Al-Zaytoonah Private University of Jordan

Faculty of Engineering/Civil Engineering Department

CE 902570 Construction Management and Quantity Survey - 3 credits

Construction Management and Quantity Survey

Class Notes

By

Dr. Hesham Ahmad

Second Edition

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Chapter 1: Introduction

1.1 Definition of Quantity Survey

Quantity survey is a schedule of quantities of all the items of work in a building.

1.2 Data Required for the Preparation of an Estimate or Quantity Survey

1.2.1 Drawings

Complete and fully dimensioned drawings (i.e. plans, elevations, sections and other details) of the building or work in question are required.

1.2.2 Specifications

Detailed specifications, giving the nature, quality and class of work, materials to be used, quality of the material, their proportions, and method of preparation are required.

1.2.3 Rates

The rates of various of work, materials to be used in the construction, wages of different categories of labor (skilled or unskilled) and cost of transportation charges should be available for preparing an estimate of work cost.

1.2.4 Actual Finished Work

Quantities can be calculated from the actual work done in the project site.

- The quantities mainly can be calculated as:

Quantity = Length × Width × (Height or Thickness),

Quantity = Area of cross-section × Length,

Quantity = Length × Width,

Quantity = Length.

Quantity = Number of Units.

Quantity = Weight.

1.3 Importance of Quantity Survey

1. Quantity survey is essential to estimate before the construction starts the *probable cost* of construction for the complete work. The construction cost includes cost of materials, cost of transportation, cost of labor, cost of scaffolding, cost of tools and plants, establishment and supervision charges, cost of water, taxes and reasonable profit of the contractor, etc. The estimate is required in inviting tenders for the works and to arrange contract for a complete project.

2. Quantity survey is required to estimate the quantities of the various materials required and the labor involved for satisfactory completion of a construction project.

3. It is also useful to check the works done by contractors during and after the execution. Also the payment to the contractor is done according to the actual measurements of the completed part of each item of work.

4. A complete quantity survey or estimate is useful to provide useful advice to clients on:

(i) Valuation of properties (land and building) for sale, purchase and mortgage etc.

(ii) Fixation of standard rent.

(iii) For insurance and claim for damages in a building.

(iv) For the process of resolving disputes by referring to a third party.

1.4 Types of Estimates and Quantity Survey

1.4.1 Preliminary or Approximate Estimate

This is to find out an approximate cost in a short time. It is used to give an idea of the cost of a proposed project. This estimate helps the client or sanctioning authority to make decision of the administrative approval.

The approximate cost is prepared from the comparison with similar works. The approximate cost can be found by using methods that depends on the area or cubic content of a building and then multiplying this by an estimated rate for the unit of the area or cubic content. Approximate quantities of materials and labor required per m^2 of the area for a proposed building also can be found.

1.4.2 Detailed Estimate

After getting the administrative approval, this estimate is prepared in detail prior to inviting of tenders. The whole project is divided into sub-works, and the quantities of each sub-work are calculated separately. The dimensions of the required work are taken from the drawings of the project.

1.4.3 Quantity Estimates

This is a complete estimate of quantities for all items during project implementation.

1.4.4 Revised Estimate

Prepared if the estimate exceeded by 5% due to the rates being found insufficient or due to some other reason.

1.4.5 Maintenance Estimate

Estimating required quantities and cost of work to maintain a structure (road, building, etc.)

1.5 Contracts

Contract is an agreement between two or more parties creating obligations (إلتزامات) that are enforceable or recognizable at law (ملزمة و معترف بها قانونياً)

It establishes an obligation of each party (حزب، فريق, جهة) to fulfill what it is agreed to perform.

1.5.1 Obligations of the employer (المالك)

1. Appointing of the engineer to administer the contract
2. Provision of the site
3. Provision of information, permits, and approvals
4. Providing funds and making payments in accordance with the contract
5. Participation in consultations with the engineer to agree matters on claims or conflicts between parties.

1.5.2 Obligations of the Contractor (المقاول)

1. Execution and completion of the works and remedying (يعالج) any defects (عيوب) therein.
2. Provision of (يجب على المقاول توفير ما يلي:):
    a. Labor, materials, plant, and equipment needed
    b. Preparation of progress report
    c. Works program for execution, and updating it whenever required
    d. Setting out of the works
    e. Measurement and/or assisting the engineer to do so
    f. Records of his personnel and equipment
    g. Sample of materials specified
    h. Testing and re-testing
    i. Temporary works
    j. Facilities for other contractors working on the site

k. Keeping the site clean, and remove rubbish

3. The contractor is required to:

   a. Sign the contract when he is called to do so

   b. Obtain and submit securities, guarantees, and insurance policies

   c. Ensure that his representatives will be available on site at all times

   d. Prepare and submit the contractor's document, including "as built drawings" and manuals of operation and maintenance

   e. Attend to the engineer's instructions

   f. Provide access to the employer's personnel to enter the site

   g. Prepare and submit payment statement and documentation

   h. To uncover works for inspection when required

   i. Rectify (Correct) defective works

   j. Secure or compensate the employer against any claims

   k. Submit notices to the engineer whenever he encounters circumstances that may cause future claims

   l. Getting approval before assigning sub-contractors or partners of the works

   m. Respond for consultation with the engineer

4. Comply with the applicable laws, labor law and other local regulations.

1.5.3 Role of the Engineer (الإستشاري أو الإشراف)

Usually the employer will enter into a consultancy agreement with the engineer to design and/or supervise the works.

The engineer shall have no authority to amend the contract.

Engineer role can be:

1. As the employer's agent:

   a. Administration of the contract – dealing with the procedures, provision of information and interpretations, issuance of variations, approval of samples, etc.

   b. Cost accountancy and payments

2. As a supervisor:

The engineer must ensure that the work is being performed to fulfill the contract documents.

3. As a certifier:

The engineer is required to certify or approve the payments that should be paid by the employer to the contractor. Those payments should be made periodically, mostly on monthly basis, and should depend on the quantity of works finished by the contractor.

4. As a determiner:

The engineer must act as a mediator to help the parties towards agreement in issues such as claims for reimbursement of costs (تعويضات مالية) or extension of time (تمديد وقت المشروع).

5. Issuance of instructions and variations (إصدار التعليمات و التعديلات):

Include: issuance of additional or modified drawings, actions in relation to defective works, issuance of clarifications, giving approval, and ordering variations.

1.6 Types of Contracts

1.6.1 Measured or Unit rate Contract

In this type of contract, the price is computed by multiplying quantities of work executed by the unit rate offered by the contractor in his tender. The rates are usually set out in the Bill of Quantities (BOQ).

Such contracts often used where there are significant changes in the quantities or working conditions. So, when there are certain reasonable differences of the quantities accepted by all the parties, then the contract can be paid for by multiplying the actual measured quantities by the unit rates.

Advantages:

1. Suitability: This type of contract is widely used in the execution of large projects financed by public bodies or governments. It also suits the works which can be split into separate items and the quantity of each item could be estimated with reasonable accuracy.

2. The employer pays for the actual work executed.

3. The contractor usually allows for a certain margin of variation, with a clear mechanism for valuation of such variations.

4. The engineer / employer has liberty to provide some drawings during the execution of the project, after award.

Disadvantages:

l. The employer cannot be absolutely sure of the total cost of the project until the whole work is completed. In case the quantities in the BOQ are inaccurate or roughly approximated, the value of the work may vary considerably. The contractor may try to offer an unbalanced tender on the basis of his anticipation of the uncertainty of quantities of certain items.

2. Both the engineer and the contractor have to do considerable computations and book-keeping during the progress of work.

3. Extra works or varied items of work are often a source of conflict. The contractor may press for higher rates than he would have tendered for in the beginning.

1.6.2 Lumpsum contract

In a lumpsum contract, the contractor agrees to carry out the entire work as indicated in the drawings and described in the specifications, for a specified fixed lumpsum amount.

Sometimes, the contract makes provisions to adjust the "lump sum" allowing for extra work and limited variations.

Normally, a bill of quantities is not usually included, and if included it does not form part of the "Contract Documents", but may be used just for guidance.

Instead, a schedule of rates may be of value to evaluate the cost of extras or omissions.

Advantages:

l. From the employer's stand point, and if no extras are contemplated, the tender sum tells him the exact cost of the project. Sometimes the employer will be working within a tight margin of budget.

2. From the contractor's stand point, because the design will often be prepared by him, the contractor can gain through proper planning and efficient management to increase his margin of profit and/or to control timing.

3. Both parties need less number of staff for book-keeping (عملية مسك الدفاتر أي تسجيل جميع المعاملات المحاسبية), accounting and measurement.

Disadvantages:

l. In lumpsum contracts, there should be a complete set of plans and specifications, or what is called "Employer's Requirements" which should be sufficiently detailed.

2. Variations in lumpsum contract may trigger conflicts about whether or not a particular item of work falls within the agreed scope of work, and whether there has been a variation to such scope.

3. This type of contract will not be suitable for works with scope and nature that cannot be predicted accurately in advance. The outcome will be unfair for the contractor to assume all risks and uncertainties, or for the employer to pay a higher cost.

1.6.3 Cost-plus contract

This type of contract differs from both the measured and the lumpsum contract in that the employer agrees to pay the contractor for the actual cost of the work plus an agreed percentage of this actual cost to cover overhead and profit.

The contractor agrees to execute the works based on the drawings and specifications and any other information that will be provided to him from time to time during progress of the works.

The percentage to be paid should not be applied on the costs of salaries of the contractor's staff, whether on-site or off-site.

Advantages:

1. Early completion of the work - The work can be started even before the design and estimates are prepared. Decisions can be taken speedily, and flexibility allows adoption of alternates for construction to suit the Employer's Requirements.

2. The quality of the work can be assured. The contractor is induced to perform the work in the best interest of the employer.

3. No conflicts will be anticipated as to extras or omissions.

Disadvantages:

1. The final cost to the employer cannot be foretold.

2. Both parties have to do a lot of accounting and book-keeping regarding labour; purchase of materials and plant and use of equipment.

3. The contractor has no incentive to economize or finish the work speedily.

Suitability:

In spite of some drawbacks in certain cases, this form of contract can be used suitably for:

a- Emergency works that require speedy construction and where no time is available to prepare drawings for it.

b- Construction of special or expensive projects, such as palaces, where the cost of the work is of no consequence but the materials and workmanship to be purchased are just to suit the choice and taste of the employer.

Remark:

An alternate to the cost-plus contract is the cost-plus fixed fee contract, where the contractor will be paid for the actual cost of construction plus a fixed amount of fees for his overhead and profit. The fee does not fluctuate with the actual cost of the project. This factor may overcome the possible drawback of the cost-plus contract.

1.6.4 Construction Management Contract (C.M.):

In this type of contract, the employer engages a specialized construction manager (C.M.) to provide administrative service for him and manage the work on his behalf. The (C.M.) has full control on (Cost and Time), on the budget and programming, and is usually paid on a staff-reimbursement basis.

The (C.M.) assists in choosing the design consultant and the various contractors for a project divided into packages (structural, finishes, electro-mechanical, etc.).

The technical role is kept with the design-professional, but as to control, coordination, certification and dispute resolution, the (C.M.) normally possesses the major role.

Chapter 2: Quantity Survey Items and Methods

2.1 Introduction

Quantity surveying and the estimated quantities of materials required on a project are normally determined by professional surveyor or engineer.

The estimated quantities are provided to the interested bidders on a project to provide their prices. In this method of bidding, the contractors are all bidding on the same quantities. The estimators of contractors spend time developing the unit price of the different items in a project. To win the bid, contractors will work on keeping the cost of purchasing and installing the materials as low as possible.

As the project is built, the actual quantities are checked against the estimated quantities. For example, if the estimated quantity of concrete for a wall is 23 m^3, but the actual installed concrete is 26 m^3, then the contractor would be paid for the additional 3m^3.

When there is a large difference between the estimated and actual quantities, an adjustment to the unit price can be made. Small adjustments are usually made at the same unit as the contractor bid. Large errors may require that the unit price be renegotiated.

If the contractor is aware of potential changes between the estimated quantities and those that will be required in the project, the contractor may price his or her bid to take advantage of this situation. For example, if the contractor is aware that the filling material in the project will be changed from excavated soil to base-course, then he can provide low unit price for filling with excavated soil (say 5 JD/m^3) and high unit price for the base-course (say 15 JD/m^3). If the back-fill quantities were assumed to be 2000 m^3 of soil and 100 m^3 of base-course, so the assumed total price as in the bid will be 11,500 JD. But if the quantities were changed to 100 m^3 of soil and 2000 m^3 of base-course, then the new price of the actual work because of this change will be 30,500 JD, which will provide more profit to the contractor.

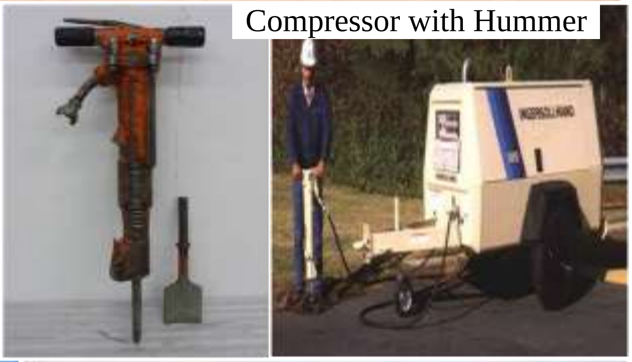
2.2 Excavation


Excavation


Loader


Excavator


Wheel Excavator with Hummer


Compressor with Hummer


Truck


Dozer


Grader


JCB

2.2.1 Swell and Compaction

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

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

Compacted Volume = Natural Volume X Shrinkage

Loose Volume = Natural Volume X (1 + Swell)

Example:

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

Answer:

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

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

Example:

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

Answer:

Compacted Volume = Natural Volume X Shrinkage

Loose Volume = Natural Volume X (1 + Swell)

Natural Volume = 200 m^3 ÷ 0.95 = 210.5 m^3

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

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

2.2.2 Cross-section Method (Grid Method)

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

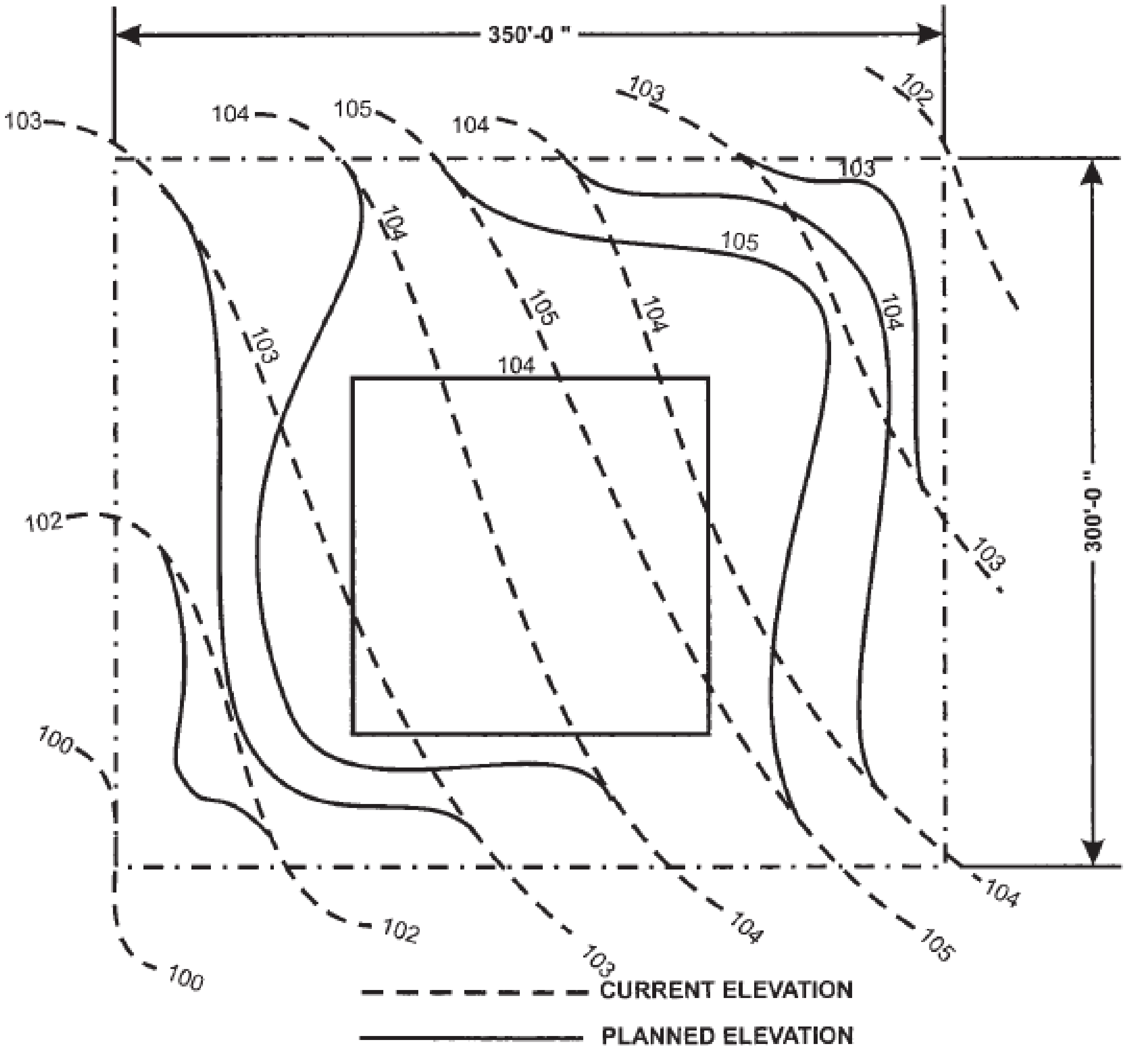


FIGURE 9.3. Sample Site Plan.

