- (b) Semi-gravity
- (c) Cantilever
- (d) Counterfort
- (e) Buttressed
- (f) Sheet piling
- (g) Anchored



Figure 6.1: Typical Retaining wall

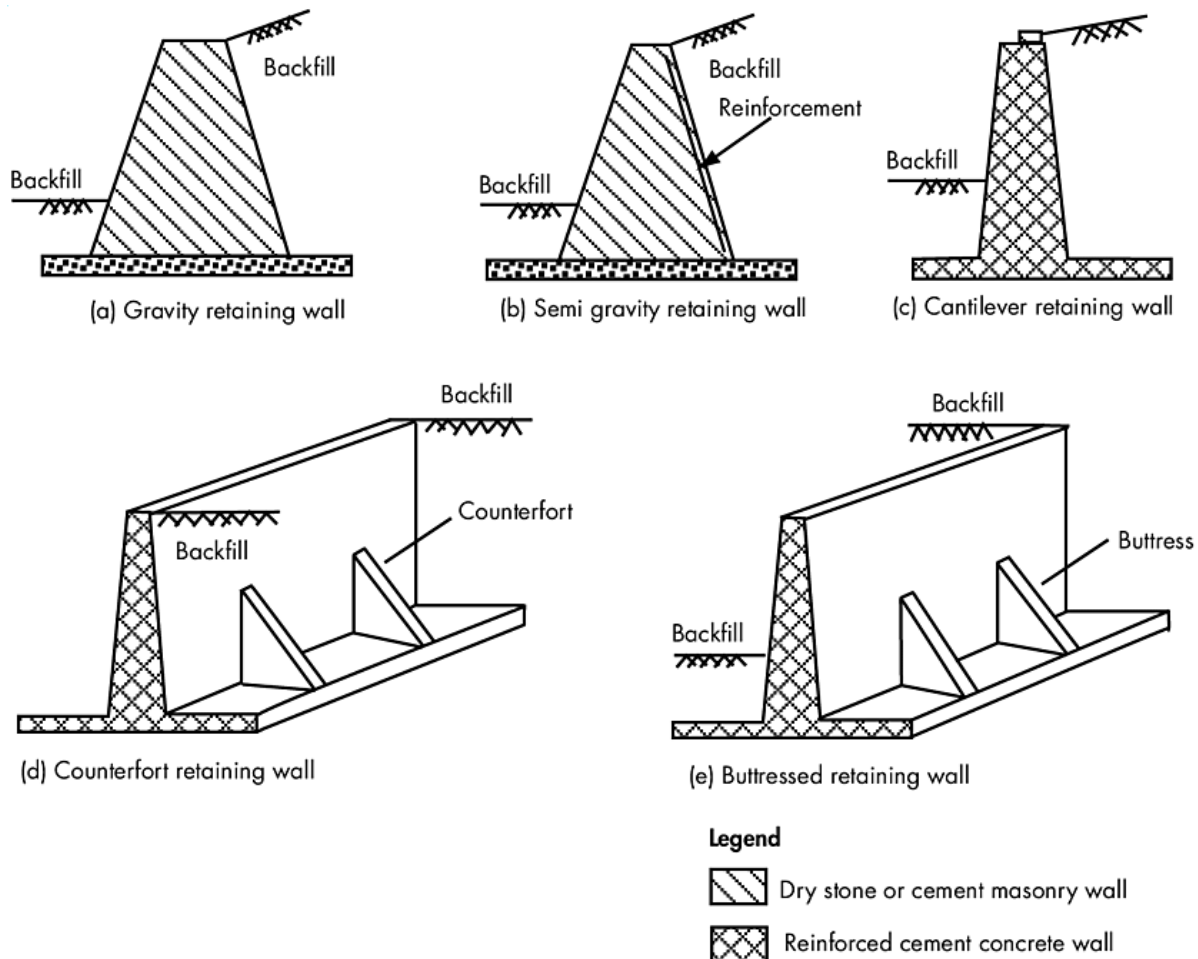


Figure 6.2: Different Types of Retaining Wall

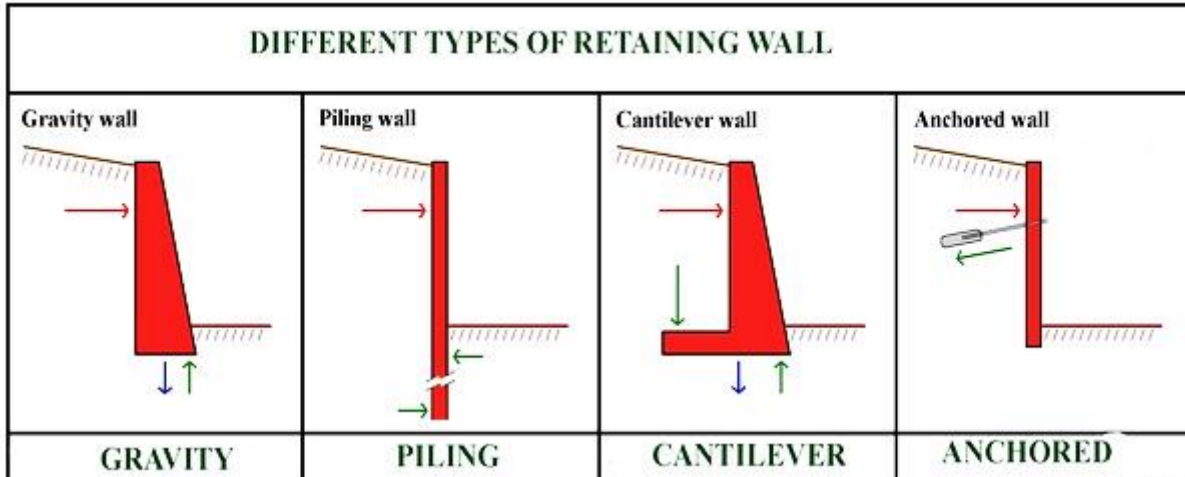


Figure 6.3: Different Types of Retaining Wall

### 6.3 Components of a typical RCC retaining wall

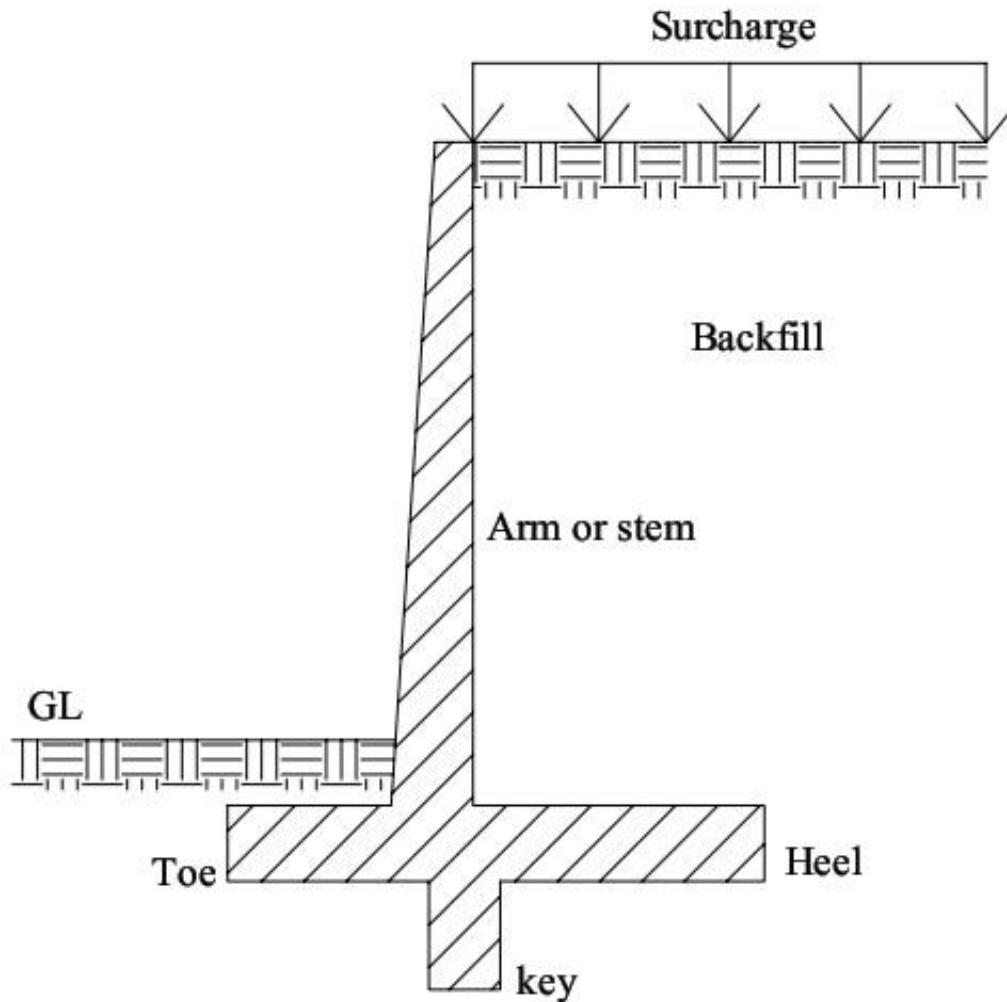


Figure 6.4: Components of a Typical Cantilever Retaining Wall



### 6.4 Worked Out Problem

Calculate the quantity of the materials required for the construction of the following retaining wall.

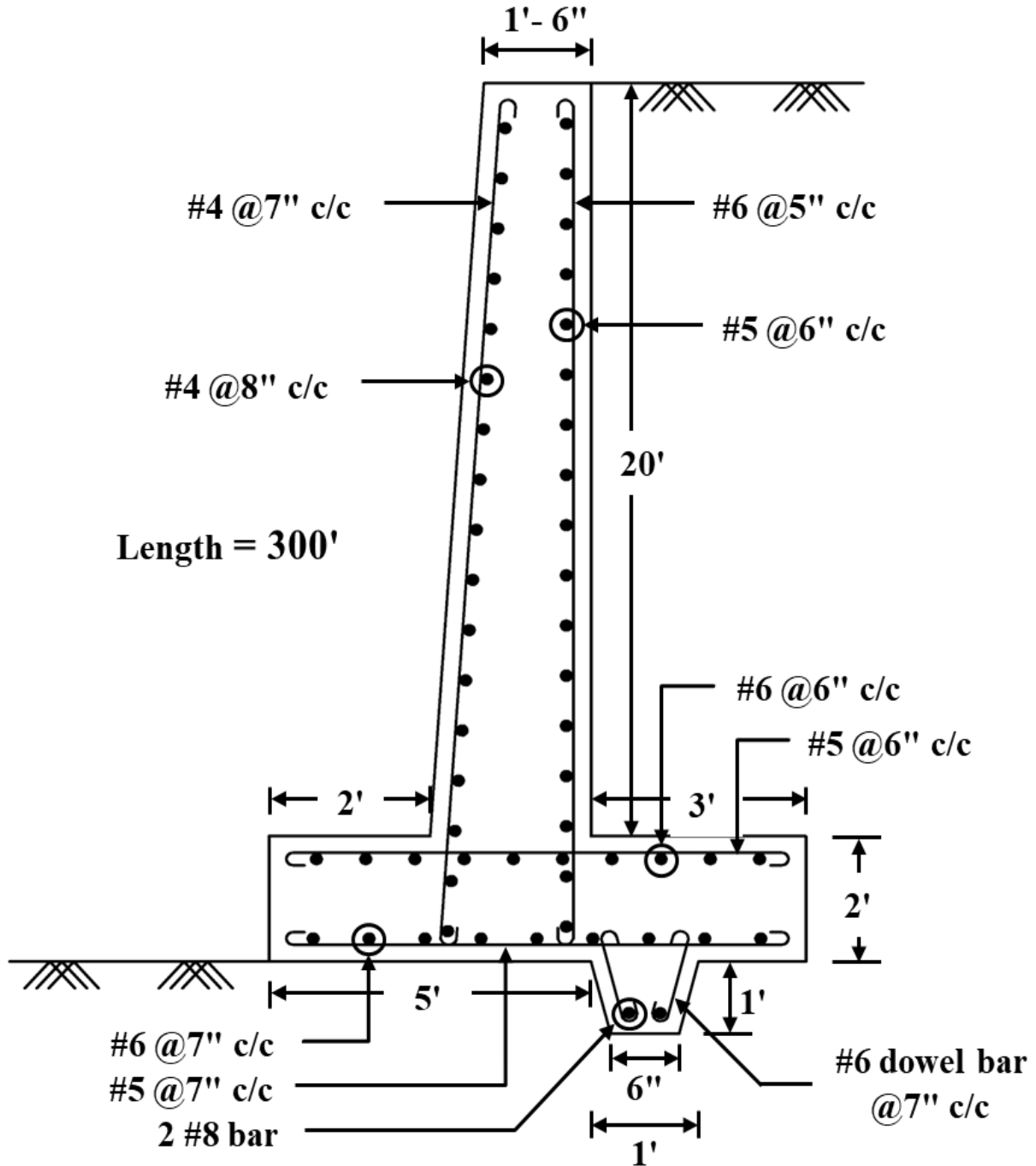


Figure 6.5: Section of a Retaining Wall



Length of wall = 300 ft

Cover for all sides = 3 in

**Estimation of concrete (1:2:4)**

$$\text{Volume of wall/Stem} = \frac{1}{2} \times (1.5' + 3') \times 20' \times 300' = 13500 \text{ cft}$$

$$\text{Volume of base} = 8' \times 2' \times 300' = 4800 \text{ cft}$$

$$\text{Volume of key} = \frac{1}{2} \times (0.5' + 1') \times 1' \times 300' = 225 \text{ cft}$$

$$\text{Total volume of concrete} = 13500 + 4800 + 225 = 18525 \text{ cft}$$

$$\text{Total volume of wet concrete} = 1.5 \times 18525 = 27787.5 \text{ cft}$$

**Table 6.1: Summary of Materials**

Materials	Volume (cft)	Quantity
Cement	$\frac{1}{7} \times 27787.5 = 3969.6$	3176 bags
Fine Aggregate (Sand)	$\frac{2}{7} \times 27787.5 = 7939.3$	7939.3 cft
Coarse Aggregate (Brick chips)	$\frac{4}{7} \times 27787.5 = 15878.6$	134890 Nos.

## Estimation of Reinforcement

### a) Reinforcement in wall

Inside vertical reinforcement (# 6 @ 5" c/c)

$$= \left[ \frac{300' \times 12 - 3'' - 3''}{5} + 1 \right] \times \left[ 20' + 2' - \frac{3''}{12} - \frac{3''}{12} + \left( 2 \times 9.5 \times \frac{6}{8 \times 12} \right) \right]$$

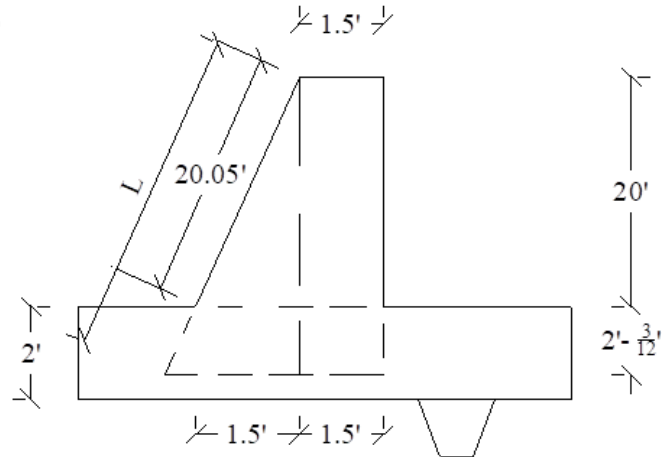
$$= 16330.5 \text{ ft}$$

Outside vertical reinforcement (# 4 @ 7" c/c)

From figure

$$\frac{20.05'}{20'} = \frac{L}{21.75'}$$

$$\Rightarrow L = 21.8'$$



**Figure 6.6: Calculation of Inclined Length of Outside Vertical Reinforcement**

$$= \left[ \frac{300' \times 12 - 3'' - 3''}{7} + 1 \right] \times \left[ 21.8' - \frac{3''}{12} + \left( 2 \times 9.5 \times \frac{4}{8 \times 12} \right) \right] = 11493.2 \text{ ft}$$

Inside horizontal reinforcement (# 5 @ 6" c/c)

$$= \left[ \frac{22' \times 12 - 3'' - 3''}{6} + 1 \right] \times \left[ 300' - \frac{3''}{12} - \frac{3''}{12} + \left( 2 \times 9.5 \times \frac{5}{8 \times 12} \right) \right] = 13221.5 \text{ ft}$$

Outside horizontal reinforcement (# 4 @ 8" c/c)

$$= \left[ \frac{21.8' \times 12 - 3'' - 3''}{8} + 1 \right] \times \left[ 300' - \frac{3''}{12} - \frac{3''}{12} + \left( 2 \times 9.5 \times \frac{4}{8 \times 12} \right) \right] = 1007.2 \text{ ft}$$

### b) Reinforcement in base

Along length of wall (Top) (# 6 @ 6" c/c)

$$= \left[ \frac{8' \times 12 - 3'' - 3''}{6} + 1 \right] \times \left[ 300' - \frac{3''}{12} - \frac{3''}{12} + \left( 2 \times 9.5 \times \frac{6}{8 \times 12} \right) \right] = 4811 \text{ ft}$$

Along length of wall (Bottom) (# 5 @ 7" c/c)

$$= \left[ \frac{8' \times 12 - 3'' - 3''}{7} + 1 \right] \times \left[ 300' - \frac{3''}{12} - \frac{3''}{12} + \left( 2 \times 9.5 \times \frac{5}{8 \times 12} \right) \right] = 4163.9 \text{ ft}$$

Along width of wall (Top) (# 5 @ 6" c/c)

$$= \left[ \frac{300 \times 12 - 3'' - 3''}{6} + 1 \right] \times \left[ 8' - \frac{3''}{12} - \frac{3''}{12} + \left( 2 \times 9.5 \times \frac{5}{8 \times 12} \right) \right] = 5093.8 \text{ ft}$$

Along width of wall (Bottom) (# 6 @ 7" c/c)

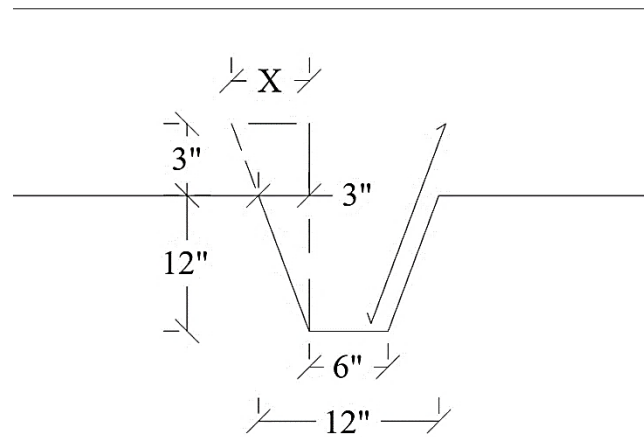
$$= \left[ \frac{300 \times 12 - 3'' - 3''}{7} + 1 \right] \times \left[ 8' - \frac{3''}{12} - \frac{3''}{12} + \left( 2 \times 9.5 \times \frac{6}{8 \times 12} \right) \right] = 4469.1 \text{ ft}$$

### c) Reinforcement in key

From figure

$$\frac{3''}{12''} = \frac{X}{15''}$$

$$\Rightarrow X = 3.75''$$



Along length of wall (2#8 bar)

$$= 2 \times \left[ 300' - \frac{3''}{12} - \frac{3''}{12} + \left( 2 \times 9.5 \times \frac{8}{8 \times 12} \right) \right] = 602.2 \text{ ft}$$

**Figure 6.7: Reinforcement in Key**

Dowel bar (# 6 @ 7" c/c)

$$= 2 \times \left[ \frac{300 \times 12 - 3'' - 3''}{7} + 1 \right] \times \left[ \frac{\sqrt{15^2 + 3.75^2}}{12} - \frac{3''}{12} + \left( 2 \times 9.5 \times \frac{6}{8 \times 12} \right) \right] = 2290.2 \text{ ft}$$

**Table 6.2: Calculation of Weight of Reinforcement**

Bar	Total length (ft)	Weight/ length (lb/ft)	Weight (lb)
#4 bar	11493.2 + 10007.2 = 21501	0.668	14363
#5 bar	13221.5 + 4163.9 + 5093.8 = 22480	1.043	23447
#6 bar	16330.5 + 4811 + 4469.1 + 2290.2 = 27901	1.502	41908
#8 bar	603	2.670	1611

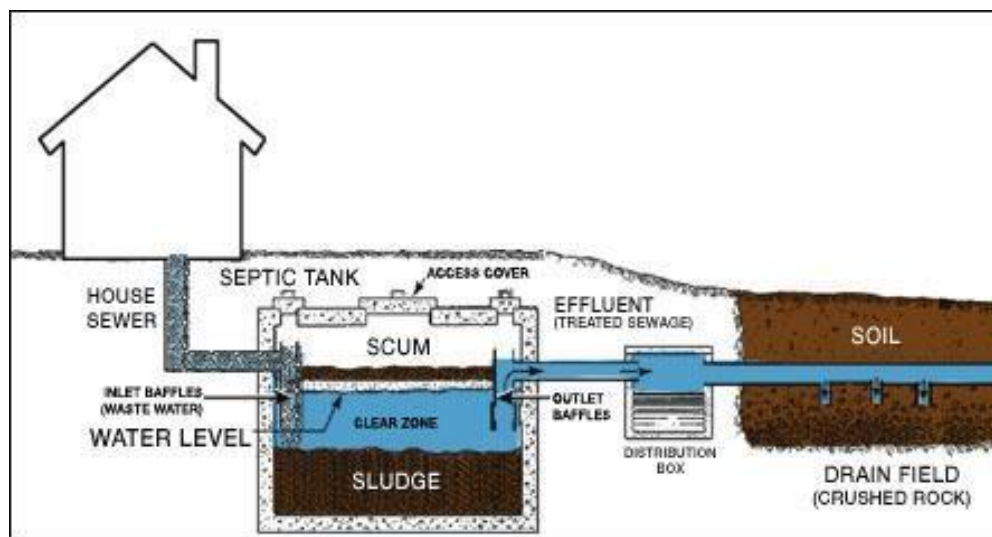
## Part 7: Estimation of a Septic Tank

### 7.1 Definition of Septic Tank

A **septic tank** is a watertight chamber made of concrete, fiberglass, PVC or plastic, through which domestic wastewater (sewage) flows for primary treatment.<sup>[1]</sup> Settling and anaerobic processes reduce solids and organics, but the treatment is only moderate.<sup>[1]</sup> Septic tank systems are a type of onsite sewage facility (OSSF). They can be used in areas that are not connected to a sewerage system, such as rural areas. The treated liquid effluent is commonly disposed in a septic drain field which provides further treatment.

### 7.2 Components of Septic Tank

1. **Inspection Pit:** A hole in the ground, lined with site built or manufactured sides that receive wastewater from house or building. The wastewater then flows from inspection pit to septic tank.
2. **Septic Tank:** The septic tank is buried, watertight container typically made of concrete, fiberglass, or polyethylene. It holds the wastewater long enough to allow solids to settle out, forming sludge, and oil and grease to float to the surface as scum. It also allows partial decompositions of the solid materials. Compartments and a T-shaped outlet in the septic tank prevent the sludge and scum from leaving the tank and traveling into the soak pit.
3. **Soak Pit:** A soak pit, also known as a soak away or leach pit, is a covered, porous-walled chamber that allows water to slowly soak into the ground. Pre-settled effluent from a collection and storage/treatment or (semi-) centralized treatment technology is discharged to the underground chamber from which it infiltrates into the surrounding soil.



**Figure 7.1: Components of a Septic Tank**

### 7.3 Worked Out Problem

The following figure is related to workout problem. The septic tank has a total height of 9 ft (including 6" floor slab and 6" cover slab). Soak pit has a total height of 30 ft (including 4" cover slab).