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

Cross-section method entails dividing the site into a grid and then determining the cut and fill for each of the grids. The size of the grid should be a function of the site, the required changes, and the required level of accuracy. The following figure shows the site divided into 50-foot grid in both directions.

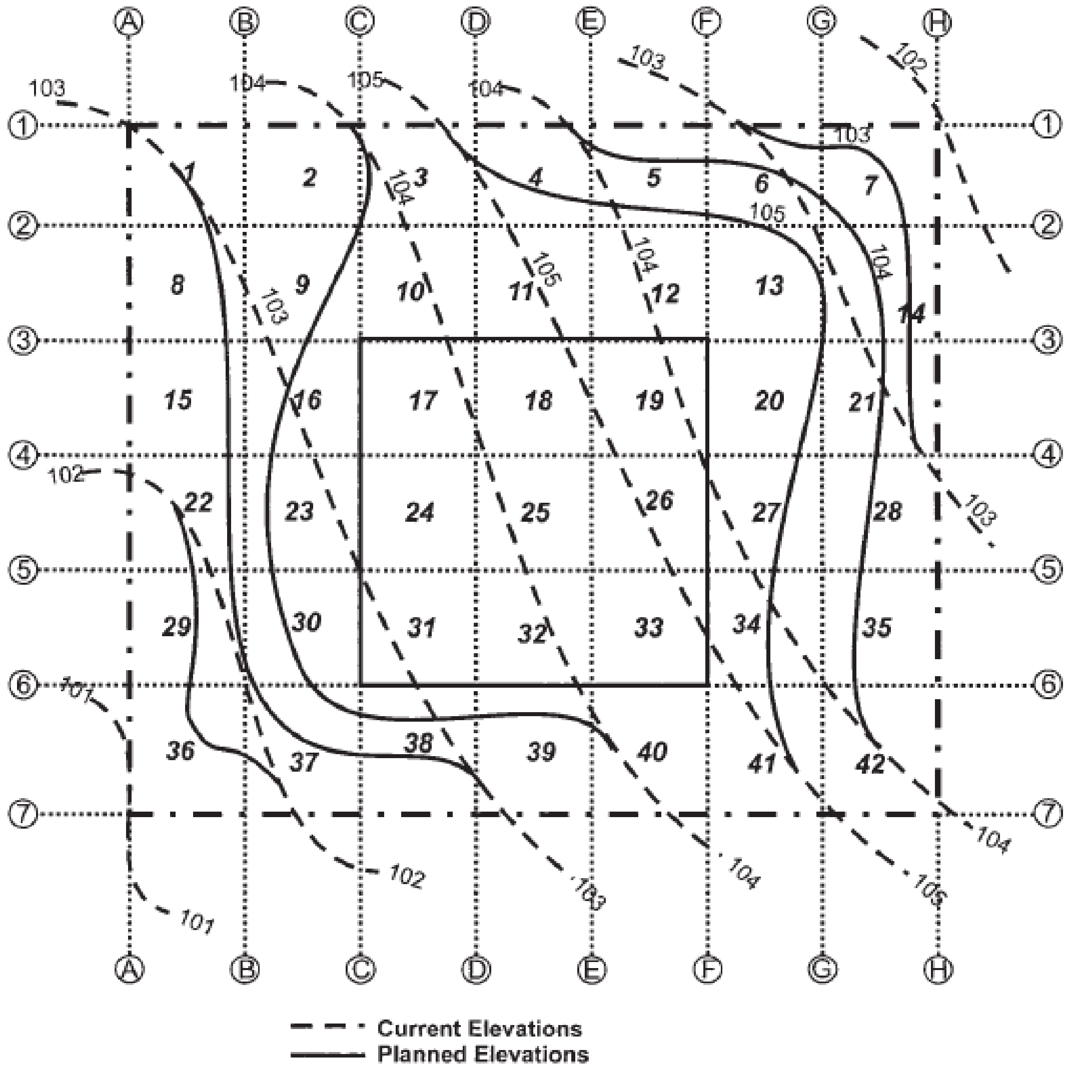


FIGURE 9.4. Site Plan Divided into 50′ Square Grid.

The next step is to determine the approximate current and planned elevation for each grid line intersection. The following figure shows the labeling method that should be used for this process.

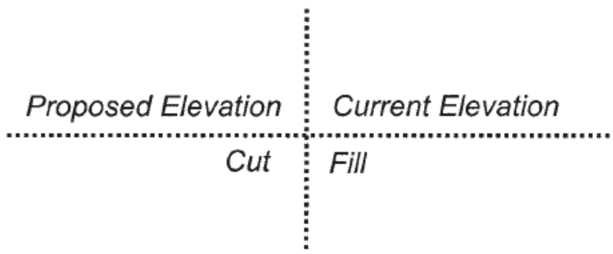


FIGURE 9.5. Labeling Convention.

Because contour lines rarely cross the grid intersection, it is necessary to estimate the current and proposed elevations at each of the grid intersection points. If the proposed elevation is greater than the current elevation, fill will be required. Conversely, if the planned elevation is less than the current elevation, cutting will be needed. Then, the grids that contain both cut and fill should be examined by checking the corners of the individual grid boxes. In the figure these are grids 3, 4, 10, 11, 12, 17, 18, 19, 25, 27, 32, 34, 39, and 41.

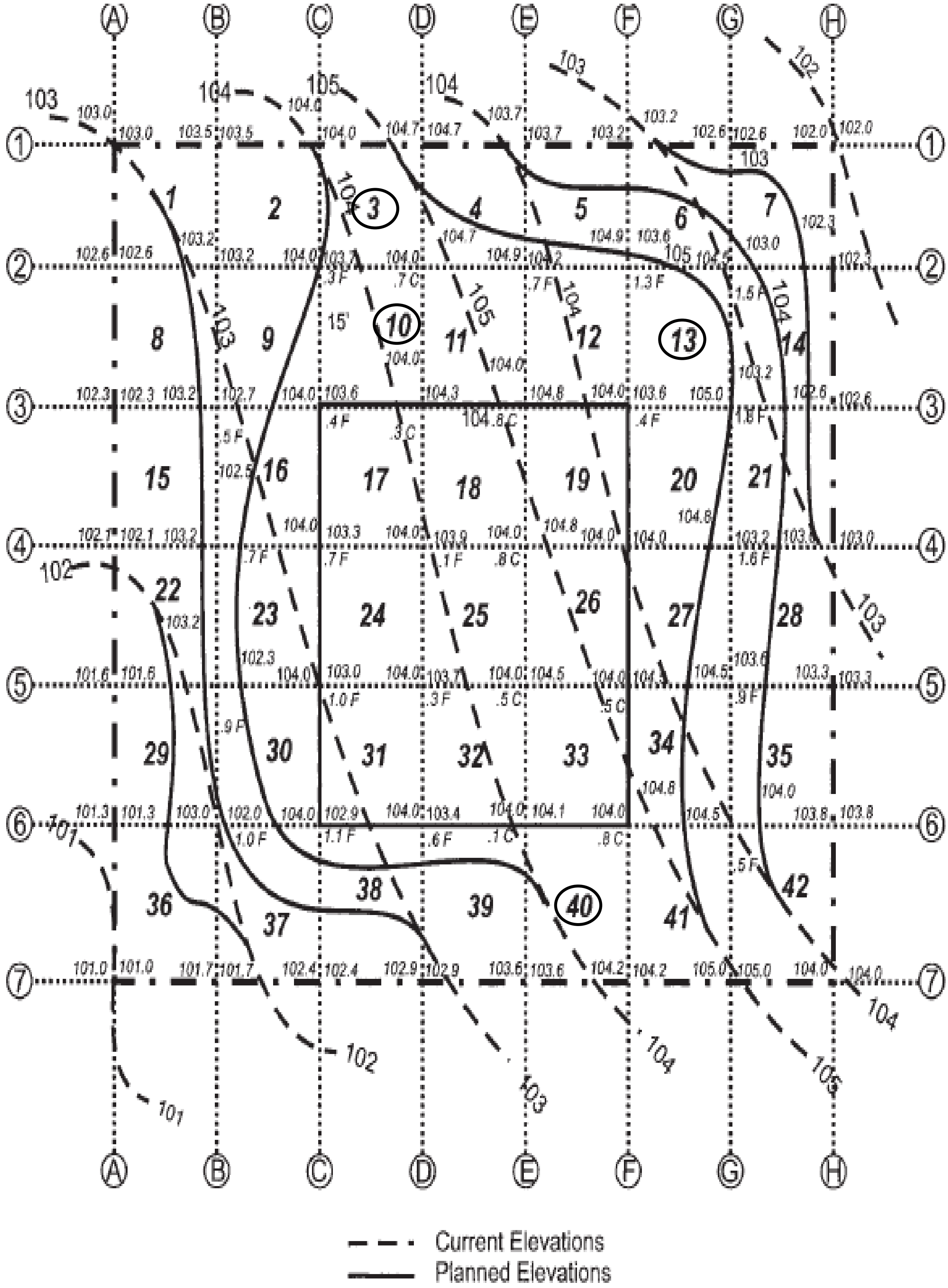


FIGURE 9.6. Grid with Elevations.

EXAMPLE 9-4 FILL VOLUME

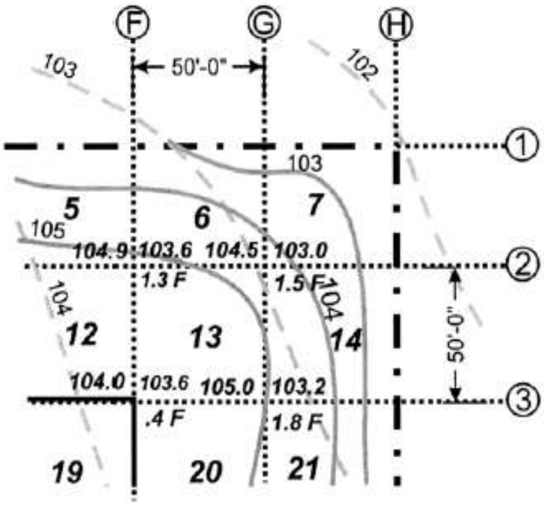


FIGURE 9.7. Excerpt of Grid 13.

Using grid 13 (Figure 9.7) from Figure 9.6 as an example, determine the fill quantity. From Figure 9.7, the information in Figure 9.8 is known about grid 13.

$$\text{ccf of fill} = \frac{\text{Sum of fill at intersections}}{\text{Number of intersections}} \times \text{Area}$$

$$\text{ccf of fill} = \frac{1.3' + 1.5' + 0.4' + 1.8'}{4} \times 2{,}500 \text{ sf}$$

$$= 3{,}125 \text{ ccf of fill}$$

That amount of fill is then entered in the fill column of the cut and fill worksheet (Figure 9.16).

Point	Planned Elevation	Existing Elevation	Fill (ft.)
F2	104.9'	103.6'	1.3
G2	104.5'	103.0'	1.5
F3	104.0'	103.6'	0.4
G3	105.0'	103.2'	1.8

FIGURE 9.8. Data for Grid 13.

EXAMPLE 9-5 CUT VOLUME

The volume of cut is determined in exactly the same fashion for cuts as fills. The information in Figure 9.9 is known from using grid 40; as an example (Figure 9.10), the following information is known.

$$\text{bcf of cut} = \frac{0.1' + 0.8' + 0' + 0'}{4} \times 2{,}500 \text{ sf} = 563 \text{ bcf cut}$$

That amount of cut is then entered in the cut column on the cut and fill worksheet (Figure 9.16).

Point	Planned Elevation	Existing Elevation	Cut (ft.)
E6	104.0'	104.1'	0.1
F6	104.0'	104.8'	0.8
E7	103.6'	103.6'	0.0
F7	104.2'	104.2'	0.0

FIGURE 9.9. Data for Grid 40.

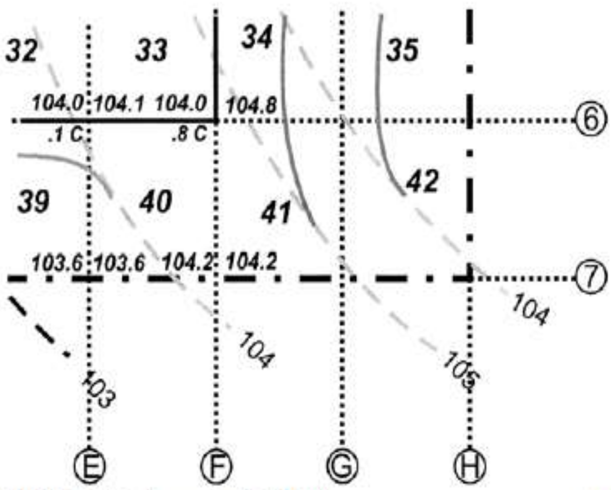


FIGURE 9.10. Excerpt of Grid 40.

When a specific grid contains both cut and fill, that grid needs to be divided into grids that contain only cut, only fill, or no change. These dividing lines occur along theoretical lines that have neither cut nor fill. These lines of no change in elevation are found by locating the grid sides that contain both cut and fill. Theoretically, as one moves down the side of the grid, there is a transition point where there is neither cut nor fill. These transition points, when connected, develop a line that traverses the grid and divides it into cut and fill areas and, in some instances, areas of no change.

EXAMPLE 9-6 CUT AND FILL IN THE SAME GRID

Grid 10 (Figure 9.11) from Figure 9.6 is an example of a square that contains both cut and fill. Along line 2, somewhere between lines C and D, there is a point where there is no change in elevation. This point is found first by determining the total change in elevation and by dividing that amount by the distance between the points; second, determine the change in elevation per foot of run.