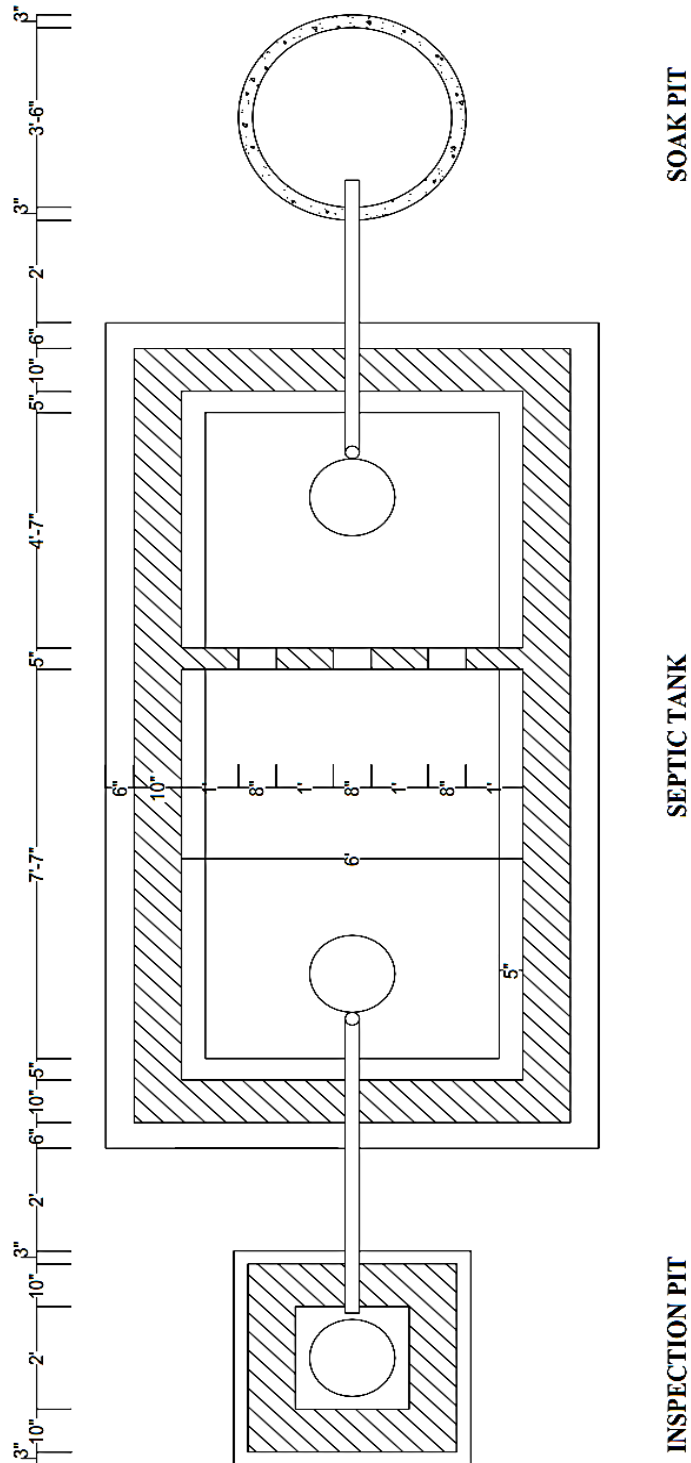


Figure 7.2: Plan of a Septic Tank


**Table 7.1: Estimation of a Septic Tank**

Item No.	Item Description	No.	Length (ft)	Width (ft)	Height/Depth (ft)	Quantity	Remarks
1	<b>Earthwork Excavation</b>						
	Septic Tank	1	16.0833	8.67	9.0	1254.54 cft	
	Soak Pit	1	12.57	---	30.0	376.99 cft	
2	<b>Cement Concrete (1:3:6) Floor of Septic Tank</b>	1	16.0833	8.67	0.5	69.72 cft	
3	<b>Precast RC Work</b>						
	Roof Cover Slab of Septic Tank	1	15.0833	7.67	0.5	57.84 cft	
	Roof Cover Slab of Soak Pit	1	12.57	---	0.33	4.19 cft	
	Side Wall of Soak Pit	---	2.94	---	29.67	87.22 eft	
4	<b>1st Class Brickwork with 1:4 Cement Mortar in septic tank</b>						
	(a) Long Wall						
	: 1st step	2	15.0833	1.25	3.0	113.12 cft	
	: 2nd step	2	15.0833	0.833	5.0	125.69 cft	
	(b) Short Wall						
	: 1st step	2	5.167	1.25	3.0	38.75cft	
	: 2nd step	2	6.0	0.833	5.0	49.98 cft	
	(c) Partition Wall						
	: 1st step	1	5.167	0.417	3.0	6.46 cft	
	: 2nd step	1	6.0	0.417	5.0	12.51 cft	
5	<b>1/2 inch Cement Plaster 1:3 with Standard Water Proofing Compound in Septic Tank</b>						
	(a) Long Wall						
	: 1st step	2	12.583	---	3.0	75.498 sft	
	: 2nd step	2	13.417	---	5.0	134.17 sft	
	(b) Short Wall						
	: 1st step	2	5.167	---	3.0	31.002 sft	
	: 2nd step	2	6.0	---	5.0	60.00 sft	
	(c) Partition Wall						
	: 1st step	---	5.167	---	3.0	31.002 sft	
	: 2nd step	---	6.0	---	5.0	60.00 sft	
6	<b>3/4 inch Cement Plaster 1:3 with Standard Water Proofing Compound in Floor of Septic Tank</b>	1	12.583	5.167	---	65.02 sft	



Item No.	Item Description	No.	Length (ft)	Width (ft)	Height/Depth (ft)	Quantity	Remarks
7	2 inch size Brick Aggregate at Bottom of Soak Pit	---	$\pi \times (3.5)^2 / 4$	---	1.0	9.62 sft	
8	Coarse Sand at Bottom of Soak Pit	---	$\pi \times (3.5)^2 / 4$	---	1.5	14.43 sft	

**Table 7.2: Cost Estimation of Septic Tank**

Item No.	Item Description	Quantity times price per quantity	Total Price (Taka)
1	Earthwork Excavation	1631.53 cft @ 1475.00 per cft	2406.50
2	Cement Concrete (1:3:6)	69.72 cft @ 8991.00 per cft	6268.52
3	Precast RC Work	149.25 cft @ 15073.53 per cft	22497.24
4	1st Class Brickwork with 1:4 Cement Mortar in Septic Tank	346.51 cft @ 5629.40 per cft	19506.43
5	1/2 inch Cement Plaster 1:3 with Standard Water Proofing Compound in Septic Tank	391.67 sft @ 882.00 per sft	3454.53
6	3/4 inch Cement Plaster 1:3 with Standard Water Proofing Compound in Floor of Septic Tank	65.02 sft @ 1323.00 per sft	860.21
7	Aggregate at Bottom of Soak Pit	9.62 cft @ 33.50 per cft	322.27
8	Coarse Sand at Bottom of Soak Pit	14.43 cft @ 33.50 per cft	483.40
9	2 inch dia Ventilating Pipe fitted position	1 No. @ Tk 15.00 each	15.00
10	6 inch diameter Pipe	5.25 ft @ Tk 30 per ft	157.50
11	C. I. (cast iron) Manhole Cover 18 inch diameter over Septic Tank	2 No. @Tk. 300.00 each	600.00
12	RCC Tees	2 No. @Tk. 150.00 each	300.00





## Part 8: Earthwork Excavation for Roadway

### 8.1 Calculation of Volume

There are three methods generally adopted for the computation of earthwork volume (according to the formation of the solid). They are:

- 1) **From cross-sections:** Measurement from cross-section is a universally applicable method.
- 2) **From spot levels:** Measurements from spot levels are sometimes applied for large excavations.
- 3) **From contours:** Rough estimates of volume may be made by treatment of the contour line and not much used in practice.

### 8.2 Measurement from Cross Sections

The cross-sectional area along the line is first calculated by standard formulae and the volumes of the prisms between successive cross-sections are then calculated by following methods:

- 1) Formulae of Mid-section method/ Average height method.
- 2) Formulae of Trapezoidal method/ Average end area method/ Mean-sectional area method.
- 3) Formulae of Prismoidal method according to Simpson's one-third rule.

### 8.3 Terms and Abbreviations

**EGL (Existing Ground Level) or GL (Ground Level):** The existing earth surface.

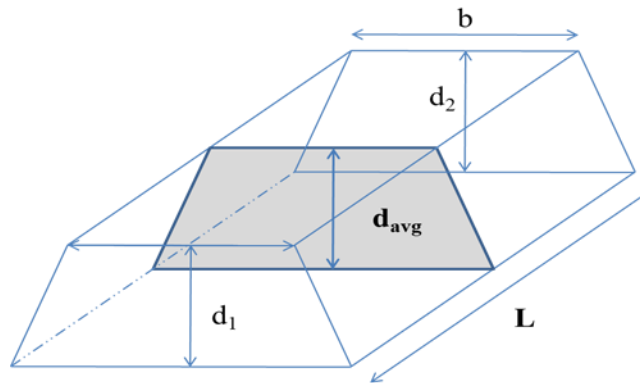
**FL (Formation Level):** The proposed level of roadway.

**RL (Reduced Level):** A level stated in relation to a known bench mark or datum.

**Longitudinal Slope/ Gradient:** Gradient may be defined as the rate of rise or fall along the length of highway.

**Side Slope:** Side slope is defined as the rate of rise or fall of the shoulders of the pavement. It depends on the soil characteristics and geographic location of the highway.

### 8.4 Mid-section formulae (Average Height Method)



**Figure 8.1: Cross-section of a Trapezoidal Section for Average Height Method**

Depth section (1) =  $d_1$  (note that  $d_1$  is the difference between GL & FL)

Depth section (2) =  $d_2$  (note that  $d_2$  is the difference between GL & FL)

$$\text{Average depth, } d_{\text{avg}} = \frac{(d_1 + d_2)}{2}$$

Width of section =  $b$

Side slope = 1:  $s$  (vertical: horizontal)

$$\text{Area of mid-section, } A_{\text{mid}} = b d_{\text{avg}} + 2 \times \frac{1}{2} s d_{\text{avg}}^2$$

$$A_{\text{mid}} = (b + s d_{\text{avg}}) \times d_{\text{avg}}$$

Length between two consecutive sections (between section (1) & (2)) =  $L$

Volume of earthwork between these two consecutive sections (between section (1) & (2)),

$$V_{1-2} = A_{\text{mid}} \times L$$

$$V_{1-2} = (b + s d_{\text{avg}}) \times d_{\text{avg}} \times L \text{ (may be cut or fill)}$$

### 8.5 Trapezoidal Formula/ Average End Area Method / Mean-Sectional Area Method

Depth section (1) =  $d_1$  (note that  $d_1$  is the difference between GL & FL)

Depth section (2) =  $d_2$  (note that  $d_2$  is the difference between GL & FL)

$$\text{Area at end 1, } A_1 = (b + s d_1) \times d_1$$

$$\text{Area at end 2, } A_2 = (b + s d_2) \times d_2$$

$$\text{Mean sectional area, } A_{\text{mean}} = \frac{(A_1 + A_2)}{2}$$

Width of section =  $b$

Side slope = 1:  $s$  (vertical: horizontal)

Length between two consecutive sections (between section (1) & (2)) =  $L$

Volume of earthwork between these two consecutive sections (between section (1) & (2)),

$$V_{1-2} = A_{\text{mean}} \times L \text{ (may be cut or fill)}$$

### 8.6 Prismoidal formula

Depth section (1) =  $d_1$  (note that  $d_1$  is the difference between GL & FL)

Depth section (2) =  $d_2$  (note that  $d_2$  is the difference between GL & FL)

$$\text{Average depth, } d_{\text{avg}} = \frac{(d_1 + d_2)}{2}$$

$$\text{Area at end 1, } A_1 = (b + sd_1) \times d_1$$

$$\text{Area at end 2, } A_2 = (b + sd_2) \times d_2$$

$$\text{Area of mid-section, } A_{\text{mid}} = (b + sd_{\text{avg}}) \times d_{\text{avg}}$$

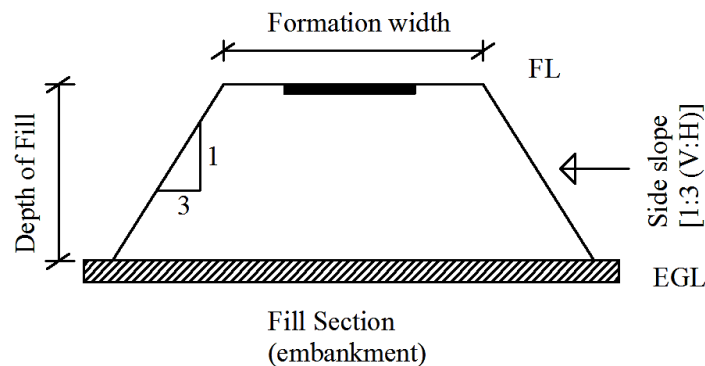
Length between two consecutive sections (between section (1) & (2)) =  $L$

Volume of earthwork between these two consecutive sections (between section (1) & (2)),

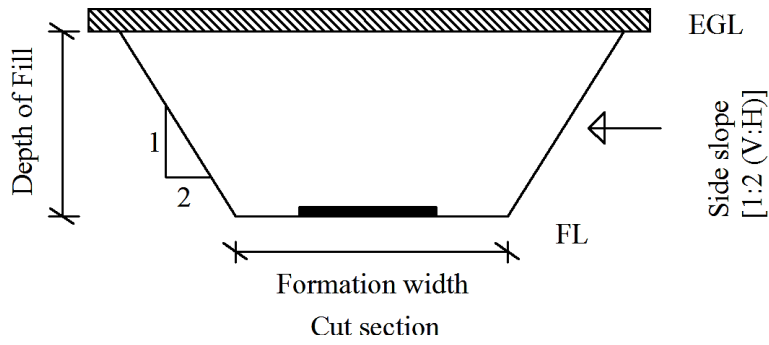
$$V_{1-2} = \frac{(A_1 + 4A_{\text{mid}} + A_2)}{6} \times L \text{ (may be cut or fill)}$$

### 8.7 Worked Out Problem

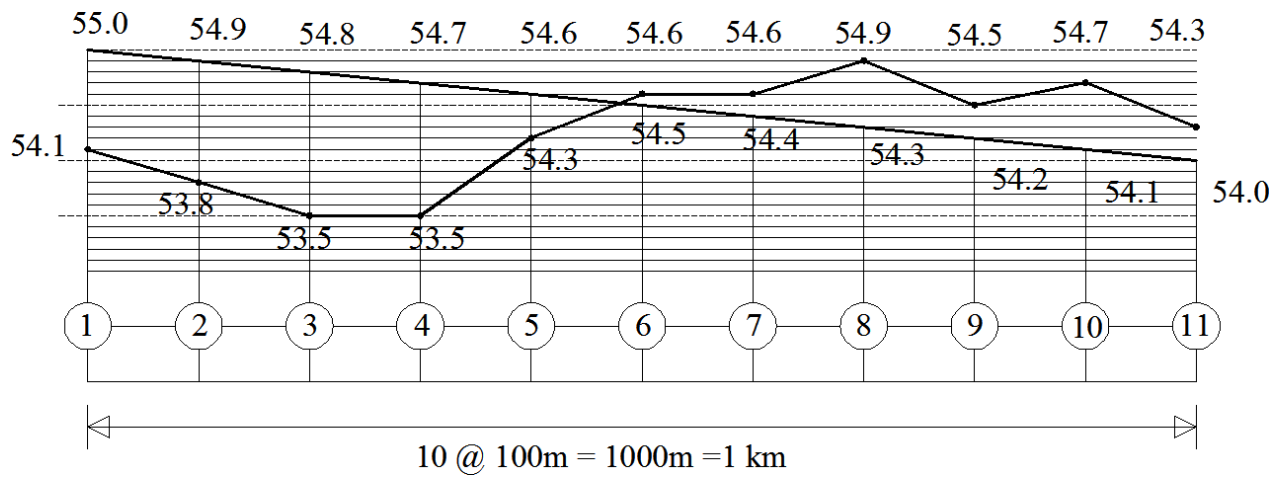
A 1 km road is to be constructed in existing ground level having reduced levels 54.1, 53.8, 53.5, 53.5, 54.3, 54.6, 54.9, 54.5, 54.7 and 54.3 meters at 100 m intervals. A required reduced level at station 1 is 55 meter and the downward gradient is 1 in 1000. The width of the road at formation level is 8 meter. Slopes to be maintained at cutting and filling are 1:2 (V: H) and 1:3 (V: H) respectively. Calculate the volume of Earthwork.



**Figure 8.2: Typical Fill Section**



**Figure 8.3: Typical Cut Section**

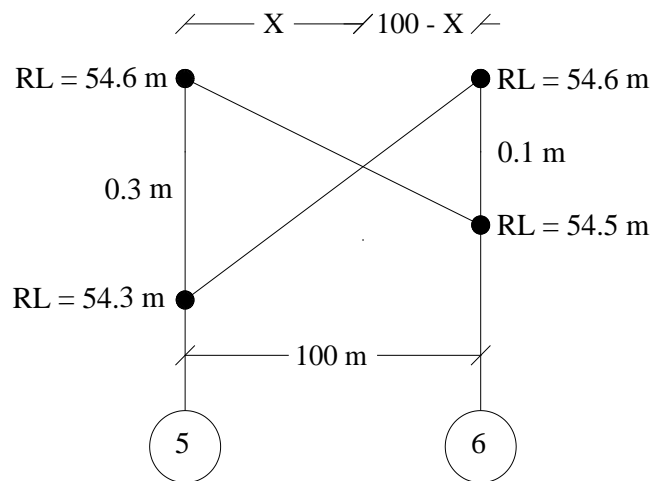


**Figure 8.4: Long Section of the Road**

From figure,

$$\frac{X}{0.3} = \frac{100 - X}{0.1}$$

$$\Rightarrow X = 75 \text{ m}$$



**Figure 8.5: Length of Cut and Fill between Station 5 & 6.**


**Table 8.1: Earthwork Computation Table (Mid-section / Average Height Method)**

Station	FL (m)	EGL (m)	Depth, d = EGL ~ FL (m)	Average depth $d_{avg}$ (m)	Area $A_{mid} = (b + sd_{avg})d_{avg}$ (m <sup>2</sup> )	Length L (m)	Volume $V = A_{mid} \times L$ (m <sup>3</sup> )	Remark
1	55	54.1	0.9					
				1	$(8 + 3 \times 1) \times 1 = 11.00$	100	1100.00	Fill
2	54.9	53.8	1.1					
				1.2	$(8 + 3 \times 1.2) \times 1.2 = 13.92$	100	1392.00	Fill
3	54.8	53.5	1.3					
				1.25	$(8 + 3 \times 1.25) \times 1.25 = 14.68$	100	1468.00	Fill
4	54.7	53.5	1.2					
				0.75	$(8 + 3 \times 0.75) \times 0.75 = 7.68$	100	768.00	Fill
5	54.6	54.3	0.3					
				0.15	$(8 + 3 \times 0.15) \times 0.15 = 1.26$	75*	95.06	Fill
0	X	X	0					
				0.05	$(8 + 2 \times 0.05) \times 0.05 = 0.40$	25*	10.18	Cut
6	54.5	54.6	0.1					
				0.15	$(8 + 2 \times 0.15) \times 0.15 = 1.25$	100	124.50	Cut
7	54.4	54.6	0.2					
				0.4	$(8 + 2 \times 0.4) \times 0.4 = 3.52$	100	352.00	Cut
8	54.3	54.9	0.6					
				0.45	$(8 + 2 \times 0.45) \times 0.45 = 4.01$	100	400.50	Cut
9	54.2	54.5	0.3					
				0.45	$(8 + 2 \times 0.45) \times 0.45 = 4.01$	100	400.50	Cut
10	54.1	54.7	0.6					
				0.45	$(8 + 2 \times 0.45) \times 0.45 = 4.01$	100	400.50	Cut
11	54	54.3	0.3					

Volume of total cutting = 1688.18 m<sup>3</sup>

Volume of total filling = 4824.56 m<sup>3</sup>



**Assignment 1:** Calculate the volume of cutting and filling for the previous worked out problem using the trapezoidal method.

**Hints:**

**Table 8.2: Earthwork Computation Table (Trapezoidal formula/Average End Area Method)**

Station	FL (m)	EGL (m)	Depth, d= EGL-FL (m)	Area $A = (b + sd)d$ (m <sup>2</sup> )	Mean Area $A_{\text{mean}}$ (m <sup>2</sup> )	Length L (m)	Volume $V = A_{\text{mean}} \times L$ (m <sup>3</sup> )	Remarks
1	55	54.1	0.9					
2	54.9	53.8	1.1					
3	54.8	53.5	1.3					
4	54.7	53.5	1.2					
5	54.6	54.3	0.3					
0	-	-	0					
6	54.5	54.6	0.1					
7	54.4	54.6	0.2					
8	54.3	54.9	0.6					
9	54.2	54.5	0.3					
10	54.1	54.7	0.6					
11	54	54.3	0.3					



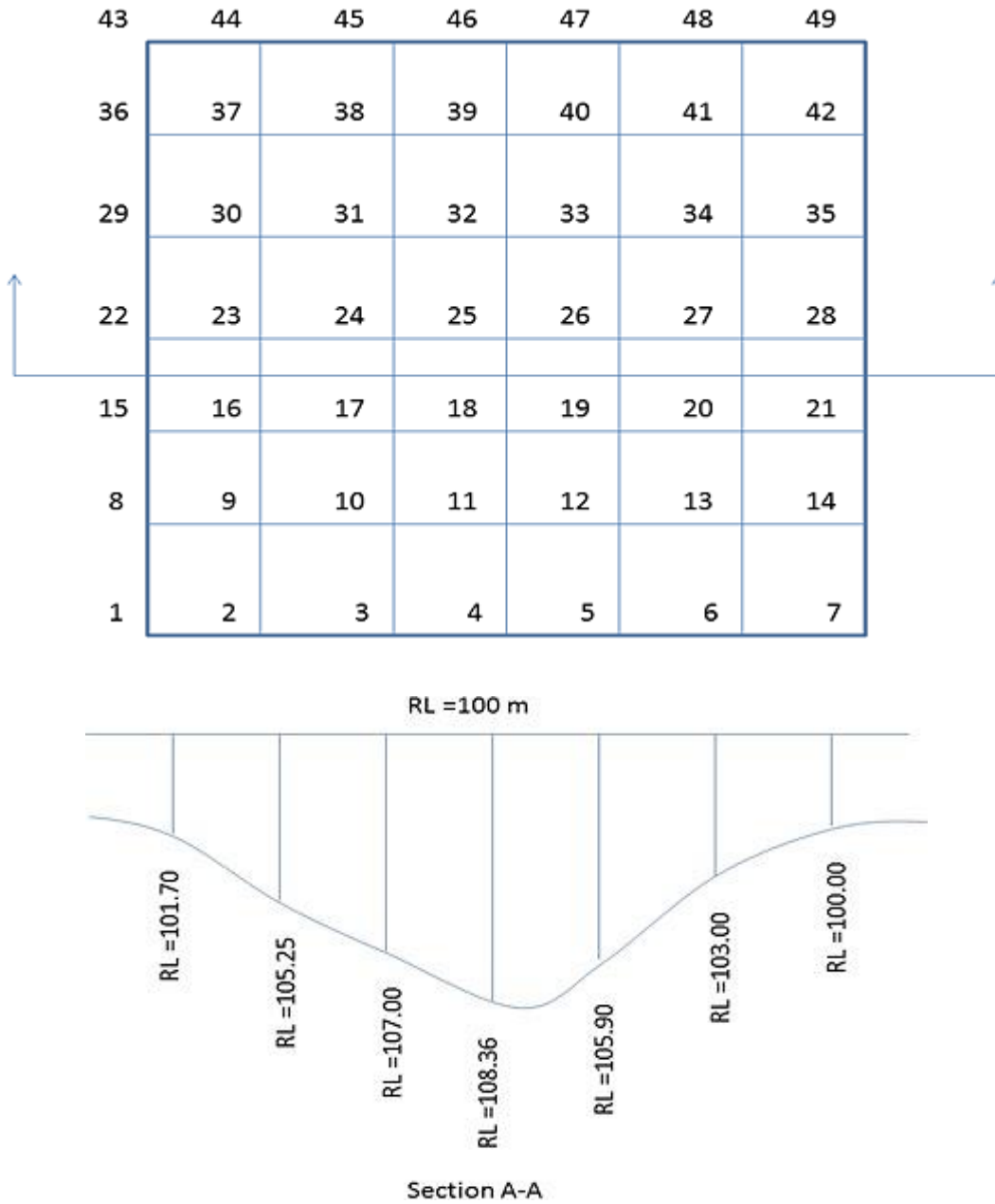
**Assignment 2:** Calculate the volume of cutting and filling for the previous worked out problem using the Prismoidal method.