Total change in elevation (C–D)

$$= 0.3' + 0.7' = 1.0' \text{ change in elevation}$$

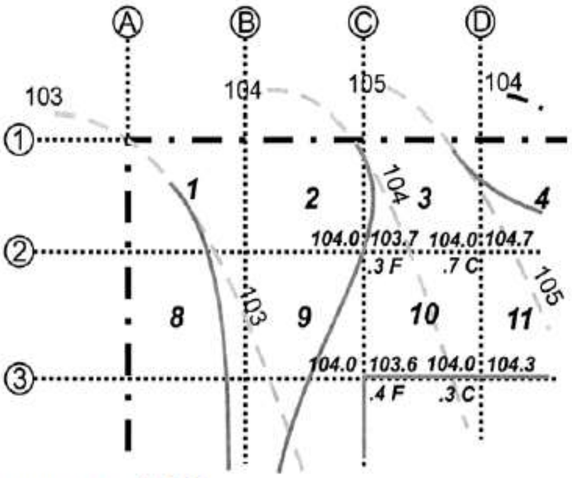


FIGURE 9.11. Grid 10.

Change in elevation per foot of run (C–D)

$$= 1.0'/50' = 0.02' \text{ per foot of run}$$

Because the elevation change is 0.02 foot per foot of run, the estimator can determine how many feet must be moved along that line until there has been a 0.3-foot change in elevation.

$$\text{Distance from C2} = 0.3'/0.02' \text{ per foot of run} = 15'$$

This means that as one moves from point C2 toward point D2 at 15 feet past point C2, there is the theoretical point of no change in elevation, or the transition point between the cut and the fill. Because the same thing occurs along line 3 between points C3 and D3, the same calculations are required.

Total change in elevation (C–D)

$$= 0.4' + 0.3' = 0.7' \text{ change in elevation}$$

Change in elevation per foot of run (C–D)

$$= 0.7'/50' = 0.014' \text{ per foot of run}$$

From this calculation, the distance from point C3 to the point of no change in elevation can be found.

$$\text{Distance from C3} = 0.4'/0.014' \text{ per foot of run} = 29'$$

Given this information, grid 10 can be divided into two distinct grids: one for cut and one for fill. Figure 9.12 details how the grid would be divided.

The next step is to determine the area of the cut and fill portions. A number of methods are available. Perhaps the most simple is to divide the areas into rectangles and/or triangles.

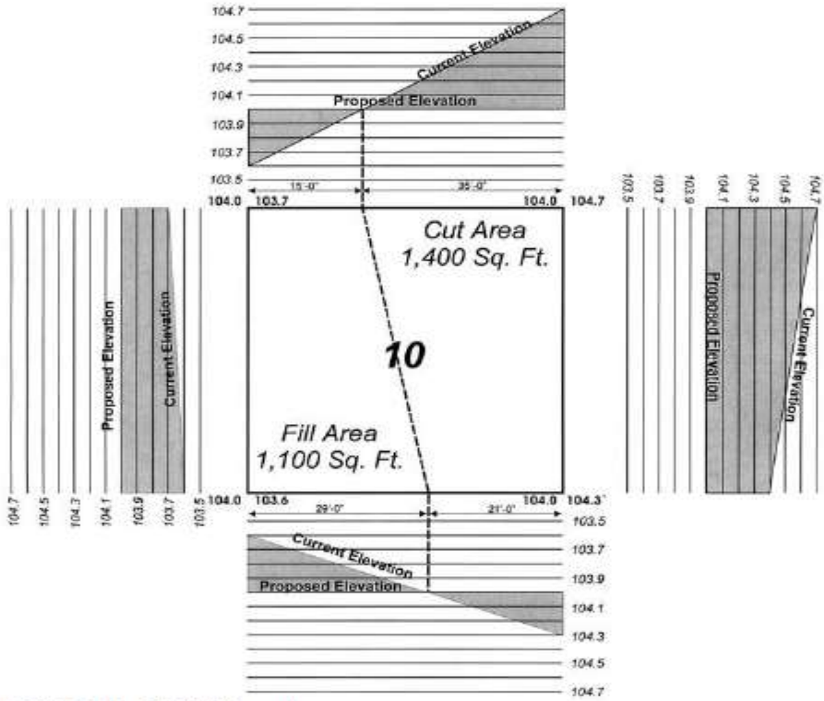


FIGURE 9.12. Grid 10 Layout.

$$\text{Fill area}_{\text{Rectangle}} = 15' \times 50' = 750 \text{ sf}$$

$$\text{Fill area}_{\text{Triangle}} = 0.5 \times 14' \times 50' = 350 \text{ sf}$$

$$\text{Total fill area} = 750 \text{ sf} + 350 \text{ sf} = 1{,}100 \text{ sf}$$

$$\text{Fill} = \frac{0.3' + 0.4' + 0' + 0'}{4} \times 1{,}100 \text{ sf} = 193 \text{ ccf of fill}$$

The area of the cut equals the area of the grid less the area of the fill.

$$\text{Cut area} = 2{,}500 \text{ sf} - 1{,}100 \text{ sf} = 1{,}400 \text{ sf}$$

$$\text{Cut} = \frac{0.3' + 0.7' + 0' + 0'}{4} \times 1{,}400 \text{ sf} = 350 \text{ bcf of cut}$$

These cuts and fills are entered into the cut and fill columns on the cut and fill worksheet (Figure 9.16).

EXAMPLE 9-7 CUT AND FILL

Occasionally when the grid is divided, a portion of the grid will be neither cut nor fill. Grid 3 is an example of such an occurrence. Figure 9.13 is an excerpt from the site plan. In that grid, the change from fill to cut occurs on line 2 between C and D.

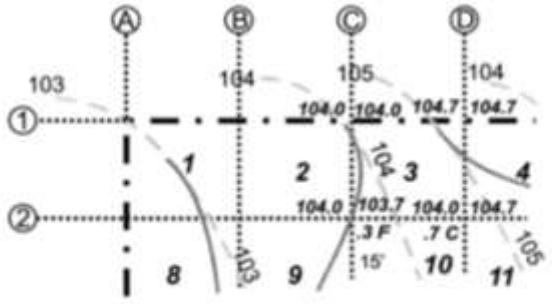


FIGURE 9.13. Grid 3.

Total change in elevation (C–D)

$= 0.3' + 0.7' = 1.0'$ change in elevation

Change in elevation per foot of run (C–D)

$= 1.0'/50' = 0.02'$ per foot of run

From this calculation, the distance from point C2 to the point of no change in elevation can be found.

$$\text{Distance from C2} = 0.3'/0.02' \text{ per foot of run} = 15'$$

$$\text{Fill area} = 0.5 \times 50' \times 15' = 375 \text{ sf}$$

$$\text{Cut area} = 0.5 \times 50' \times 35' = 875 \text{ sf}$$

$$\text{Fill} = \frac{0.3' + 0' + 0'}{3} \times 375 \text{ sf} = 38 \text{ ccf of fill}$$

$$\text{Cut} = \frac{0.7' + 0' + 0'}{3} \times 875 \text{ sf} = 204 \text{ bcf of cut}$$

Figure 9.14 shows the dimensions and proportions between cut, fill, and the unchanged area of grid 3. The remaining 1,250 sf theoretically have no cut or fill.

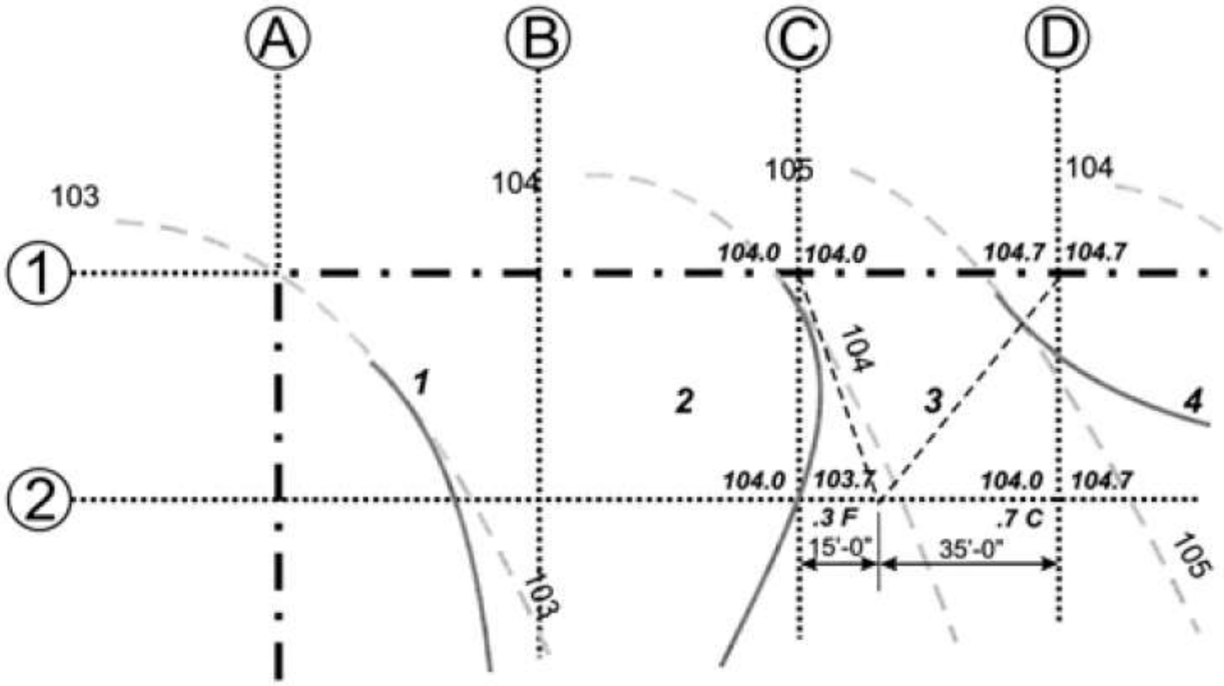


FIGURE 9.14. Cut and Fill Area.

Figure 9.15 is the entire site plan with the areas of no cut and fill shown. Figure 9.16 is the completed cut and fill worksheet for the entire plot.

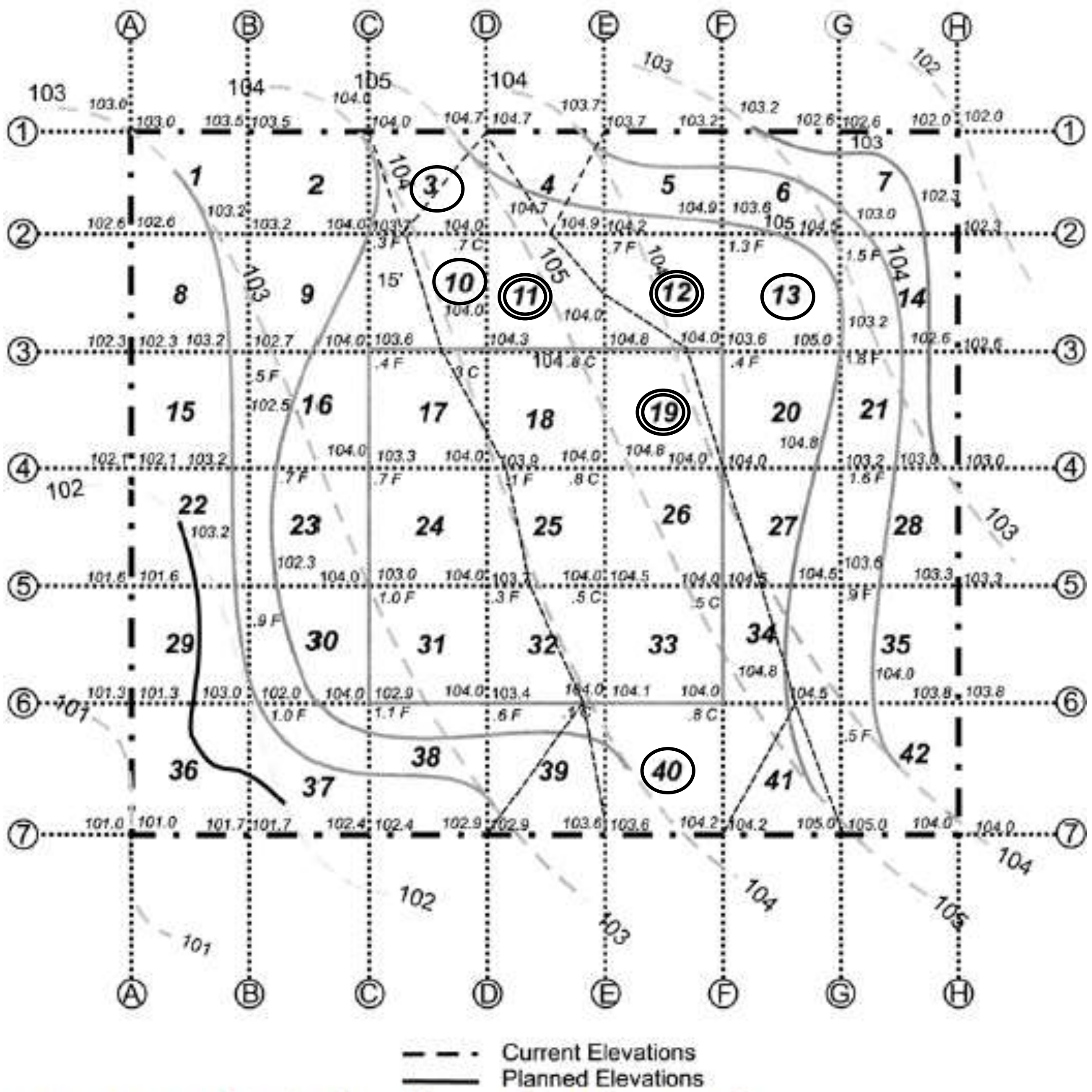


FIGURE 9.15. Complete Site Plan with Areas of No Change Noted.

ESTIMATE WORK SHEET

Project: *Little Office Building* | **Estimate No.** 1234
Location *Littleville, TX* | **Sheet No.** *1 of 1*
Architect *U. R. Architects* | **CUT & FILL** | **Date** *1/1/20XX*
Items *Rough Grading* | **By** *LHF* **Checked** *JBC*

Grid	Fill At Intersections					Fill				Cut At Intersections					Cut			
	1	2	3	4	5	Points	Average	Area	Total	1	2	3	4	5	Points	Average	Area	Total
1						0	0		0						0	0		0
2	0	0	0	0.3		4	0.075	2500	188						0	0		0
3	0	0	0.3			3	0.1	375	38	0	0	0.7			3	0.233333	875	204
4	0	0	0.7			3	0.233333	625	146	0	0	0.7			3	0.233333	625	146
5	0.7	1.3	0	0		4	0.5	2500	1,250						0	0		0
6	1.3	1.5	0	0		4	0.7	2500	1,750						0	0		0
7	1.5	0	0	0		4	0.375	2500	938						0	0		0
8	0	0.5	0	0		4	0.125	2500	313						0	0		0
9	0.5	0.4	0	0.3		4	0.3	2500	750						0	0		0
10	0.3	0	0.4	0		4	0.175	1100	193	0	0.7	0	0.3		4	0.25	1400	350
11	0	0	0.7			3	0.233333	287.5	67	0.7	0	0	0.8	0.3	5	0.3	2212.5	664
12	0	0.7	1.3	0.4	0	5	0.48	2054.5	986	0	0	0.8			3	0.266667	445.5	119
13	1.3	1.5	0.4	1.8		4	1.25	2500	3,125						0	0		0
14	1.5	0	1.8	0		4	0.825	2500	2,063						0	0		0
15	0	0.7	0	0.5		4	0.3	2500	750						0	0		0
16	0.5	0.4	0.7	0.3		4	0.475	2500	1,188						0	0		0
17	0.4	0	0	0.1	0.3	5	0.1	2101	210	0	0.3	0			3	0.1	399	40
18	0	0	0.1			3	0.033333	36	1	0	0	0.8	0.8	0.3	5	0.32	2464	788
19	0	0.4	0			3	0.133333	425	57	0.8	0	0	0.8		4	0.4	2075	830
20	0	1.6	0.4	1.8		4	0.95	2500	2,375						0	0		0
21	1.6	0	1.8	0		4	0.85	2500	2,125						0	0		0
22	0	0.9	0	0.7		4	0.4	2500	1,000						0	0		0
23	0.7	0.3	0.9	1		4	0.725	2500	1,813						0	0		0
24	1	0.3	0.7	0		4	0.5	2500	1,250						0	0		0
25	0.1	0	0	0.3		4	0.1	625	63	0	0.8	0	0.5		4	0.325	1875	609
26						0	0		0	0.8	0.5	0.5	0		4	0.45	2500	1,125
27	0	1.6	0.9	0		4	0.625	2050	1,281	0	0.5	0			3	0.166667	450	75
28	0.9	0	1.6	0		4	0.625	2500	1,563						0	0		0
29	0	0.9	0	1		4	0.475	2500	1,188						0	0		0
30	0.9	1	1	1.1		4	1	2500	2,500						0	0		0
31	1.1	0.6	1	0.3		4	0.75	2500	1,875						0	0		0
32	0.3	0	0.6	0		4	0.225	1550	349	0	0.5	0.1	0		4	0.15	950	143
33						0	0		0	0.5	0.5	0.1	0.8		4	0.475	2500	1,188
34	0	0.9	0	0.5		4	0.35	1275	446	0.5	0	0.8	0		4	0.325	1225	398
35	0.9	0	0.5	0		4	0.35	2500	875						0	0		0
36	0	0	0	1		4	0.25	2500	625						0	0		0
37	1	1.1	0	0		4	0.525	2500	1,313						0	0		0
38	1.1	0.6	0	0		4	0.425	2500	1,063						0	0		0
39	0.6	0	0			3	0.2	1075	215	0.1	0	0			3	0.033333	175	6
40						0	0		0	0.1	0.8	0	0		4	0.225	2500	563
41	0.5	0	0			3	0.166667	475	79	0.8	0	0			3	0.266667	775	207
42	0.5	0	0	0		4	0.125	2500	313						0	0		0
									0						0	0		0
TOTAL FILL - Compacted Cubic Feet									36,317	TOTAL CUT - Bank Cubic Feet								7,453
Compacted Cubic Yards									1,345	Bank Cubic Yards								276
Shrinkage Factor								0.95		Swell Factor							0.25	
Required Bank Cubic Yards of Fill									1,416	Loose Cubic Yards of Cut to Haul								345
Net Bank Cubic Yards to Purchase									1,140									

FIGURE 9.16. Completed Cut and Fill Worksheet.