**Hints:**

**Table 8.3: Earthwork Computation Table (Prismoidal formula)**

Station	FL (m)	EGL (m)	Depth, d= EGL-FL (m)	Area A = (b + sd)d (m <sup>2</sup> )	Average depth d <sub>avg</sub> (m)	Area A <sub>mid</sub> = (b + sd <sub>avg</sub> )d <sub>avg</sub> (m <sup>2</sup> )	Length L (m)	Volume, V = $\frac{(A_1 + 4A_{mid} + A_2)}{6} \times L$ (m <sup>3</sup> )	Remarks
1	55	54.1	0.9	A1					
						A <sub>1-2</sub>			
2	54.9	53.8	1.1	A2					
						A <sub>2-3</sub>			
3	54.8	53.5	1.3	A3					
						A <sub>3-4</sub>			
4	54.7	53.5	1.2	A4					
						A <sub>4-5</sub>			
5	54.6	54.3	0.3	A5					
						A <sub>5-0</sub>			
0	-	-	0	0					
						A <sub>0-6</sub>			
6	54.5	54.6	0.1	A6					
						A <sub>6-7</sub>			
7	54.4	54.6	0.2	A7					
						A <sub>7-8</sub>			
8	54.3	54.9	0.6	A8					
						A <sub>8-9</sub>			
9	54.2	54.5	0.3	A9					
						A <sub>9-10</sub>			
10	54.1	54.7	0.6	A10					
						A <sub>10-11</sub>			
11	54	54.3	0.3	A11					

**Assignment 3:** Calculate the volume of earth filling for the ditch. Given, reduced level of filling plane is 100 m.



**Figure 8.6: Section A-A of Ditch for Assignment 3**





Reduced levels (RL) of different stations are given as follows

**Table 8.4: Reduced levels (RL) of Different Stations for Assignment 3**

Station	RL (m)	Station	RL (m)	Station	RL (m)	Station	RL (m)	Station	RL (m)
1	101.00	12	103.20	23	105.25	34	104.14	45	101.00
2	102.00	13	103.90	24	107.00	35	100.00	46	103.20
3	101.70	14	101.30	25	108.36	36	101.10	47	101.10
4	102.00	15	100.16	26	105.90	37	104.80	48	102.15
5	101.00	16	104.15	27	103.00	38	105.60	49	102.00
6	100.60	17	106.85	28	100.00	39	103.00		
7	100.10	18	107.65	29	101.70	40	107.80		
8	100.60	19	105.90	30	104.80	41	104.14		
9	106.00	20	104.00	31	105.60	42	101.00		
10	107.50	21	102.00	32	103.00	43	100.10		
11	105.10	22	101.70	33	107.8	44	102.30		

**Hints:**

- Calculate depth to be filled at each station
- Calculate volume of each grid to be filled (i.e.,  $V_{1-2-8-9} = \frac{1}{4} \times (d_1 + d_2 + d_8 + d_9) \times A_{1-2-8-9}$ )
- Sum up all to get total volume (**Total volume =  $V_{1-2-8-9} + V_{2-3-9-10} + \dots$** )

## Part 9: Estimation of a Roof Truss

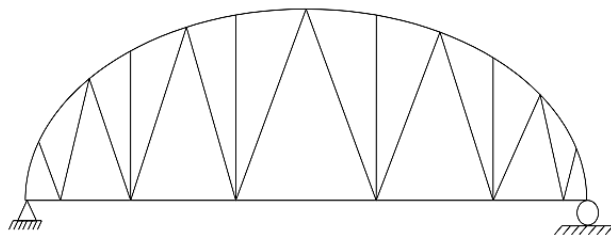
A truss is a structure composed of slender members joined together at their end points. Planar trusses lie in a single plane. Typically, the joint connections are formed by bolting or welding the end members together to a common plate, called a gusset plate. The basic building block of a truss is a triangle. Large trusses are constructed by attaching several triangles together. A new triangle can be added to a truss by adding two members and a joint. A truss constructed in this fashion is known as a simple truss.



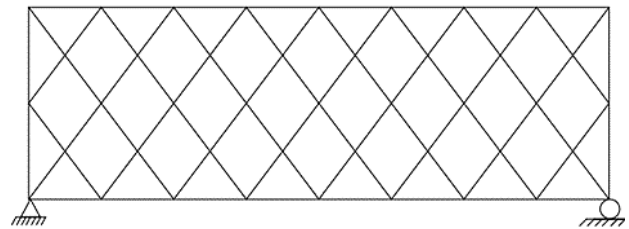
Figure 9.1: Different Roof Trusses

### 9.1 Types of Trusses

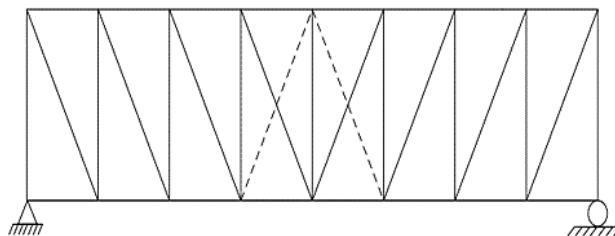
Various types of trusses are used around the world. Some of them are shown below:



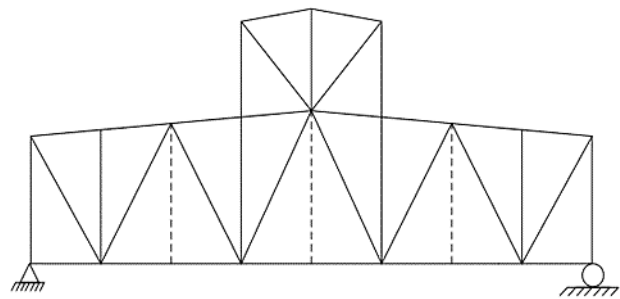
Bowstring Truss



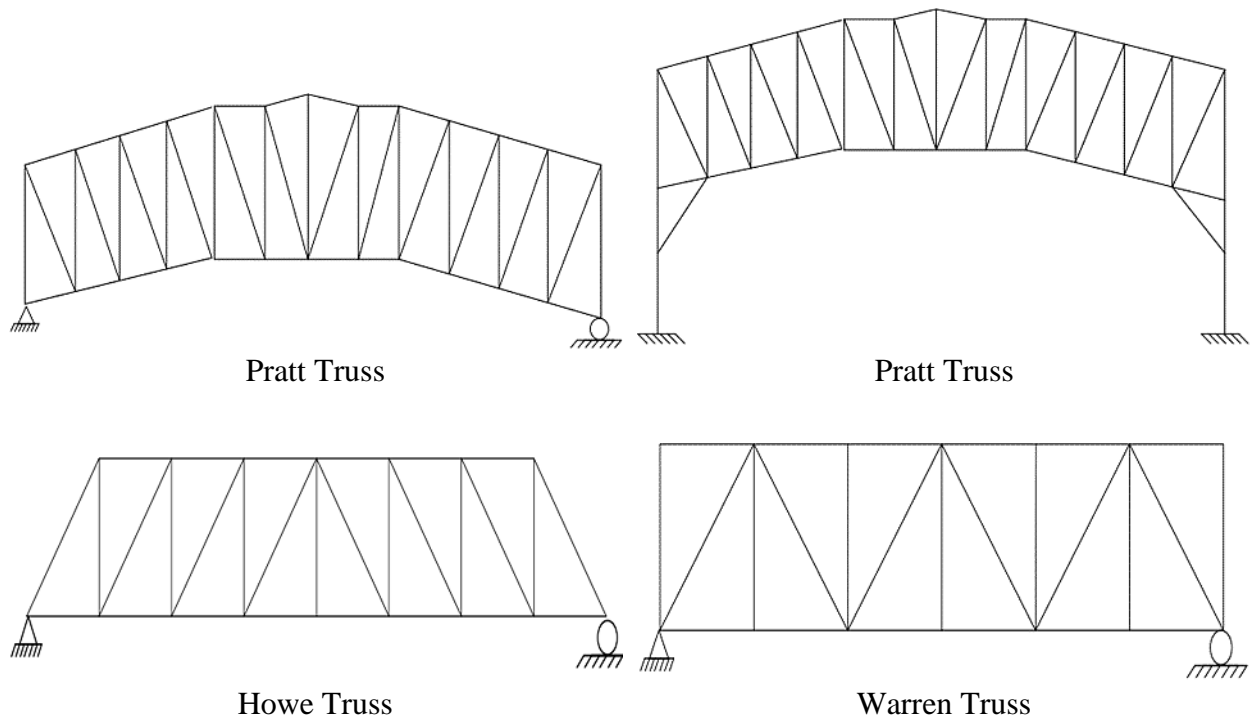
Towne Lattice Truss



Pratt Truss



Truss with monitor



**Figure 9.2: Different Types of Trusses**

## 9.2 Basic Terminologies of a Truss

**Bay:** Bay is the distance between two main trusses.

**Span:** Span is the distance between supports of a truss.

**Rise:** The rise of a truss is vertical distance between apex and line joining the supports.

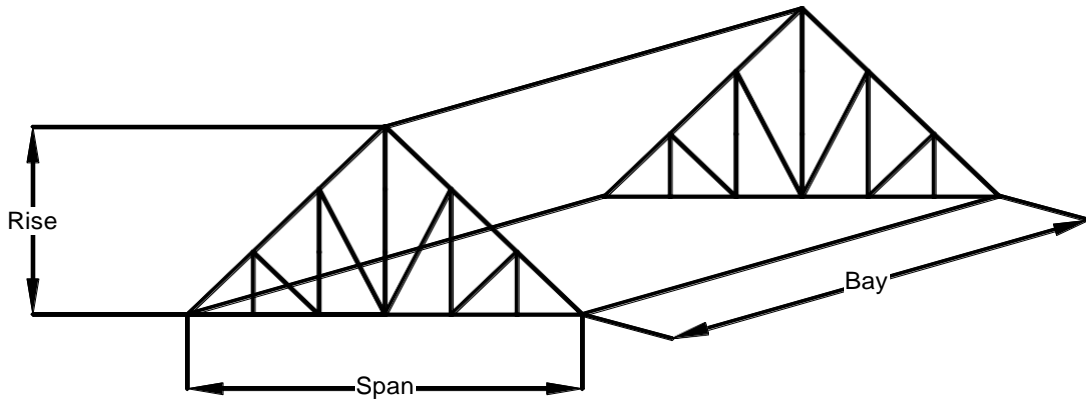
**Pitch:** The ratio of the rise to the span is called the pitch.

**Top Chord:** The uppermost line of members which extend from one support to the other through the apex is called the upper chord.

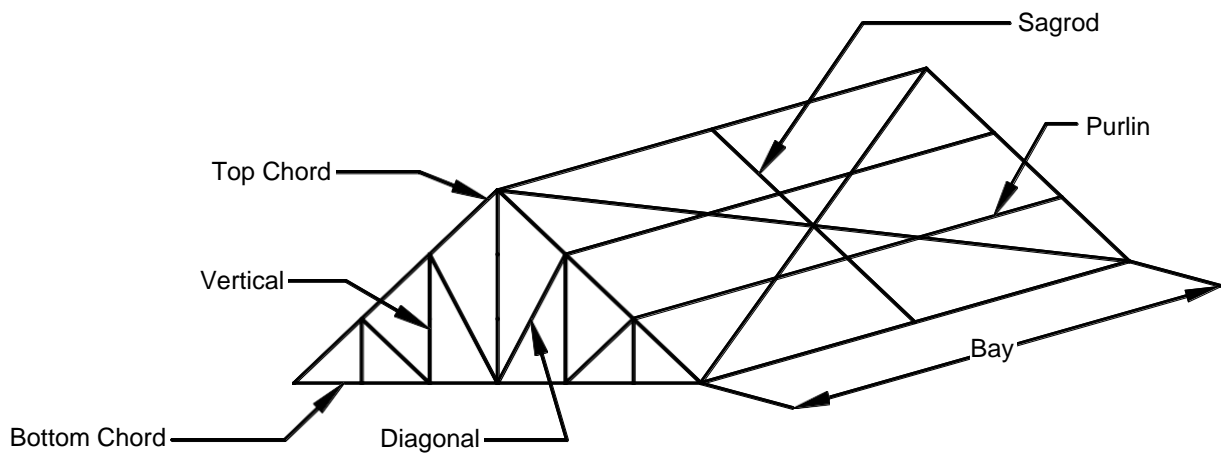
**Bottom Chord:** The bottom chord consists of the lowermost line of members extending from one support to other.

**Verticals:** Vertical members connecting top and bottom chords.

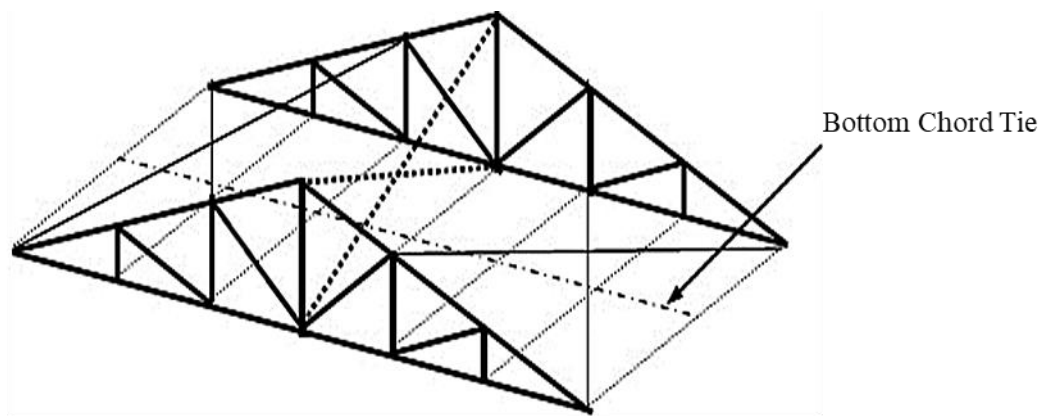
**Diagonals/Web Members:** Inclined members connecting top and bottom chords.



**Figure 9.3: Dimensions of a Truss System**



**Figure 9.4: Components of a Truss**



..... Bottom Chord Bracing    ——— Top Chord Bracing    ..... Vertical Bracing

**Figure 9.5: Bracing System of Truss**

### 9.3 Worked Out Problem

A Pratt type roof truss was designed from the following data:

**Design Data:**

Bay distance (truss-to-truss distance) = 25 feet.

Span = 40 feet

Span-to-rise ratio (pitch) = 4:1

Rise = 10 feet

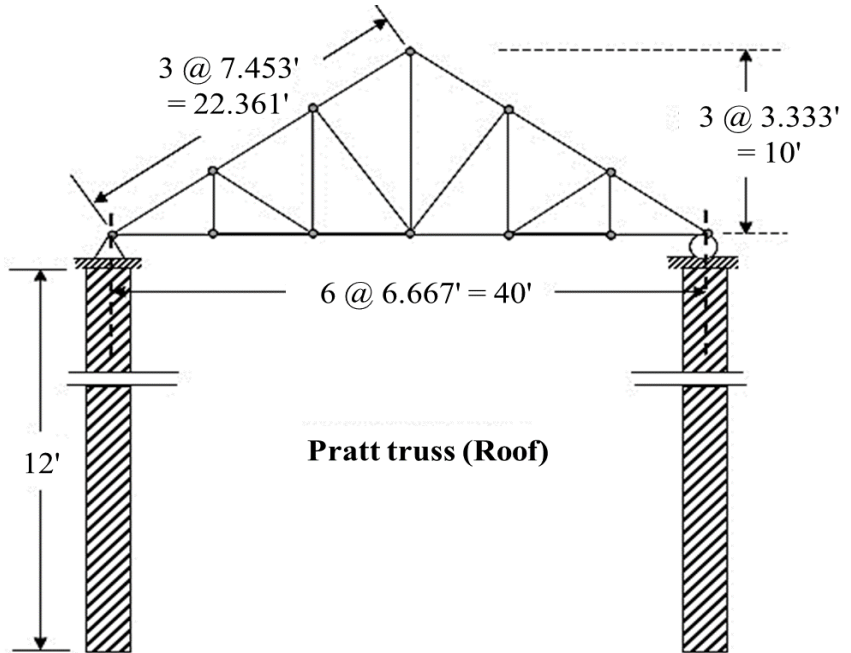


Figure 9.6: Pratt type Roof Truss

Table 9.1: Member Specifications

Member Type	Design Section	Unit Weight (lb/ft)
Top chord	$L 3\frac{1}{2} \times 3 \times \frac{1}{4}$	5.40
Bottom chord	$L 4 \times 3 \times \frac{5}{16}$	7.20
Verticals	$L 2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{16}$	3.10
Web member / Diagonals	$L 3 \times 2\frac{1}{2} \times \frac{3}{16}$	3.39
Vertical bracing	$L 1\frac{1}{2} \times 1\frac{1}{2} \times \frac{1}{4}$	2.34
Top chord bracing	$L 1\frac{3}{4} \times 1\frac{3}{4} \times \frac{1}{4}$	2.77
Bottom chord strut	$L 2 \times 2 \times \frac{5}{16}$	3.92
Purlin	C 7 × 9.8	9.80
Sagrod	#3 bar	0.38


**Solution:**

The various members of the truss network are designed as follows:

**Table 9.2: Calculation of Total Weight of the Truss Members**

Member Type	Shape of Section	Design Section	Quantity	Length (ft)	Unit Weight (lb/ft)	Total Weight (lb)
Top Chord	Angle	$L 3 \frac{1}{2} \times 3 \times \frac{1}{4}$	12	7.453	5.40	482.954
Bottom Chord	Angle	$L 4 \times 3 \times \frac{5}{16}$	12	6.667	7.20	576.029
Verticals	Angle	$L 2 \frac{1}{2} \times 2 \frac{1}{2} \times \frac{3}{16}$	4	3.333	3.10	41.329
			4	6.667	3.10	82.671
			2	10	3.10	62.000
Web Member/ Diagonals	Angle	$L 3 \times 2 \frac{1}{2} \times \frac{3}{16}$	4	7.454	3.39	101.076
			4	9.429	3.39	127.857
Vertical Bracing	Angle	$L 1 \frac{1}{2} \times 1 \frac{1}{2} \times \frac{1}{4}$	2	26.926	2.34	126.014
Top Chord Bracing	Angle	$L 1 \frac{3}{4} \times 1 \frac{3}{4} \times \frac{1}{4}$	4	29.107	2.77	322.506
Bottom Chord Strut	Angle	$L 2 \times 2 \times \frac{5}{16}$	7	25	3.92	686.000
Purlin	Channel	C 7 × 9.8	5	25	9.8	1225.000
Sagrod	Cylindrical	#3 bar	2	22.361	0.38	16.994
<b>Total Weight = 3850.430 (lb)</b>						

Total weight of steel members = 3850.430 lb

Unit Price = A tk/lb

Total Cost =  $3850.430 \times A = X_1$  tk

Erection and Welding Cost = 10% of total cost =  $X_2$

Estimated cost =  $X_1 + X_2$  tk



## Part 10: Uses of Software in Construction Estimation

### 10.1 Introduction

Measurement software applications, as a useful IT tool, can help a quantity surveyor to speed up the measurement works. Studies have shown that workers (quantity surveyors) spent up to 80% of their working time on measurement of quantities to produce bills of quantities (Keng & Ching, 2011). The benefits of using measurement software in the preparation of Bill of Quantity (BoQ) are high accuracy, easy to edit the BoQ, speed up measurement works, high traceability, user friendly, and reduction of workforce to do measurement works. These indicate that the adoption and the use of measurement software can bring improvement in editing BoQ, accuracy, traceability, and timeliness. By using measurement software, it can enhance the service quality of quantity surveying firms and enabled them to meet the high expectations of the clients.

### 10.2 Software Used in Quantity Surveying

A large number of software is available to the quantity surveyors. The two main functions of these software include taking off measurement and preparing the BoQ. A few prominent software is listed below:

1. QuickMeasure OS
2. PriMus-To
3. PlanSwift
4. On-Screen Takeoff
5. Bluebeam Revu
6. Vu360
7. Easy-Pro Builders Estimator
8. iScope
9. Estimate
10. PlanViewer

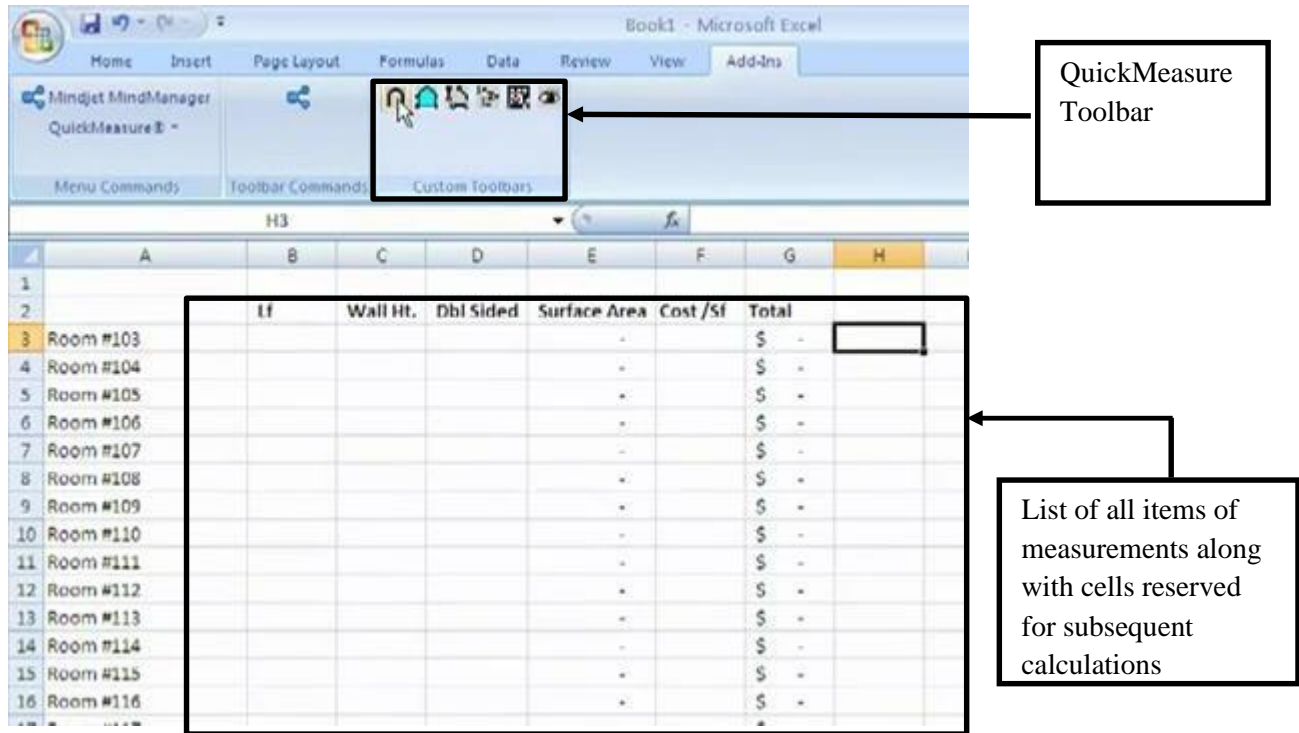
This manual discusses briefly on the usage of QuickMeasure OS.

### 10.3 QuickMeasure OS

QuickMeasure OS is one of the most popular software because of its user-friendliness, strong support system and most importantly, its integration with a widely-used and available software Microsoft Excel. A brief discussion on the use of this is provided below using the example, where it is shown how to calculate volume of brick masonry.

**Step One:** Open Excel file. Create a new list identifying all the items of measurement and include the additional columns required for complete calculations along with their formulae.





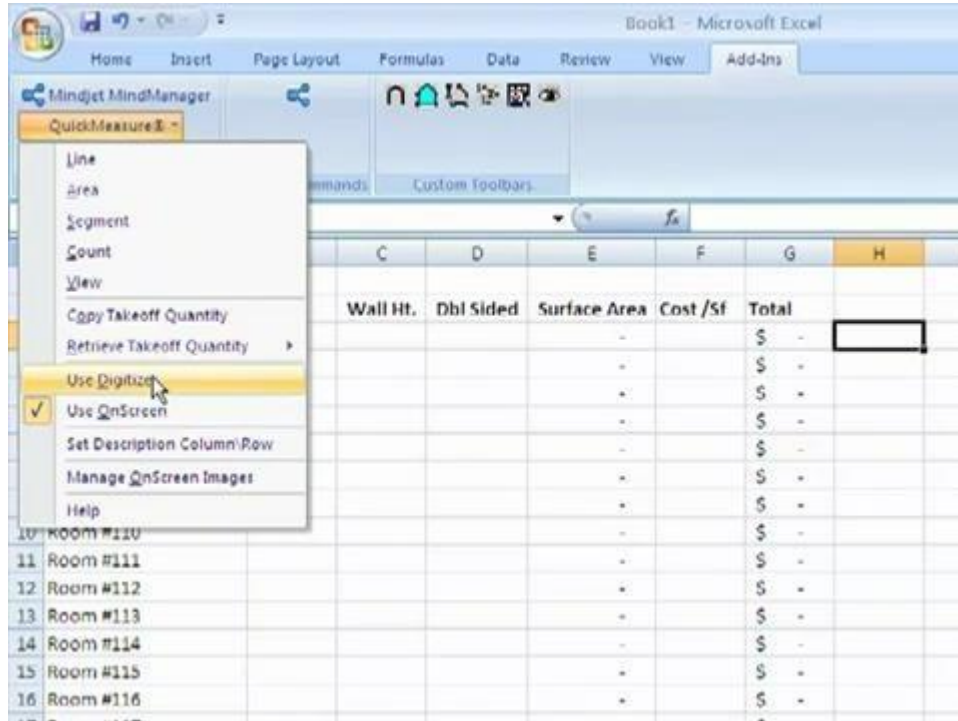
**Figure 10.1: Listing Items**

In this case, for each room, the columns created are: Length, Wall Height, Single/double sided, surface area, cost per unit surface area and total.