In the previous examples, it was assumed that the finish grade was the point at which the earthwork took place; however, this is typically not true. In Figure 9.17, the planned contour lines on the parking lot represent the top of the asphalt. Therefore, the rough grading will be at an elevation different from the one shown on the site plan. In this scenario, the elevation for the rough grading needs to be reduced by the thickness of the asphalt and base material.

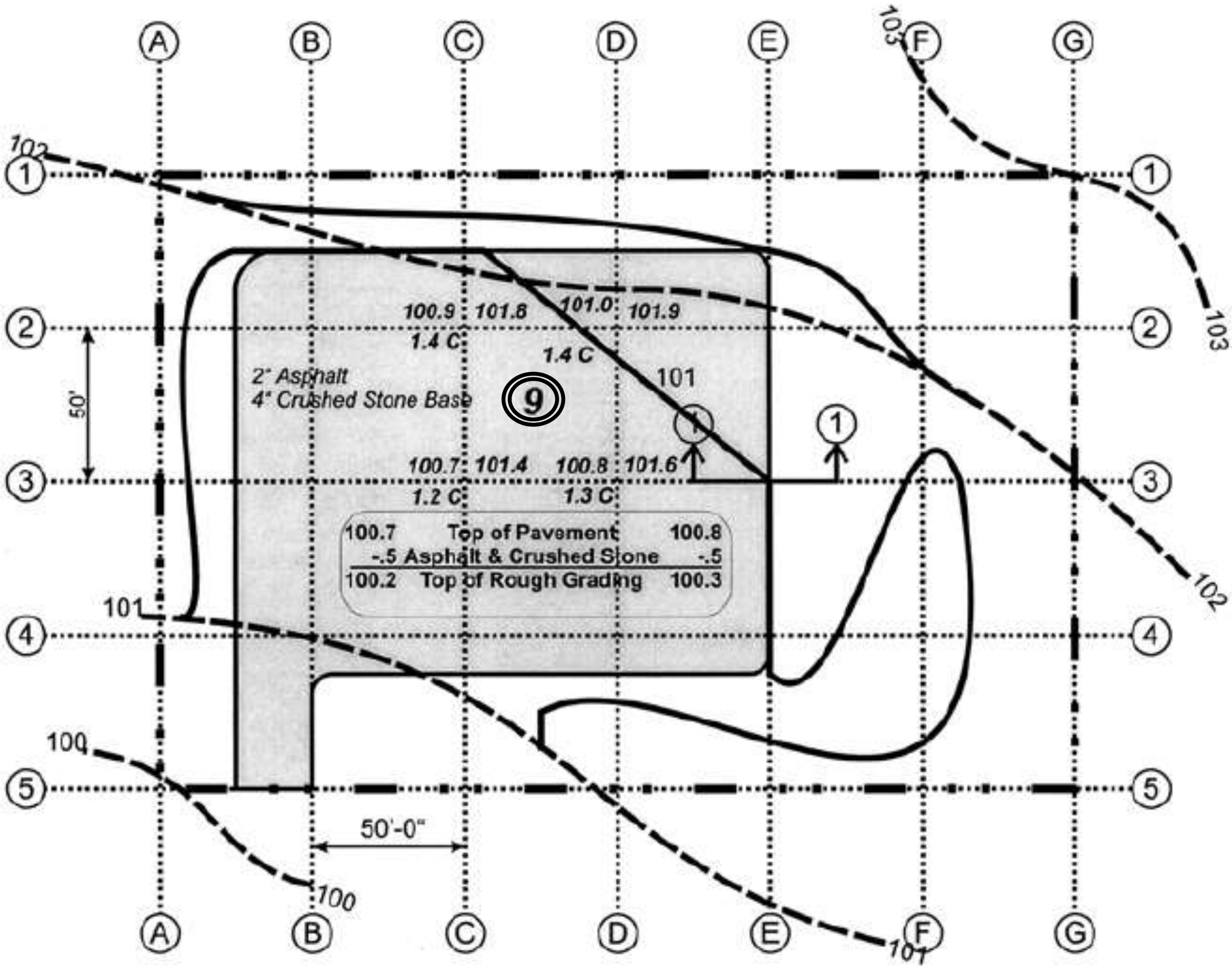


FIGURE 9.17. Parking Lot Site Plan.

EXAMPLE 9-8 CUT AND FILL WITH PAVING

Using Figures 9.17 and 9.18, determine cut for grid 9. In Figure 9.18, the top of the rough grade is 0.50 foot below the top of pavement. The cuts are the differences between the existing elevation and the top of the rough grade, and are shown in Figure 9.19.

$$\text{Cut} = \frac{1.4' + 1.4' + 1.2' + 1.3'}{4} \times 2{,}500 \text{ sf}$$
$$= 3{,}313 \text{ bcf or } 123 \text{ bcy}$$

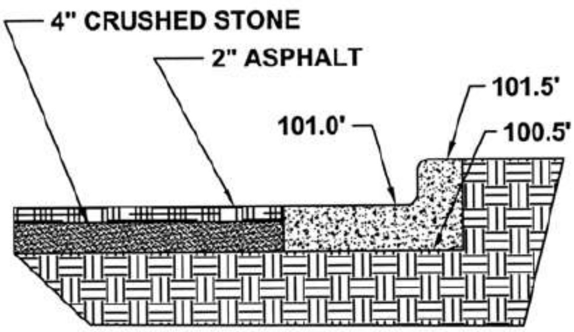
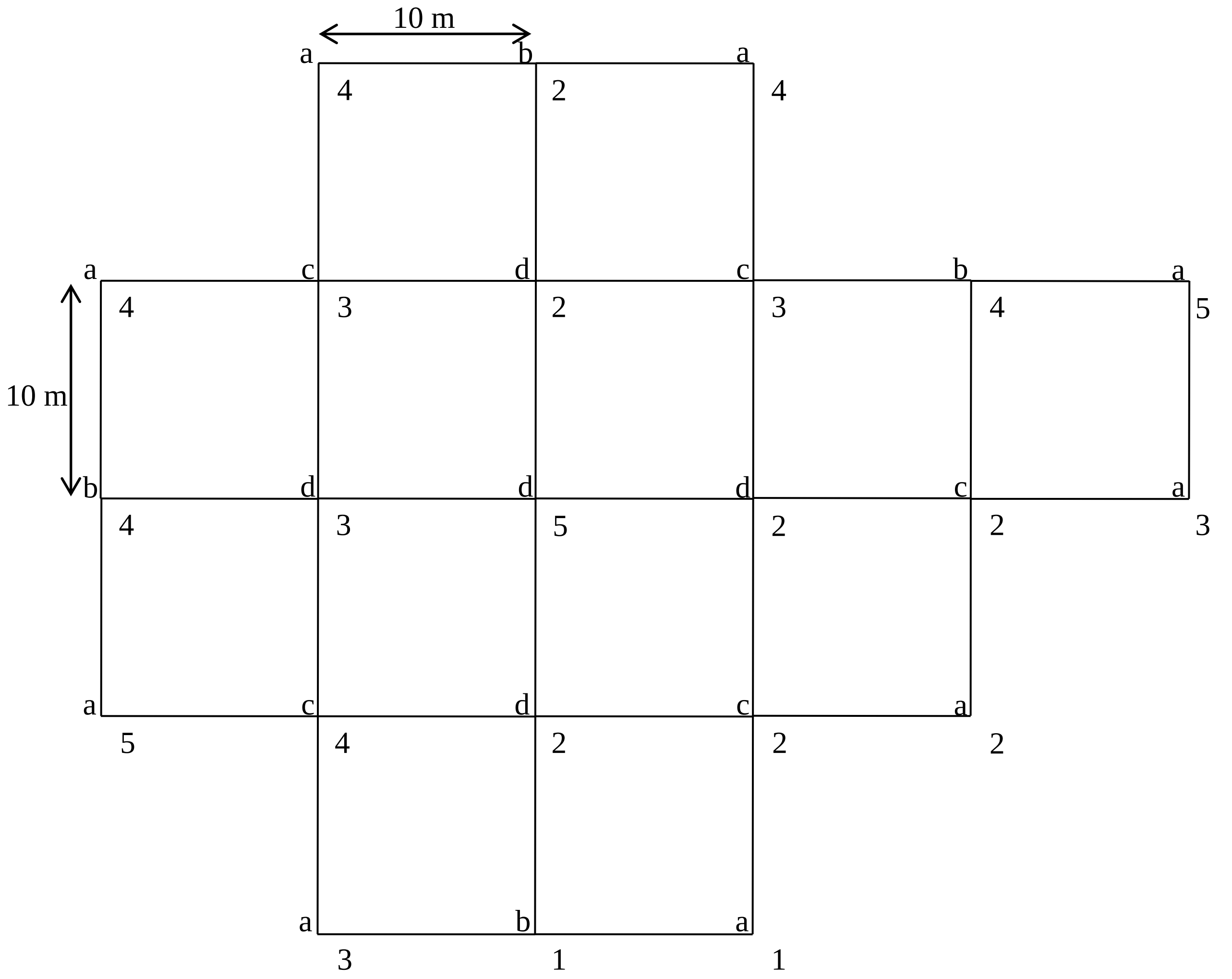


FIGURE 9.18. Cross-Section Through Pavement.

Point	Top of Pavement	Top of Rough Grade	Existing Elevation	Cut (ft.)
C2	100.9'	100.4'	101.8'	1.4'
D2	101.0'	100.5'	101.9'	1.4'
C3	100.7'	100.2	101.4'	1.2'
D3	100.8'	100.3	101.6'	1.3'

FIGURE 9.19. Data for Grid 9.

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



The volume of cutting or filling is calculated as follows:

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

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

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

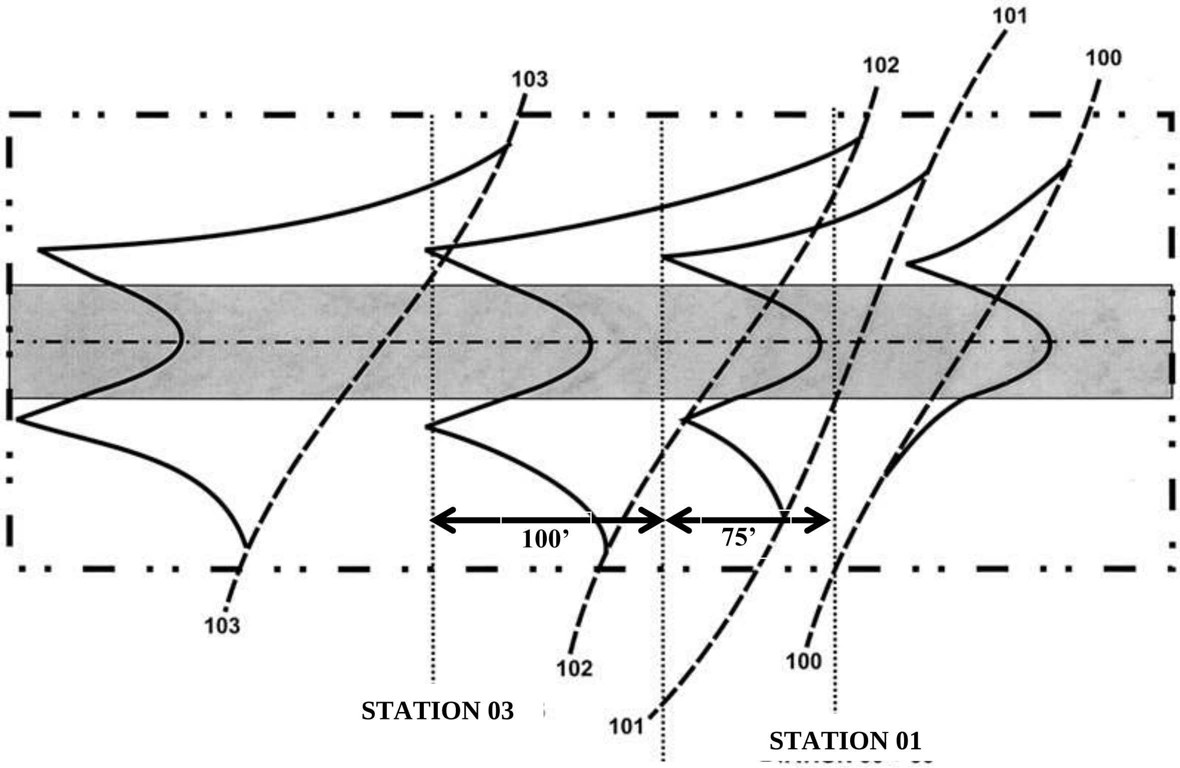
$$c = 3 + 3 + 2 + 4 + 2 = 14$$

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

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

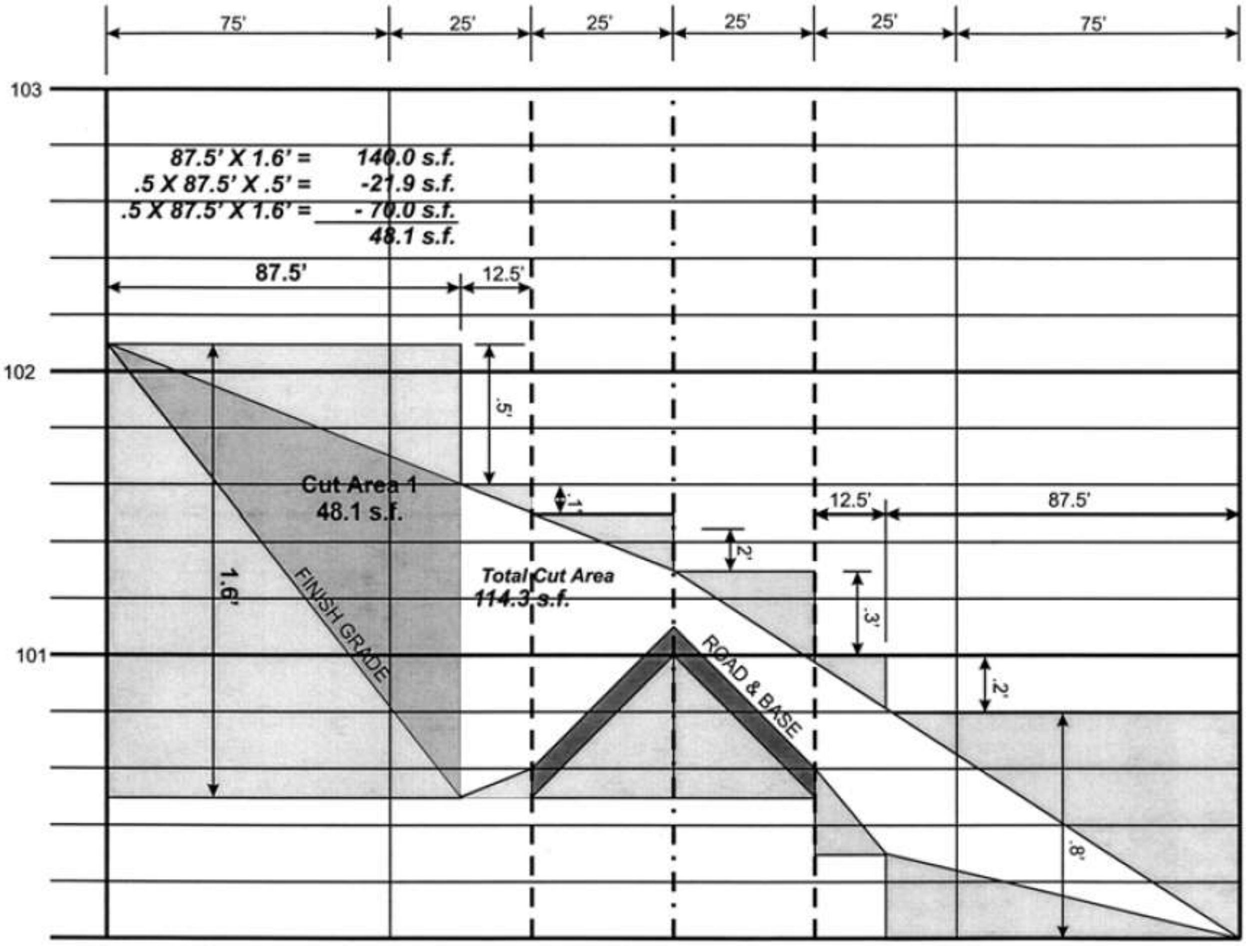
2.2.3 Average End Area

The average end area method of quantifying cut and fill is often used when dealing with long narrow tracts, such as for roads. In this method, the site is divided into stations, as shown in the following figure.



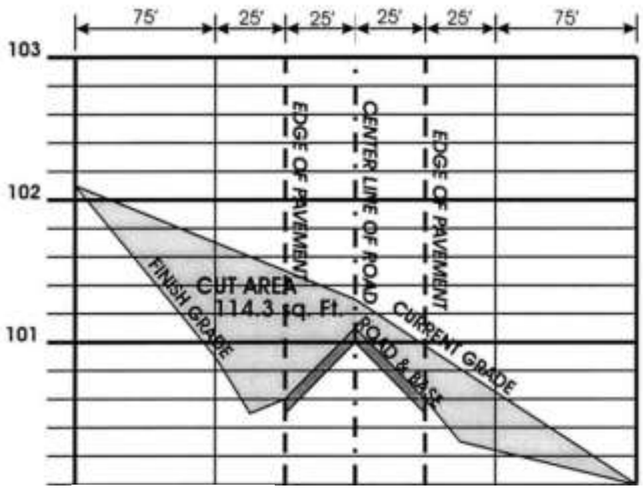
The first step in determining the volume using the average end area method is to draw a profile at the station lines. Next, the cut and fill area for each of the profiles is calculated, and finally, the cut or fill area of two adjacent profiles is averaged and multiplied by the distance between the two stations to determine the cut and fill quantity between the stations.

The following figure shows the profile for Station 01. Because these profiles are drawn to scale, the area can be calculated easily by breaking up these profiles into rectangles and triangles.

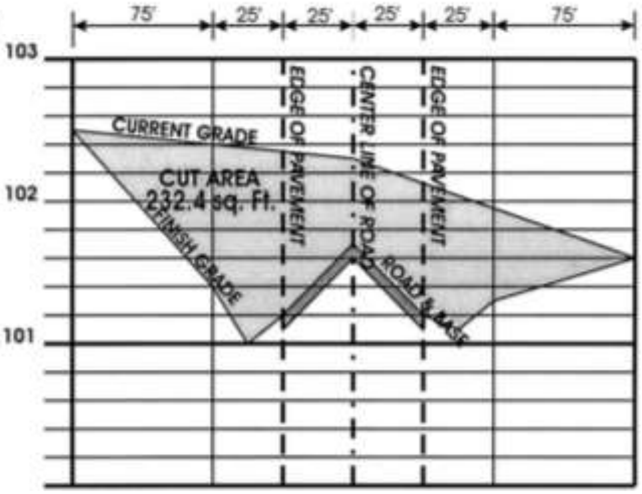


Example: Cut between station 1 and 2 is calculated as follows:

$$Cut = \frac{114.3+232.4}{2} \times 75' = 13{,}001cf$$



STATION 01



STATION 02 (at 75')

2.2.3 General Excavation

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

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

1. Building dimensions.

2. The distance of footings beyond the project wall.

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

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

5. The type of soil that will be encountered.

6. Whether the excavation will be sloped or supported.

7. The depth of the excavation.

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

FIGURE 9.29. Earthwork Slopes.

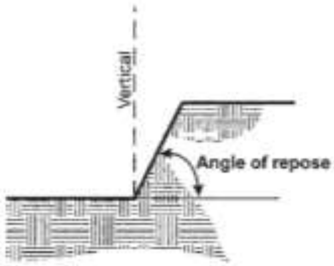


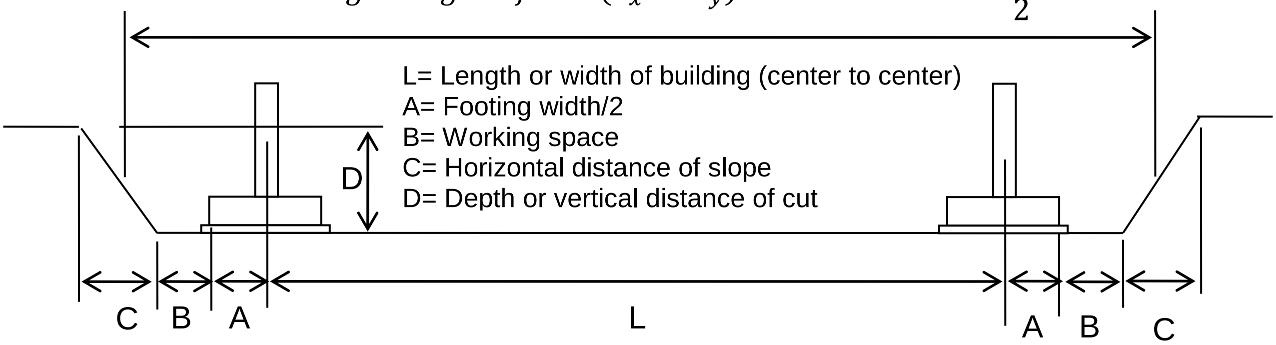
FIGURE 9.28. Angle of Repose.

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

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

2.2.3.1 Basement Excavation

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



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

Example:

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

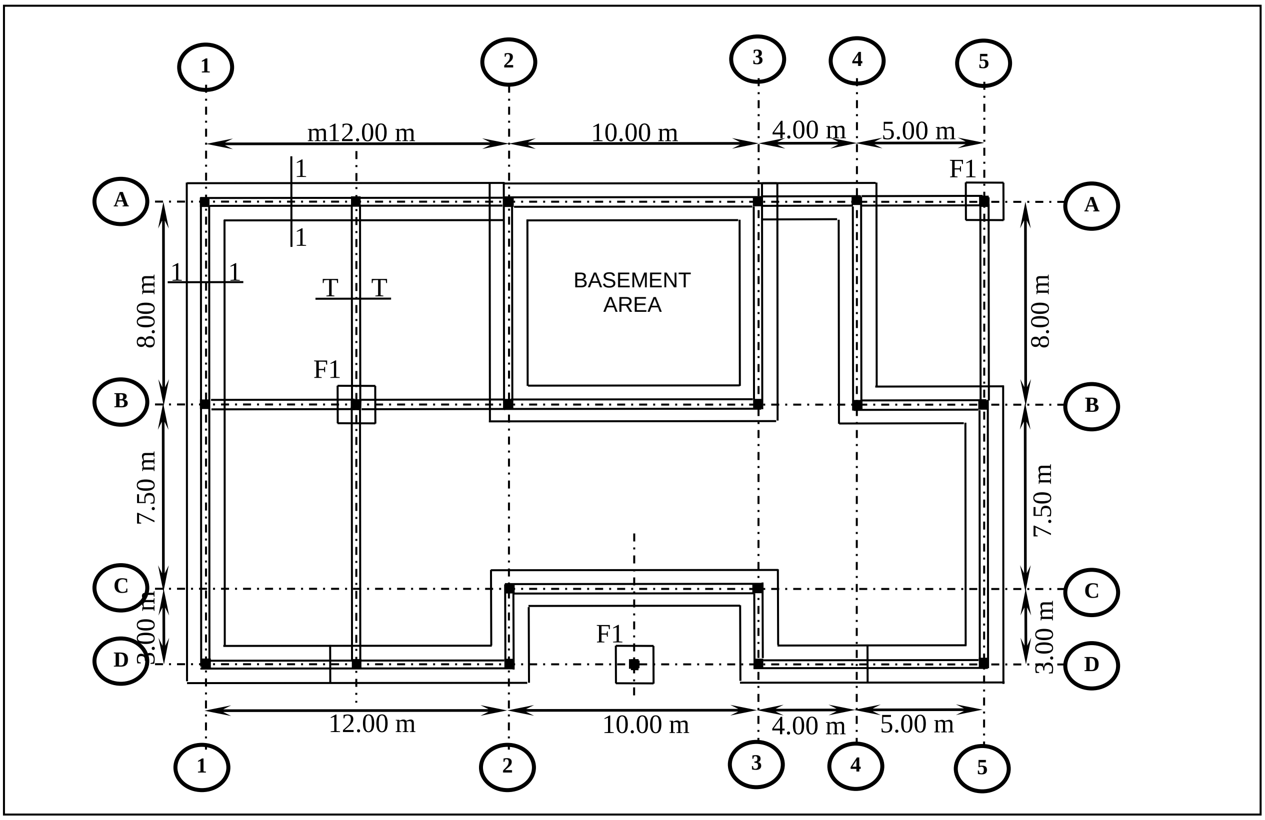
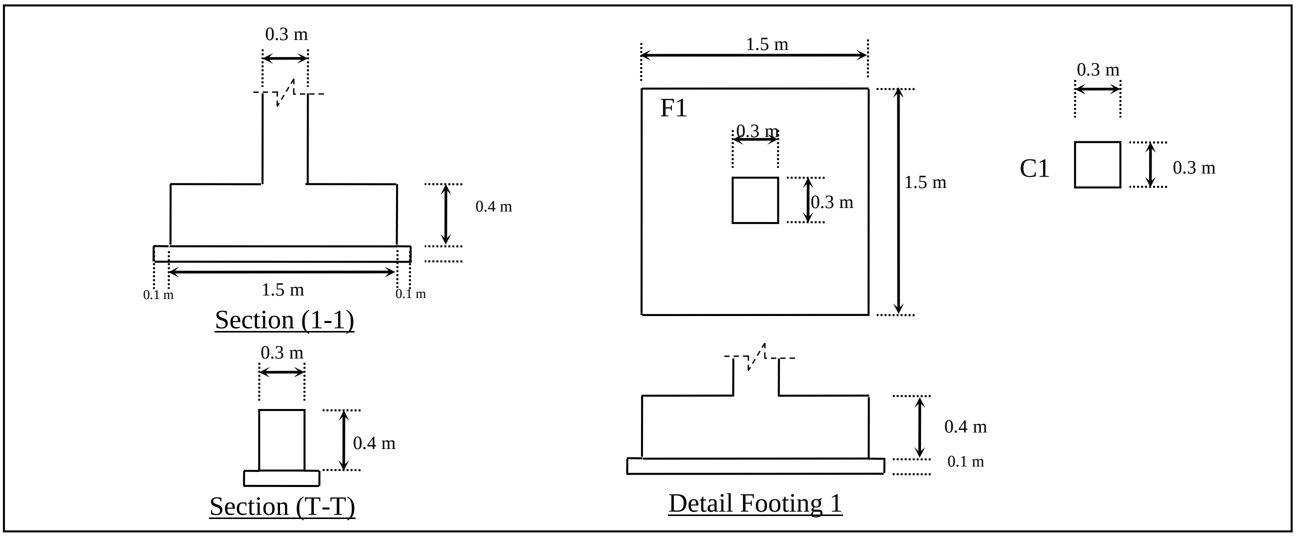


Figure 9.32. Building Plan.



Cross-Sections of Footings

Solution:

$$Average\ Length\ of\ Cut_{x\ direction} = 10 + 1.5 + 1 + 1.5 = 14\ m$$

$$Average\ Length\ of\ Cut_{y\ direction} = 8 + 1.5 + 1 + 1.5 = 12\ m$$

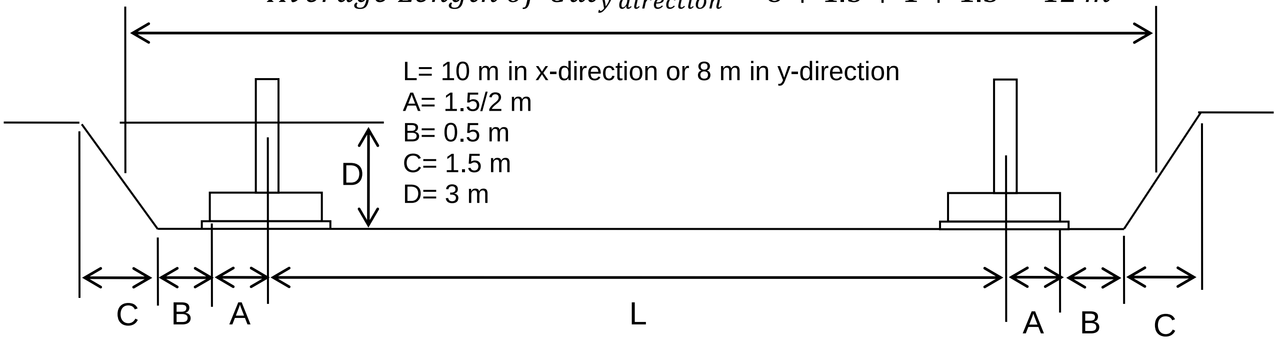
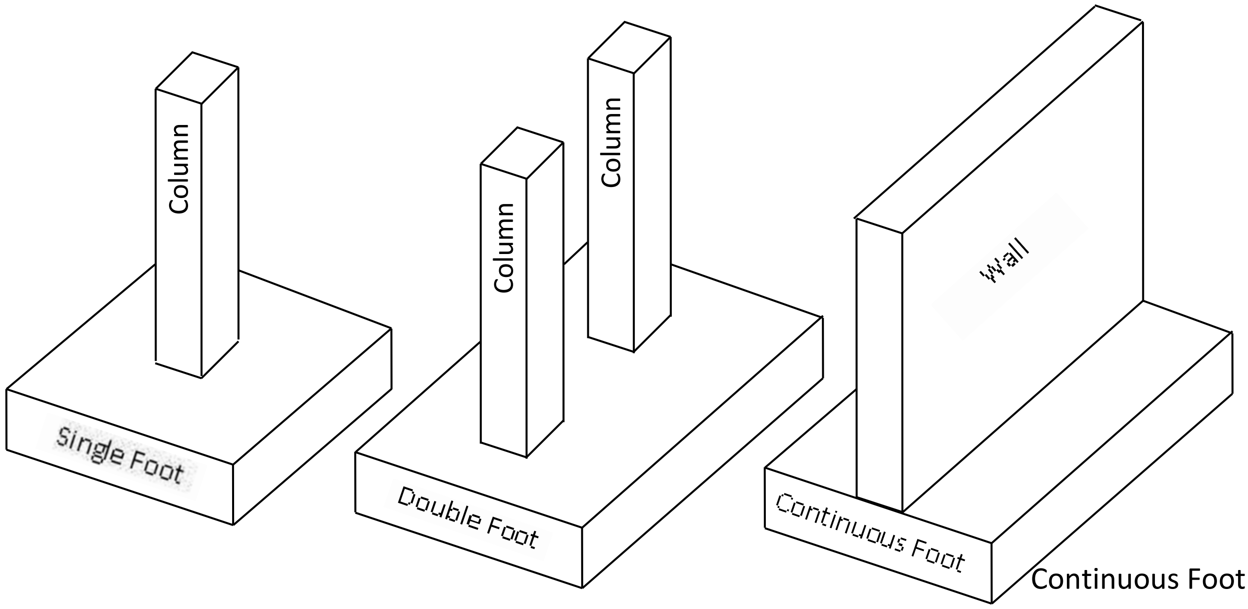