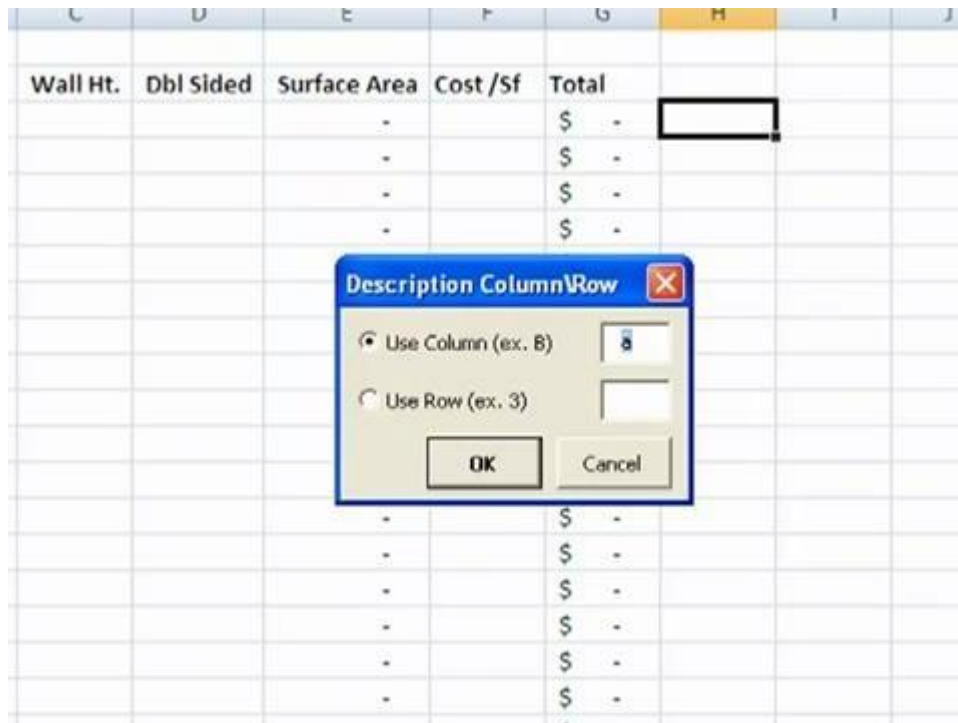
**Step Two:** The QuickMeasure Onscreen (QuickMeasure OS) loads automatically as an add-in in excel. This add-in can be used in the form of OnScreen as well as Digitizer, as shown in Figure 10.2. In this case, we are using OnScreen version.

**Step Three:** Click on “Set Description Column\Row”. This will open up a window (Figure 10.3) where you need to enter the column or row number that includes your primary product description. In this case, it is the Identity of the Rooms, so use column A.





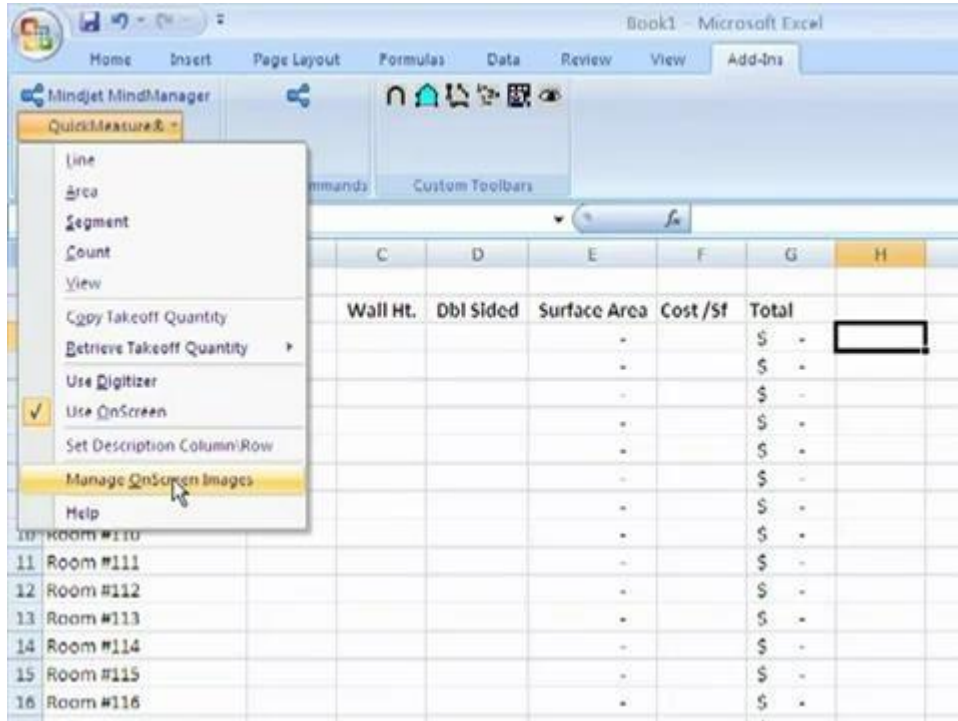
**Figure 10.2: Choosing OnScreen Option**



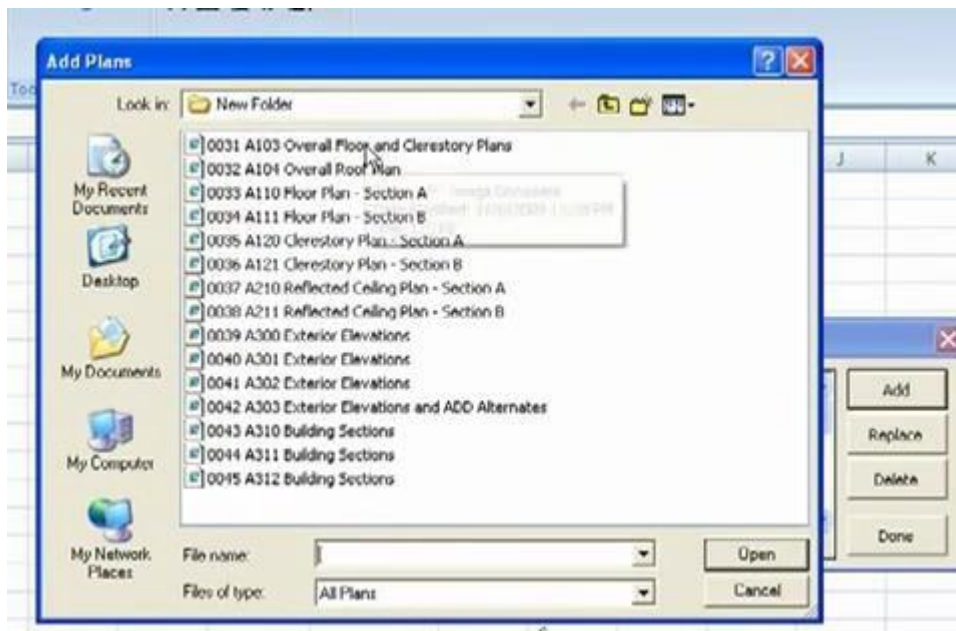
**Figure 10.3: Setting the Description Column**



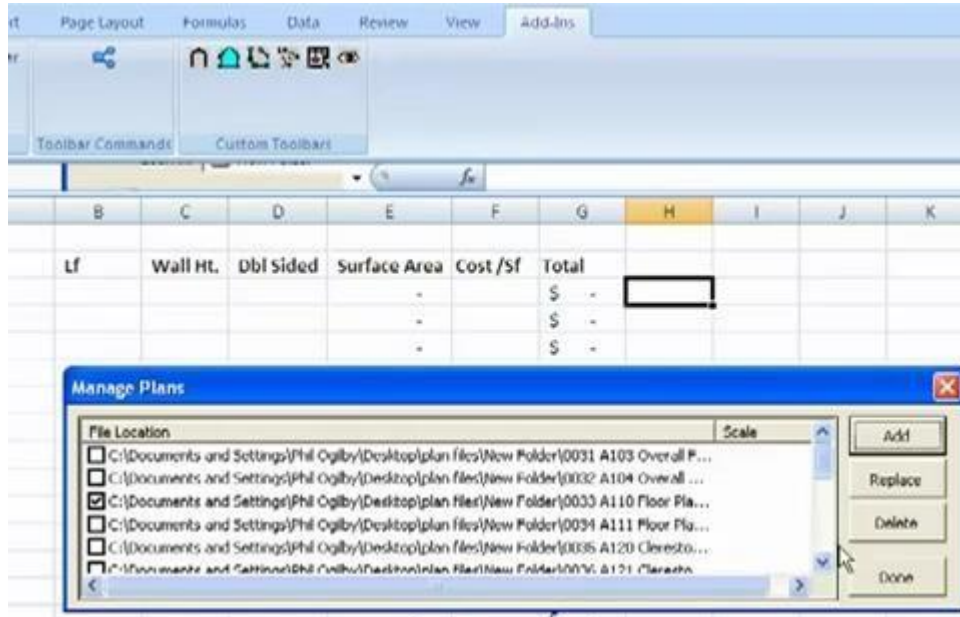
**Step Four:** Clicking on Manage OnScreen Images (Figure 10.4) will open up a window to load images (Figure 10.5) in the form of jpg, gif, pdf, etc. As shown in Figure 10.6, click “Add” to load more images, then click “Done” when you are finished adding images.



**Figure 10.4: Clicking on Manage OnScreen Images**



**Figure 10.5: Adding Plans**



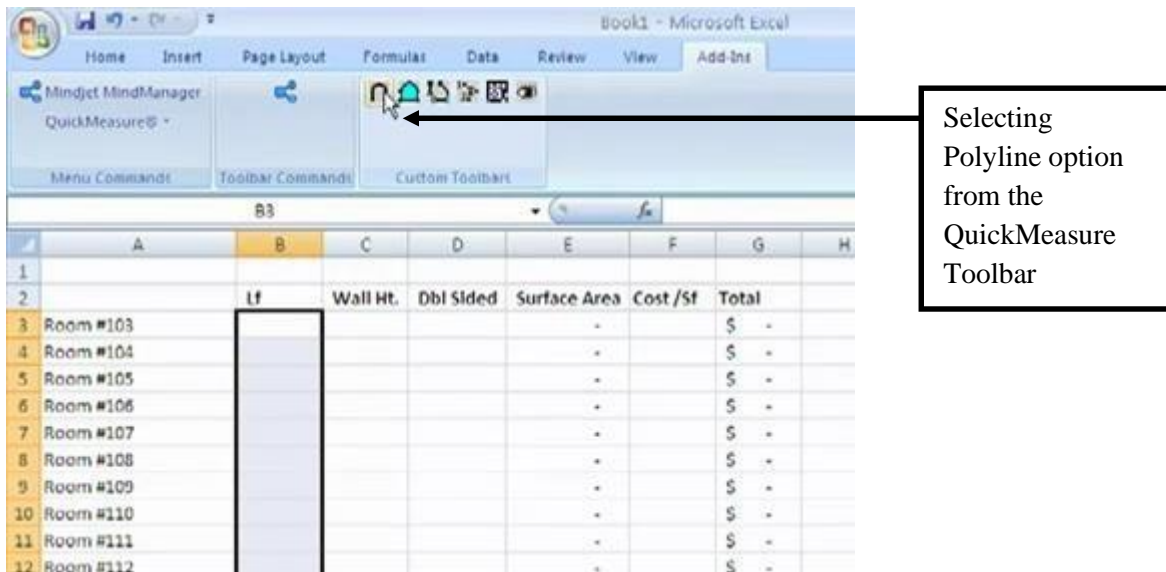
**Figure 10.6: Managing Plans**

**Step Five:** In this example we are going to find the length (linear footage) of wall by take-off and then the surface area and cost of wall for each room mentioned in different rows. Select the Linear Footage column (Column B), because this is the column that we will populate with values from take-off. This is shown in Figure 10.7.