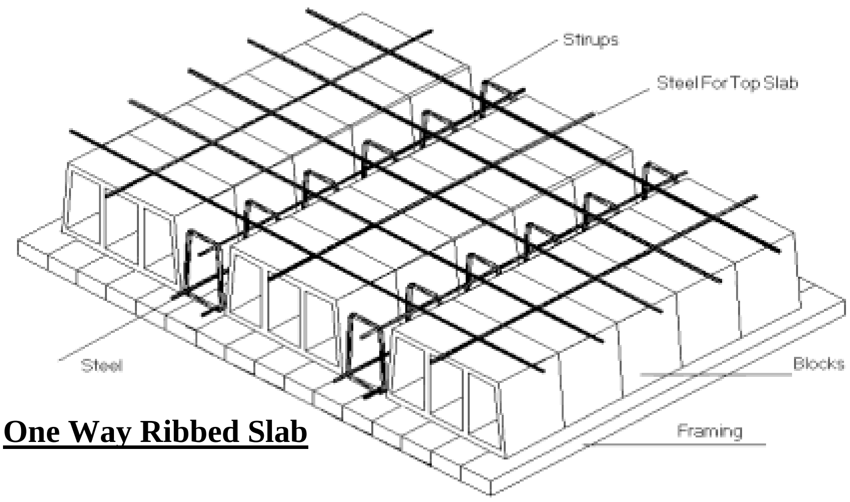
Figure 9.33. Basement Cross-Section

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

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


Putzmeister
builderbill



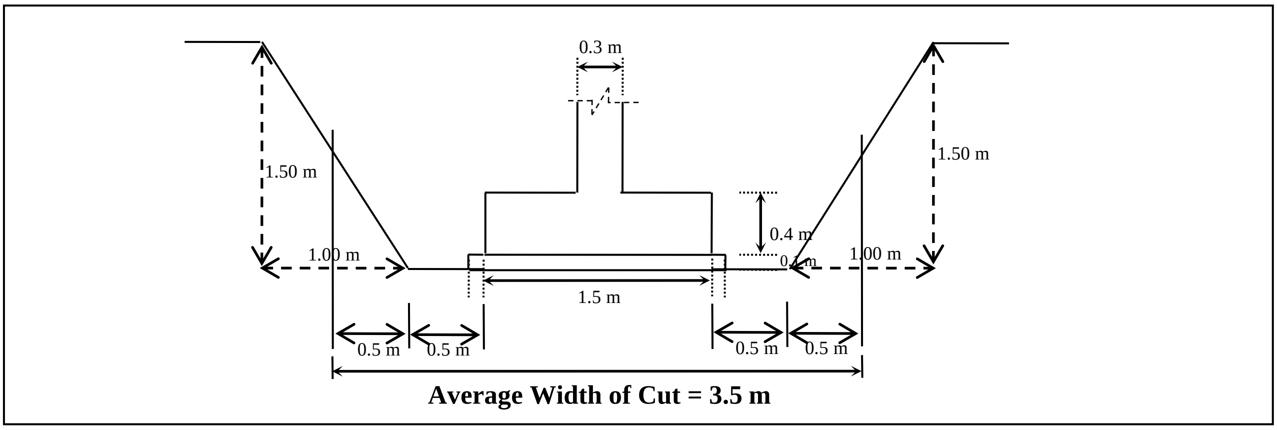


One Way Ribbed Slab

2.2.3.2 Continuous Footing Excavation

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

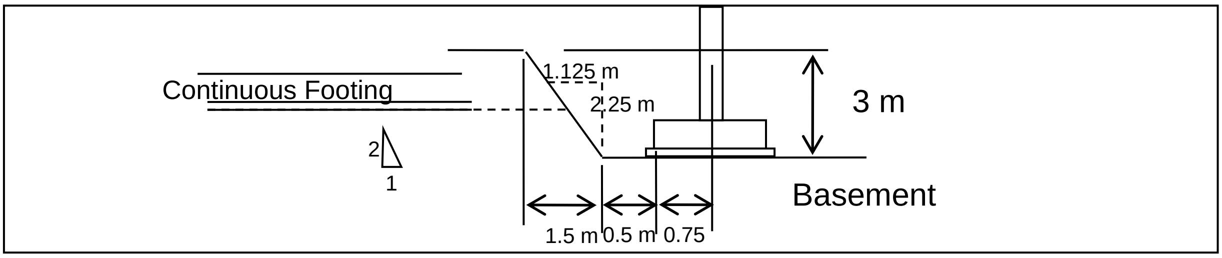
Solution:



Width of Cut = 3.5 m

Depth of Cut = 1.5 m

Length of Cut = A1toA2 + A3toA4 + A4toB4 + B4toB5 + B5toD5 + D5toD3 + D3toC3 + C3toC2 + C2toD2 + D2toD1 + D1toA1 – Width of cut already calculated in the basement excavation



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

= 91 m

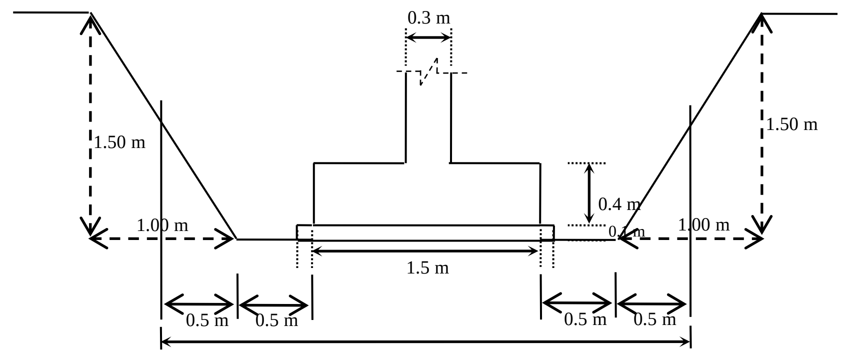
$$Volume\ of\ Continuous\ Footing\ Excavation = Length \times Width \times Depth$$

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

2.2.3.3 Spread Footing Excavation

Example:

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



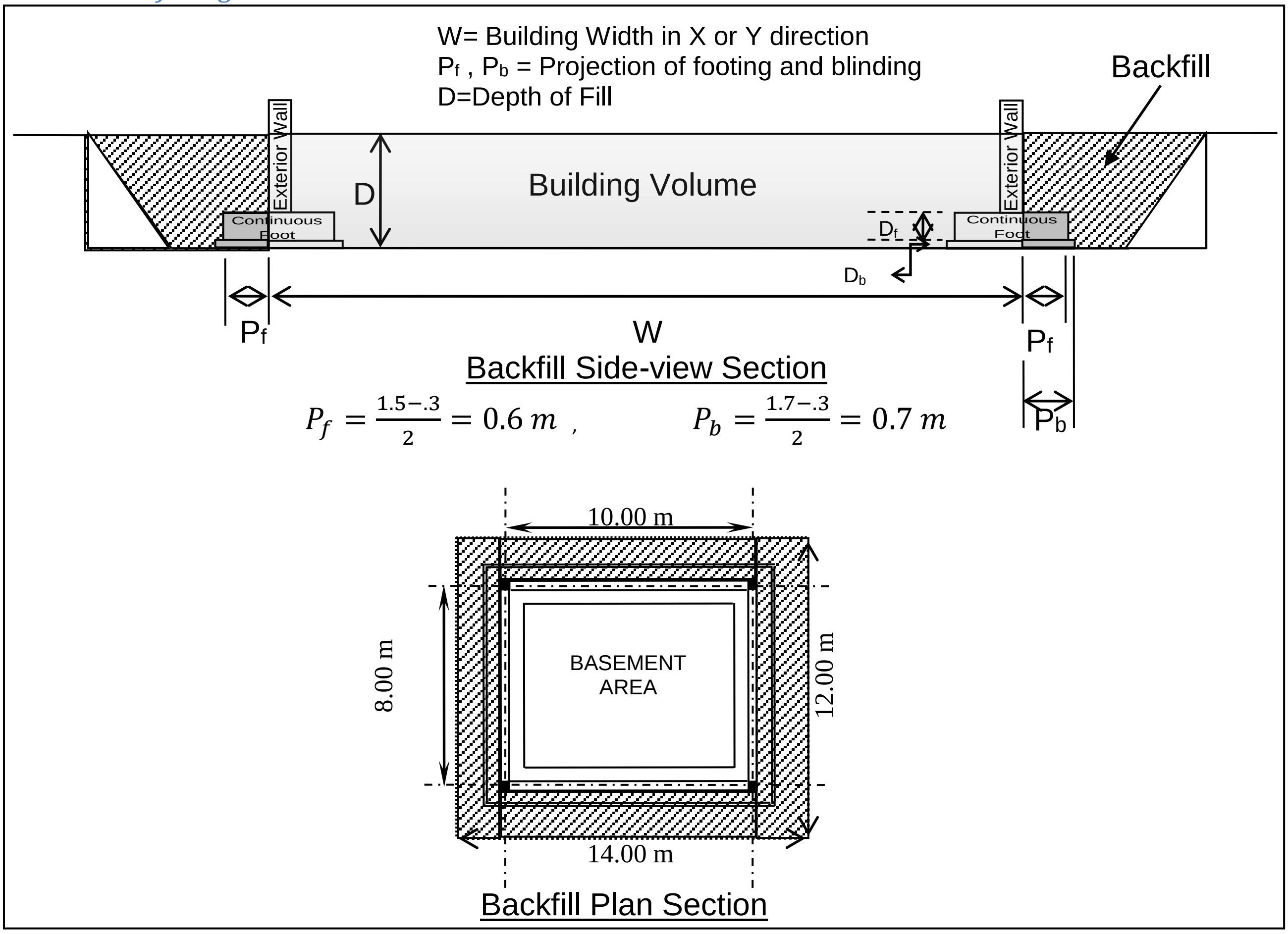
Average Width of Cut in directions x and y = 3.5 m

$$Volume\ of\ Spread\ Footings\ (F1)\ Excavation = Length \times Width \times Depth \times Number$$

$$Excavation = 3.5 \times 3.5 \times 1.5 \times 3 = 55.125\ m^3$$

2.2.4 Backfilling

2.2.4.1 Backfilling the Basement Walls



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

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

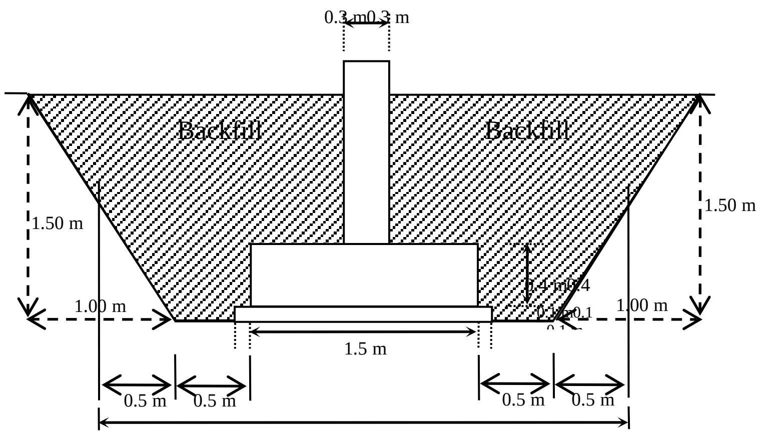
$$Footing\ and\ Blinding\ Projection\ Volume = P_f \times D_f \times L_f + P_b \times D_b \times L_b$$

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

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

2.2.4.2 Backfilling the Continuous Foundations

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



Average Width of Cut = 3.5 m

Method 1

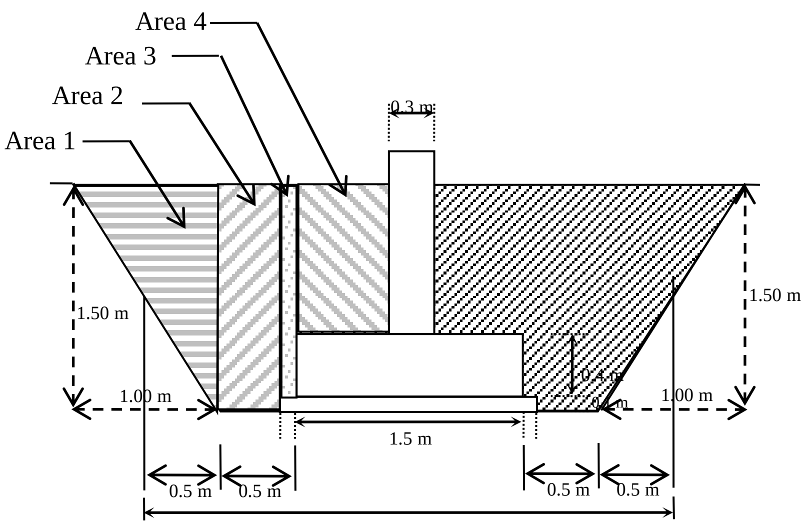
$$Volume\ of\ Continuous\ Footing\ Cut\ = 3.5 \times 1.5 \times 88.75 = 465.9375 m^3$$

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

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

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

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



Average Width of Cut = 3.5 m

Method 2

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

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

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

EXAMPLE 9-13 EQUIPMENT AND LABOR COST

Equipment selection for the removal of topsoil will probably be limited to either a bulldozer or a front-end loader. Assume that a 1-cy bucket front-end loader is selected (see Figures 9.26 and 9.27) and its production rate is estimated to be an average of 24 bcy per hour. Mobilization time is estimated at 2.5 hours, the operating cost per hour for the equipment is estimated at $11.35, and the cost for an operator is $17.75 per hour. Estimate the number of hours and the cost to strip the topsoil.