	A	B	C	D	E	F	G	H
1								
2		Lf	Wall Ht.	Dbl Sided	Surface Area	Cost/Sf	Total	
3	Room #103				-		\$ -	
4	Room #104				-		\$ -	
5	Room #105				-		\$ -	
6	Room #106				-		\$ -	
7	Room #107				-		\$ -	
8	Room #108				-		\$ -	
9	Room #109				-		\$ -	
10	Room #110				-		\$ -	
11	Room #111				-		\$ -	
12	Room #112				-		\$ -	
13	Room #113				-		\$ -	
14	Room #114				-		\$ -	
15	Room #115				-		\$ -	
16	Room #116				-		\$ -	
17	Room #117				-		\$ -	
18	Room #118				-		\$ -	
19	Room #119				-		\$ -	
20	Room #120				-		\$ -	
21	Room #121				-		\$ -	
22					-		\$ -	
23					-		\$ -	

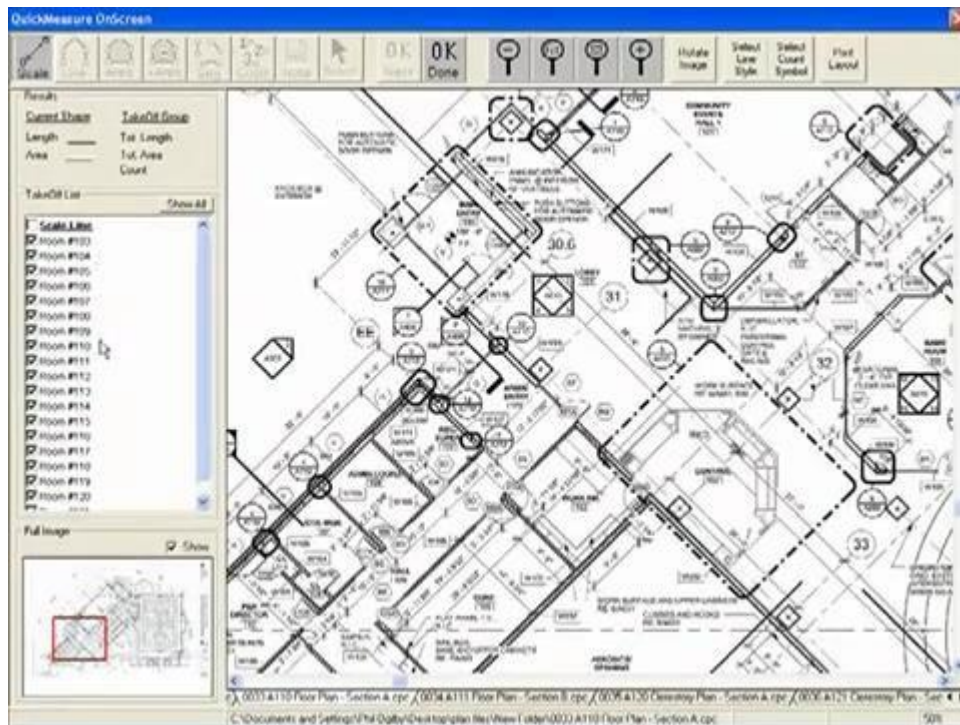
**Figure 10.7: Selecting Linear Footage Column**

In the custom toolbar, you can work with linear distances using either polyline or segments. In this example, we will select polyline, as shown by the mouse cursor in Figure 10.8.



**Figure 10.8: Selecting Polyline Option from the QuickMeasure Toolbar**

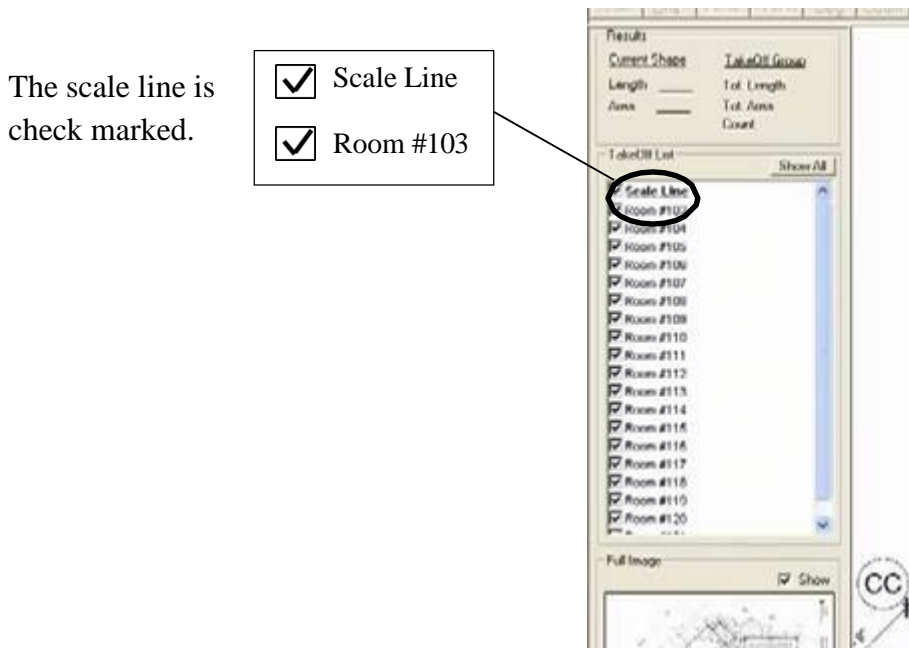
Selecting the polyline, then pressing enter will open up the QuickMeasure OnScreen Window, as shown in Figure 10.9.



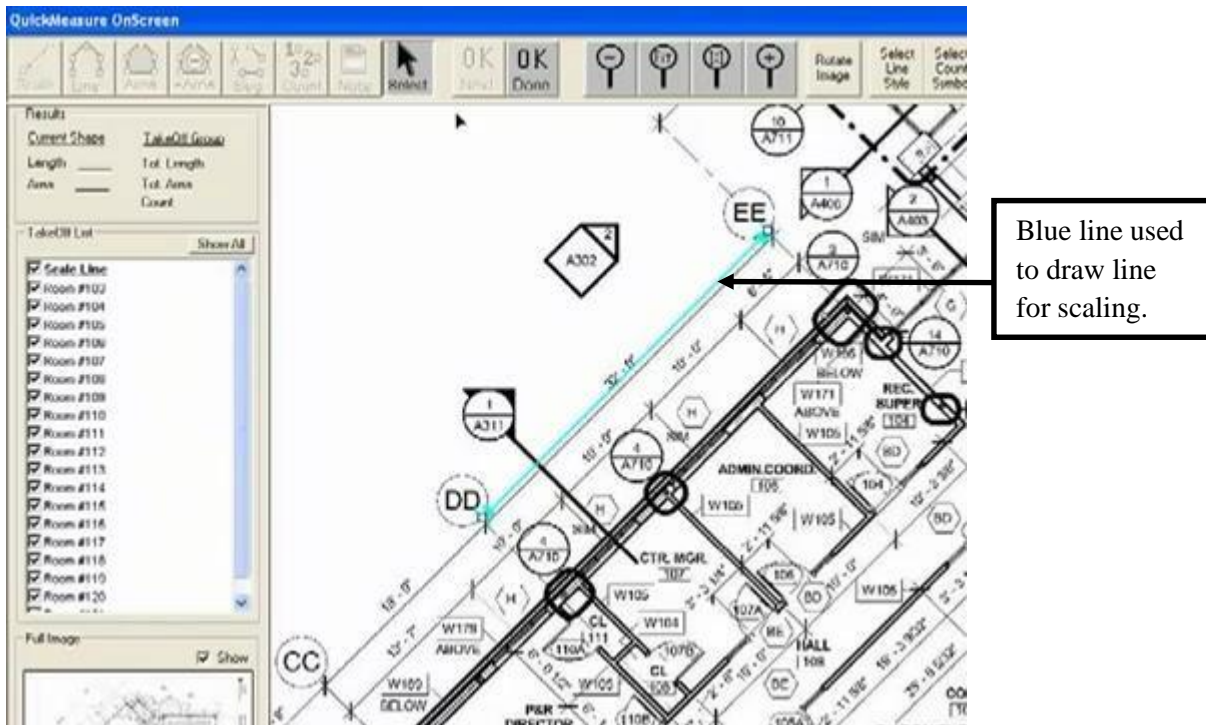
**Figure 10.9: QuickMeasure OnScreen Window**



**Step Six:** In Figure 10.9, the Scale Line is deselected by default. We now select it to set the scale of the diagram, as shown in Figure 10.10.

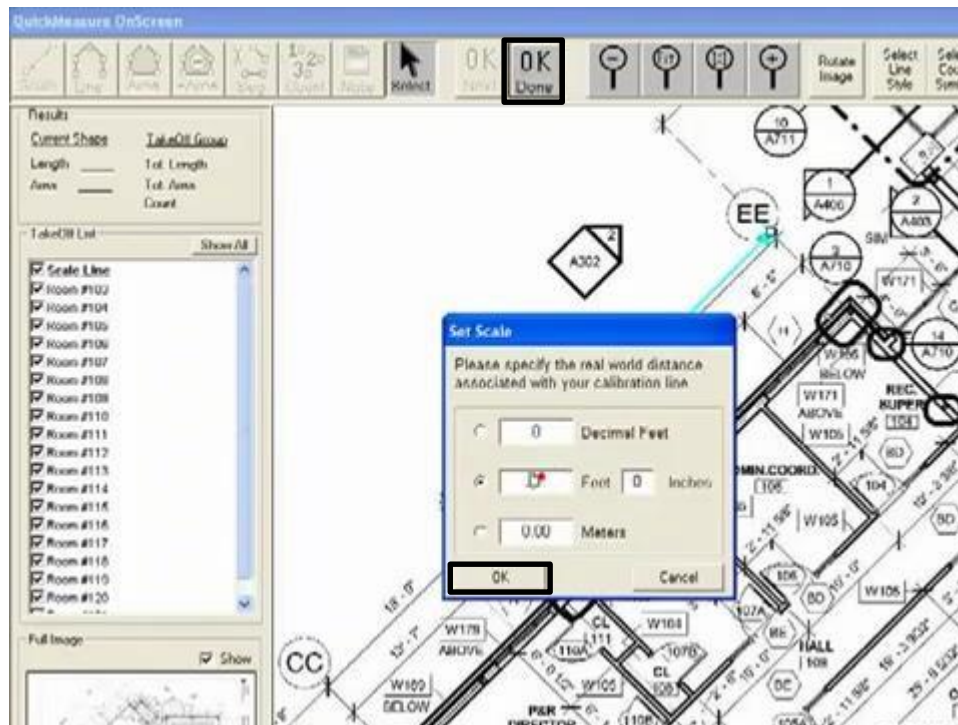


**Figure 10.10: Check Marking the Scale Line**



**Figure 10.11: Scaling the Plan**

Selecting the “Scale Line” will prompt the user to draw a line on the building plan. Drag the mouse cursor over the distance in the image file to show the distance to be scaled, as shown using the light blue line in Figure 10.11. The line length and direction can be adjusted as necessary. When you are satisfied, click on “OK Done” in the top toolbar shown in Figure 10.11. A window called “Set Scale” then opens up, where the real distance is specified. In this case, the real distance is 32 feet 0 inches, as shown in Figure 10.12. Press “OK” when done.



**Figure 10.12: Setting the Scale**

After selecting the correct scale, uncheck the tick Scale mark of the scale line. If a new scale is required, check the tick mark again to adjust scale.

**Step Seven:** Select the first room (Room #103) out of the list and then click on “Line” on the top toolbar in Figure 10.13. You can also change and predefine the line style using “Select Line Style”. After you are satisfied, click on “Line” on the top toolbar. Use the mouse to define the length of the walls of the room. In this case, blue line is used to define the walls of Room #103 as shown in Figure 10.14. Left click each time you want to set a point and double click when you are finished drawing the line. The length of the line is automatically measured as show in Figure 10.15. You can navigate around the image using Right-click button or the mouse scroll button. Once you are ready to move to the next room, click on “OK Next”. You can change line style for the new room to differentiate from the previous room. If you want to skip some rooms and jump ahead to, for example Room #112, just select Room #112 from the list on the left side and digitize the respective room.







Once you are finished with your digitizing, click “OK Done”. The Linear Footage (Column B) of the excel file will be populated with the digitized measurements. Fill up the remaining columns manually and finally get the total cost of materials for the walls as shown in Figure 10.16.



Figure 10.15: Finishing the Take-off

	A	B	C	D	E	F	G	H	I	J
1										
2		Lf	Wall Ht.	Dbl Sided	Surface Area	Cost /Sf	Total			
3	Room #103	55	0		440	\$ 4.50	\$ 1,977.84			
4	Room #104	39	0	x	617	\$ 4.50	\$ 2,774.29			
5	Room #105	69	0		549	\$ 4.50	\$ 2,471.99			
6	Room #106	40	0	x	630	\$ 4.50	\$ 2,876.79			
7	Room #107	34	0		275	\$ 4.50	\$ 1,238.05			
8	Room #108						\$ -			
9	Room #109						\$ -			
10	Room #110						\$ -			
11	Room #111						\$ -			
12	Room #112						\$ -			
13	Room #113						\$ -			
14	Room #114						\$ -			
15	Room #115						\$ -			
16	Room #116						\$ -			
17	Room #117						\$ -			
18	Room #118						\$ -			
19	Room #119						\$ -			
20	Room #120						\$ -			
21	Room #121						\$ -			
22					2,520		\$ 11,338.96			
23										

Figure 10.16: Automatic Transfer of Measurements to Excel





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