First, the total hours required to complete the topsoil removal (Example 9-12) must be calculated. Divide the total cubic yards to be excavated by the rate of work done per hour, and add the mobilization time; the answer is the total hours for this phase of work.

$$\text{Hours} = \frac{214 \text{ bcy}}{24 \text{ bcy per hour}} + 2.5 \text{ hours} = 11.4 \text{ hours}$$

The total number of hours is then multiplied by the cost of operating the equipment per hour, plus the cost of the crew for the period of time.

$$\text{Equipment cost} = \$11.35 \text{ per hour} \times 11.4 \text{ hours} = \$129$$

$$\text{Lobor cost} = \$17.75 \text{ per hour} \times 11.4 \text{ hours} = \$202$$

$$\text{Total cost} = \$129 + \$202 = \$331$$

Soil	Dozer				Tractor shovel		Front end loader		Backhoe	
	50 ' haul		100' haul		No haul		50' haul	100' haul	No haul	
	50 hp	120 hp	50 hp	120 hp	1 c.y..	2.25 c.y.	1 c.y.	2.25 c.y..	.5 c.y..	1 c.y..
Medium	40	100	30	75	40	70	24	30	25	55
Soft, sand	45	110	35	85	45	90	30	40	25	60
Heavy soil or stiff clay	15-20	40	10-15	30-35	15-20	35	10	12	10	15

FIGURE 9.26. Equipment Capacity (cy per Hour).

Load and haul		
Truck size	**Haul**	**c.y.**
6 c.y.	1 mile	12-16
6 c.y.	2 miles	8-12
12 c.y.	1 mile	18-22
12 c.y.	2 miles	12-14

FIGURE 9.27. Truck Haul (cy per Hour).

2.3 Concrete

The concrete for a project may be either ready mixed or mixed on the job.

When estimating footings, columns, beams, and slabs, their volume is determined by taking the linear dimension of each item times its cross-sectional area.

The procedure that should be used to estimate the concrete on a project is as follows:

1. Review the specifications to determine the requirements for each area in which concrete is used separately (such as footings, floor slabs, and walkways) and list the following:

    (a) Type of concrete

    (b) Strength of concrete

    (c) Color of concrete

    (d) Any special curing or testing

2. Review the drawings to be certain that all concrete items shown on the drawings are covered in the specifications.

3. List each of the concrete items required on the project.

4. Determine the quantities required from the **working drawings**. Footing sizes are checked on the wall sections and foundation plans. Watch for different size footings under different walls.

2.3.1 Jordanian Specifications

تكال أعمال الخرسانة المصبوبة في الموقع بجميع أنواعها كيلا هندسيا بالمتر المكعب لواقع الأعمال التي تم تنفيذها فعلا بعد حسم جميع الفراغات والفتحات والثغرات التي يزيد حجمها عن (٠٫٠٥) مترا مكعبا بدون حسم حجم مواد التسليح المدفونة في الخرسانة، وحسب القواعد التالية :—

* لا تكال أعمال الخرسانة الزائدة عن المساحات أو الأحجام أو المقاطع المنصوص عليها في المواصفات الخاصة.
* تكال الجيزان الأرضية ابتداء من نقط التقائها بالأعمدة.
* تكال الأعمدة والجدران ابتداء من ظهر الأساسات أو القواعد وحتى نقطة التقائها مع الجيزان أو العقدات.
* تكال خرسانة الأدراج وبسطاتها بحيث تشمل خرسانة الأدراج والبسطات ضمن الجدران أو الأعمدة المرتكزة عليها (إن وجدت) كما تكال خرسانة البسطات أو الجيزان الحاملة للأدراج والتي تشكل جزءا من العقدات.
* تكال خرسانة العقدات والجيزان والأدراج والبسطات المرتكزة على الجدران الحجرية بحيث يشمل الكيل نصف سماكة تلك الجدران الحجرية.
* تكال خرسانة العناصر الانشائية المنفصلة ابتداء من نقط ابتداء التقائها بالجدران أو الأعمدة أو الأساسات باستثناء حالات الالتقاء بالجدران الحجرية، حيث يكال معها نصف سماكة تلك الجدران الحجرية.
* خرسانة النظافة تحت الأساسات : تكال بالمتر المربع للسماكة المحددة في جدول الكميات بعد حسم الفراغات والفتحات والثغرات التي تزيد مساحتها عن (٠٫١) مترا مربعا.

طوب العقدات الخرسانية :

تكال أعمال طوب العقدات الخرسانية بالعدد للوحدة المحددة المقاسات والتفاصيل لواقع الأعمال التي تم تنفيذها فعلا ويعتبر جزء الطوبة لأغراض الكيل طوبة كاملة.

أعمال التسليح :

(أ) تكال أعمال التسليح بالطن لواقع الأعمال التي تم تنفيذها فعلا وحسب المخططات التفصيلية والجداول التفصيلية للقص والثني. ويشمل الكيل العقفات والوصلات المنصوص عليها في المواصفات الخاصة أو المبينة على المخططات.

تكال الارضيات الخرسانية كيلا هندسيا بالمتر المربع لواقع المساحات التي تم صبها فعلا من وجه الجدار الى الوجه المقابل، بحيث تخصم الفتحات التي تزيد مساحتها عن (٠٫٥) مترا مربعا. ويكون السعر شاملا لكل ما يلزم من مواد ومصنعية كتجهيز الارضيات وصبها وايناعها وتنعيم السطح، وقص الفواصل وتجهيزها وتعبئتها بالمواد الخاتمة اذا ورد نص صريح بذلك في جدول الكميات على ان تبين المخططات المعلومات والتفاصيل الكاملة المطلوبة للفواصل من حيث الاطوال والمقاسات واماكن وجودها في الارضيات الخرسانية، وغير ذلك مما يلزم لانجاز الاعمال على اكمل وجه حسبما ورد في هذه المواصفات.

2.3.2 Examples

Use the following building plan and cross-sections to calculate the concrete contained in the following items:

a. Blinding (صبة النظافة)

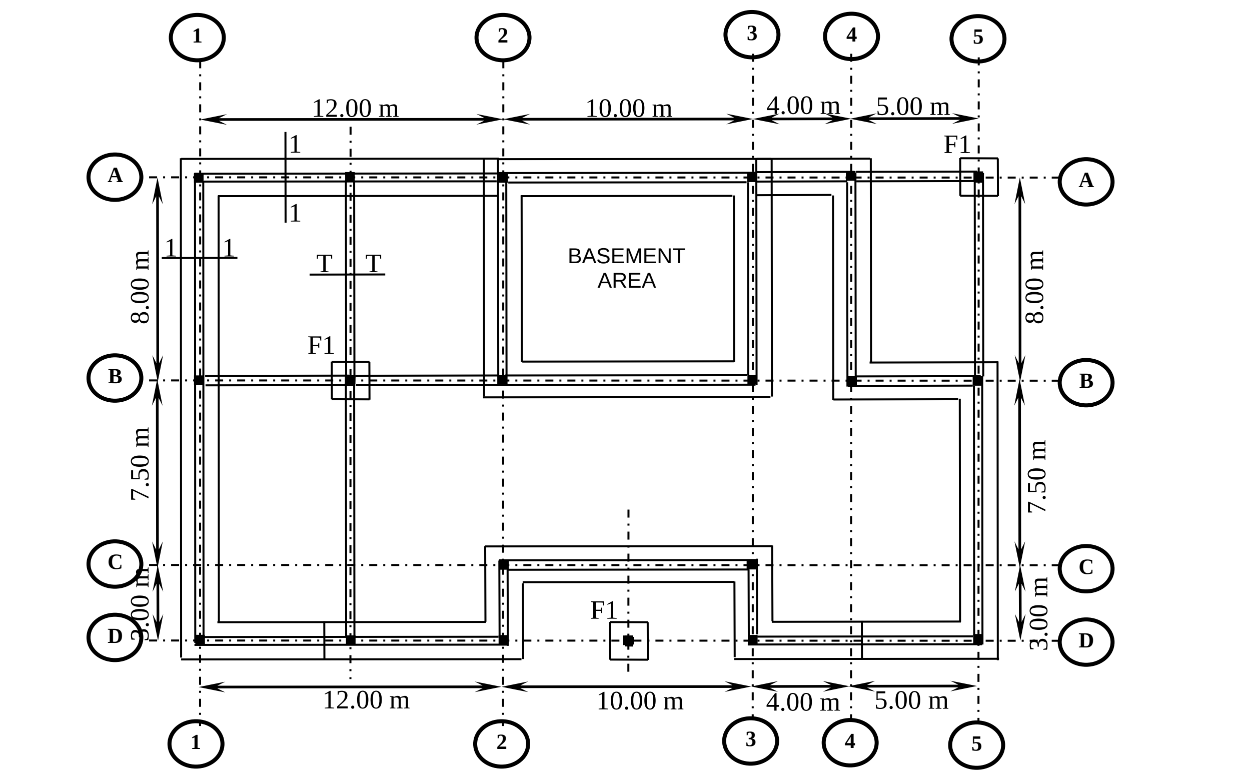
b. Continuous and Spread Footings (الأساسات المستمرة و المنفصلة), and Grade Beams (الجسور الأرضية)

c. Retaining and Bearing Walls (الجدران الإستنادية و الحاملة), and Columns (الأعمدة)

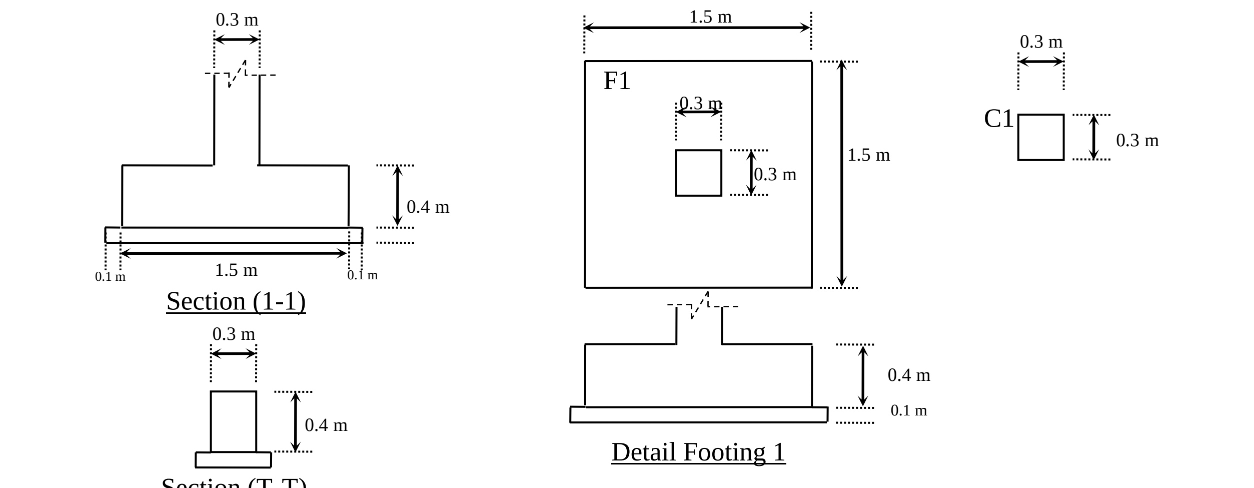
d. Basement and Ground Floorings (المدات الأرضية)

e. Staircases (الأدراج)

f. Solid and Ribbed Slabs (العقدات المصمتة أو عقدات الأعصاب)

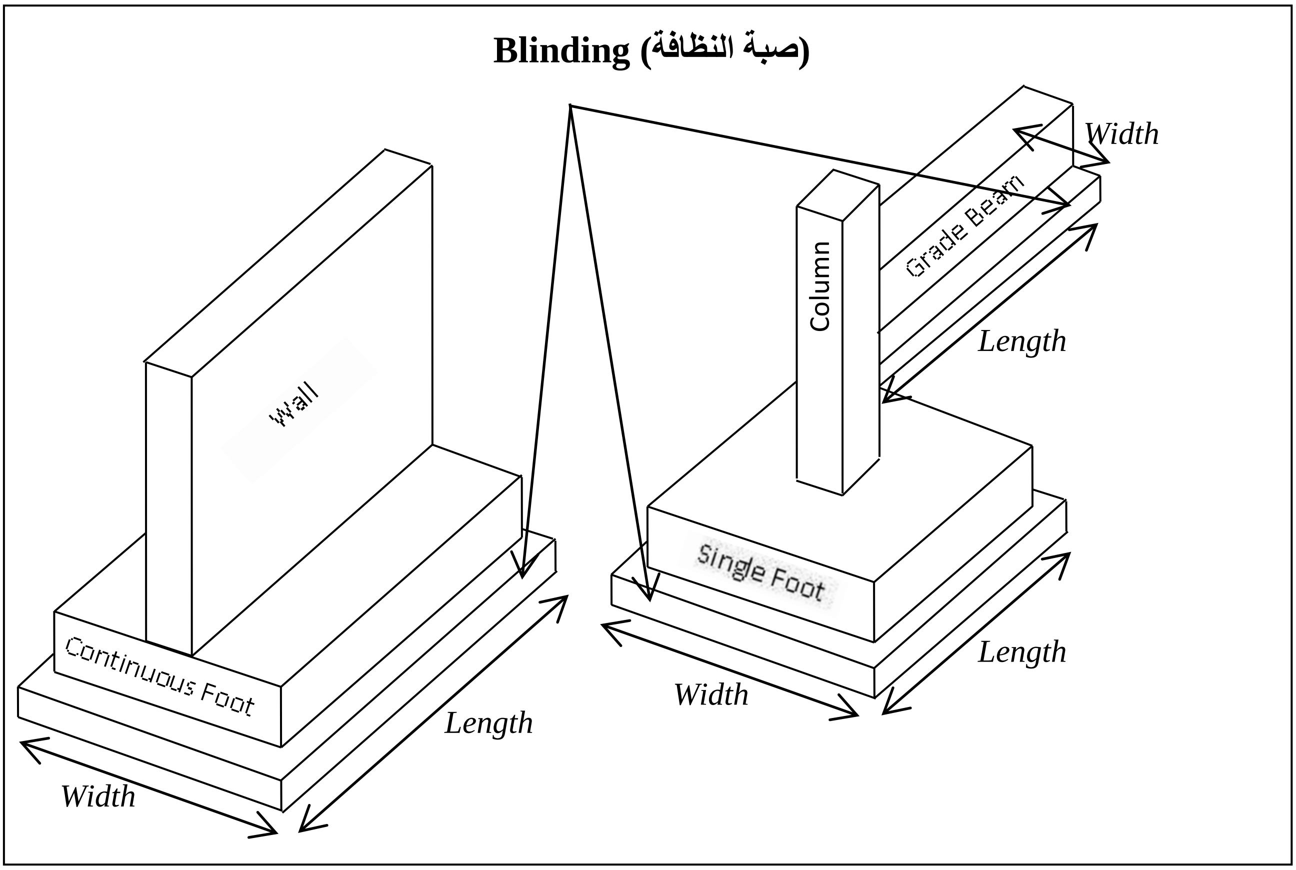


Building Footings' Plan



Cross-Sections of Footings

Blinding: (صبة النظافة) Measured in m^2



$Blinding\ of\ continuous\ Footing\ (1-1) = Width\ \times Length$

$= 1.7 \times (12 + 10 + 4 + 8 + 5 + 7.5 + 3 + 5 + 4 + 3 + 10 + 3 + 12 + 18.5 + 8 + 10 + 8 - 1.7)$

$= 219.81\ m^2$

$Blinding\ of\ Single\ Footings\ (F_1) = Width\ \times Length \times Number$

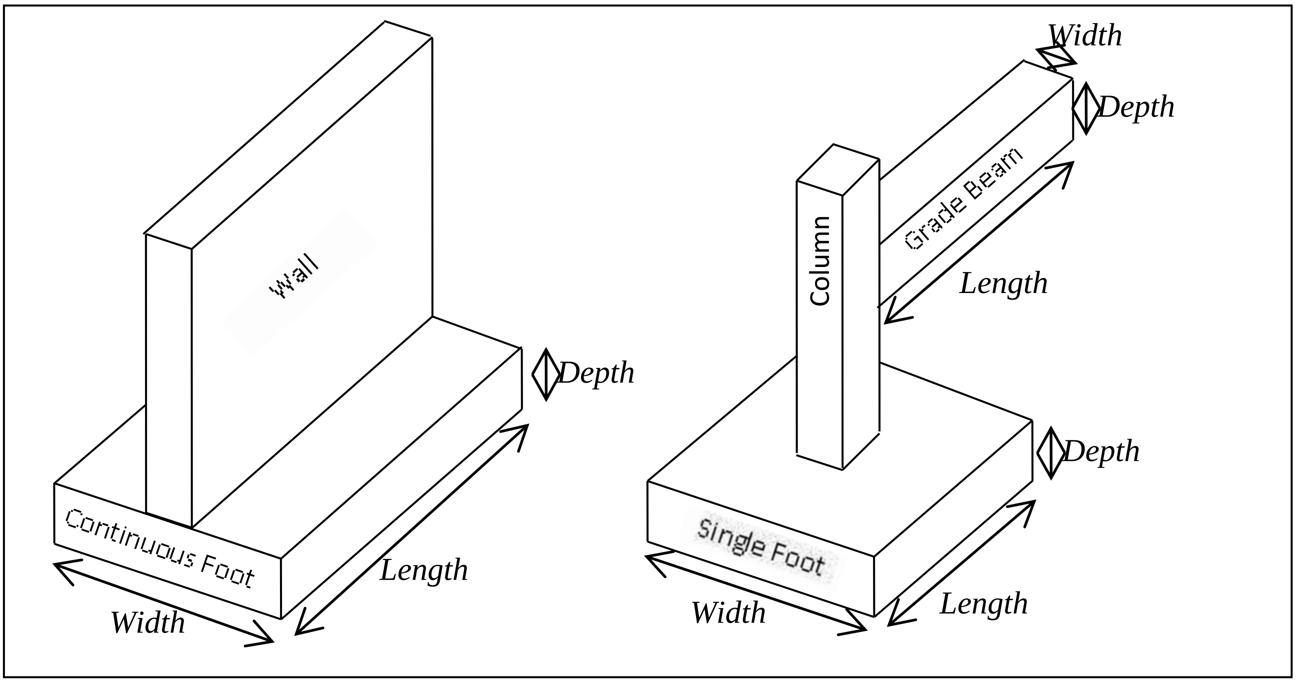
$= 1.7 \times 1.7 \times 3 = 8.67\ m^2$

$Blinding\ of\ Grade\ Beam\ (T-T) = Width\ \times Length$

$= 0.5 \times (7.7 + 10.2 + 11.4 + 4.7 + 7.7) = 20.85\ m^2$

$\boldsymbol{Total\ Blinding\ Area} = 219.81 + 8.67 + 20.85 = 249.33\ m^2$

Concrete of Footings: (خرسانة الأساسات) Measured in m^3



$Continuous\ Footing\ (1-1) = Width \times Depth \times Lenght$

$= 1.5 \times 0.4 \times (12 + 10 + 4 + 8 + 5 + 7.5 + 3 + 5 + 4 + 3 + 10 + 3 + 12 + 18.5 + 8 + 10 + 8 - 1.5)$

$= 78.42\ m^3$

If step footing is used, then add

$= 1.5 \times 0.4 \times (Difference\ of\ excavation\ elevations\ between\ the\ ground\ floor\ and\ basement\ floor) \times 2$

$Single\ Footing\ (F1) = Width \times Depth \times Lenght \times Number$

$= 1.5 \times 0.4 \times 1.5 \times 3 = \ \ m^3$

$Grade\ Beam\ (T-T) = Width \times Depth \times Lenght$

$= 0.3 \times 0.4 \times (7.7 + 10.2 + 5.7 + 5.7 + 4.7 + 7.7) = \ \ m^3$

*When ordering concrete to the project site, add 5% to the calculated volumes for waste and round off.

<u>Concrete of Walls and Columns: (خرسانة الجدران و الأعمدة)</u> Measured in m^3

a. Walls of the basement

b. Remaining Walls outside the basement

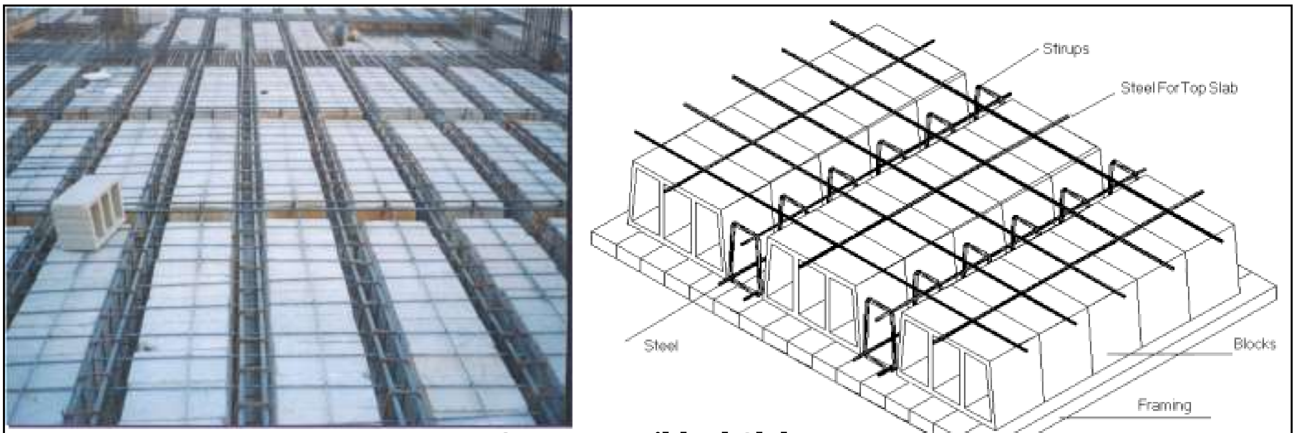
c. Walls of the staircase

d. Columns

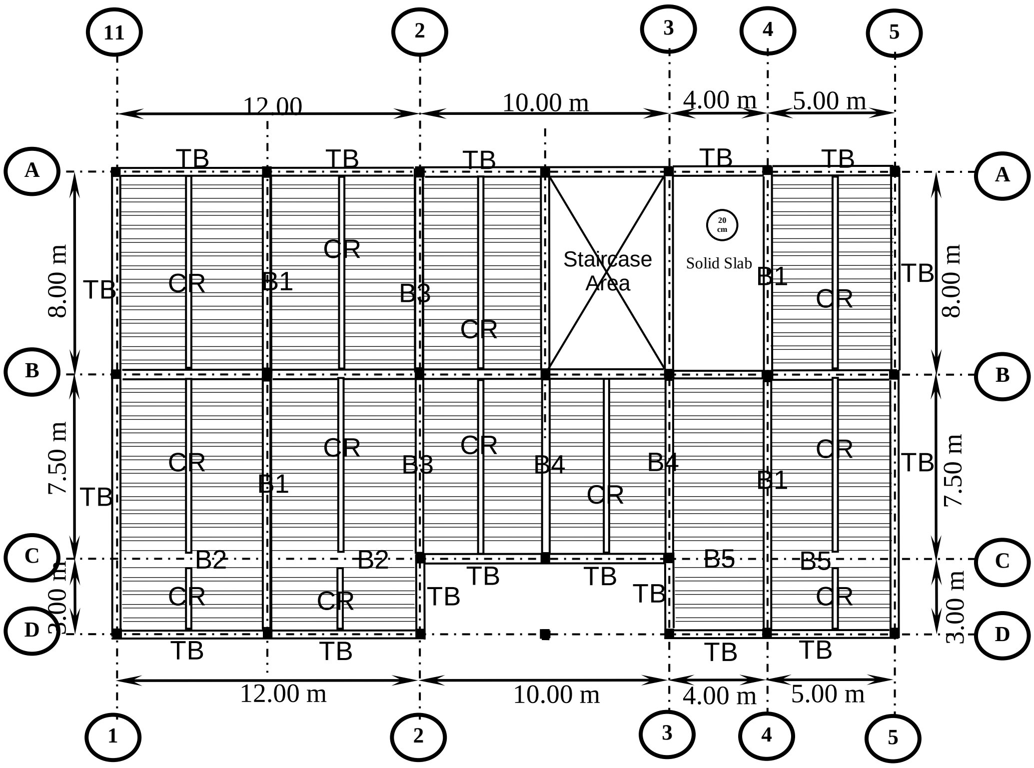
<u>Concrete of Floors: (خرسانة المدات الأرضية)</u> Measured in m^2

<u>Concrete of Stairs: (خرسانة الأدراج)</u> Measured in m^3

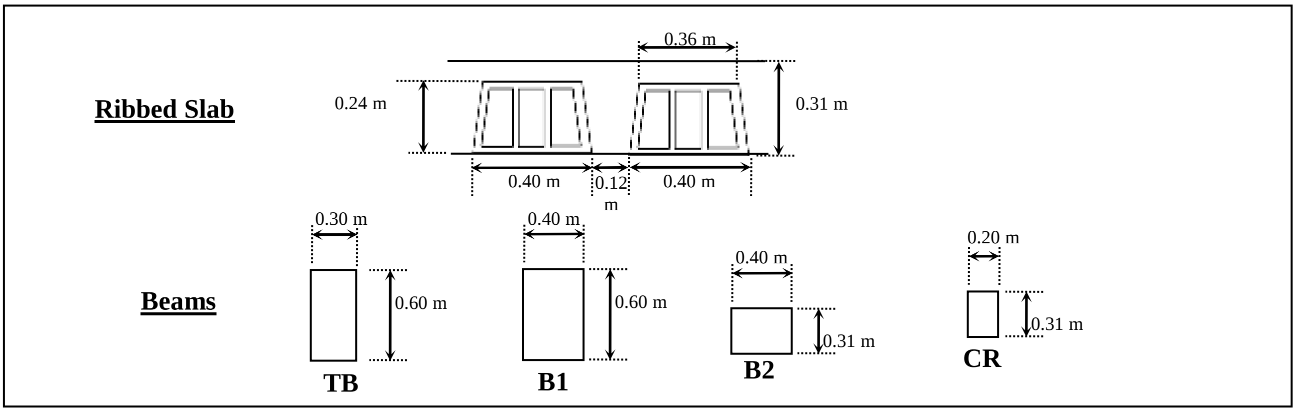
Concrete of Slabs: (خرسانة العقدات) Measured in m^3



One Way Ribbed Slab



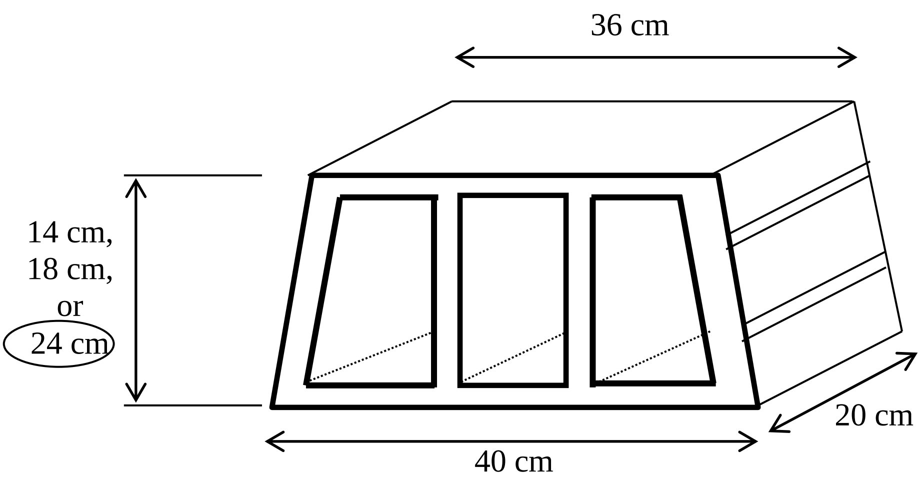
Ground Floor Slab


Ribbed Slab
0.36 m
0.24 m
0.31 m
0.40 m
0.12 m
0.40 m
Beams
0.30 m
0.60 m
TB
0.40 m
0.60 m
B1
0.40 m
0.31 m
B2
0.20 m
0.31 m
CR

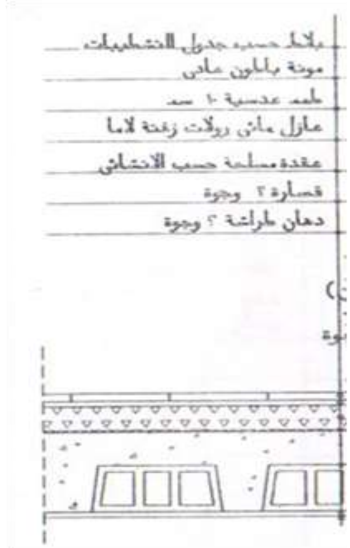
Find concrete volume for the following types of slabs:

(A) Solid Slab. (B) One-way Ribbed Slab

Item	Work Description	Unit	Dimensions			No.	Total Quantity	Notes
			Length	Width	Height			
1	Solid Slab	m^3	4.4	3.7	0.20	1	3.256	Basement Slab (A)
2	One-way Ribbed Slab	m^3	1.3	10	0.31			
			7.4	13.7	0.31			
			5.9	9.9	0.31			
			2.1	5.9	0.31		57.406	
	Reduce bricks volume					38x18		(B)
						16x13		(C)
						15x17		(D)
						7x10		(E)
	Total volume of Bricks=	No.	0.2	0.38	0.24	1217	-22.198	B,C,D, and E
	Total Concrete Volume=	m^3					35.208	



Slab Block Dimensions



2.4 Reinforcement

The reinforcing used in concrete may be reinforcing bars, welded wire mesh (WWF), or a combination of the two.

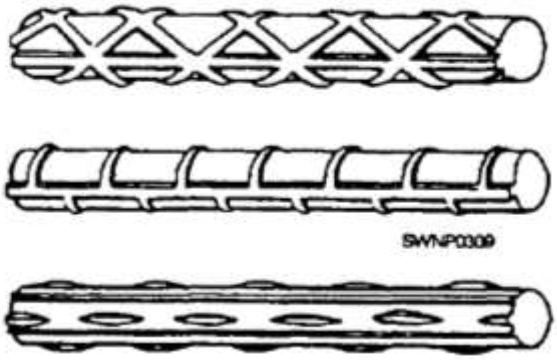


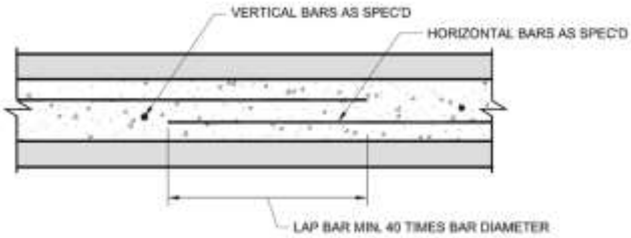
Figure 7-1.—Various types of deformed bars.

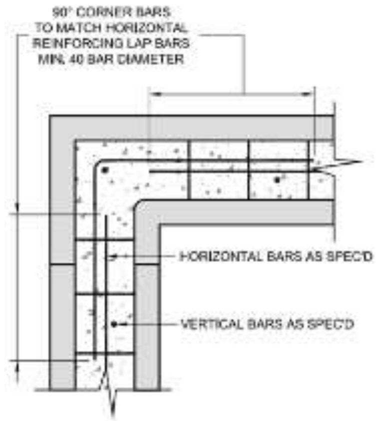
Size (mm)	6	8	10	12	14	16	18	20
Area (mm²)	28.3	50.3	78.5	113.0	153.96	201.0	254.0	314.0
Weight (kg per m)	0.222	0.395	0.617	0.888	1.209	1.58	**2.00**	2.47

Size (mm)	22	25	28	32	36	40	45	50
Area (mm²)	381.0	491.0	616.0	804.0	1020.0	1257.0	1509.0	1963.0
Weight (kg per m)	2.98	3.85	4.83	6.31	7.99	9.86	12.50	15.41

Unit weight of standard reinforcing steel bars

$$Unit\ Weight\ of\ \emptyset\ Bar = \frac{\emptyset^2}{18^2} \times 2\ \ (kg/m)$$



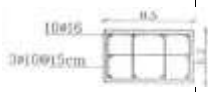


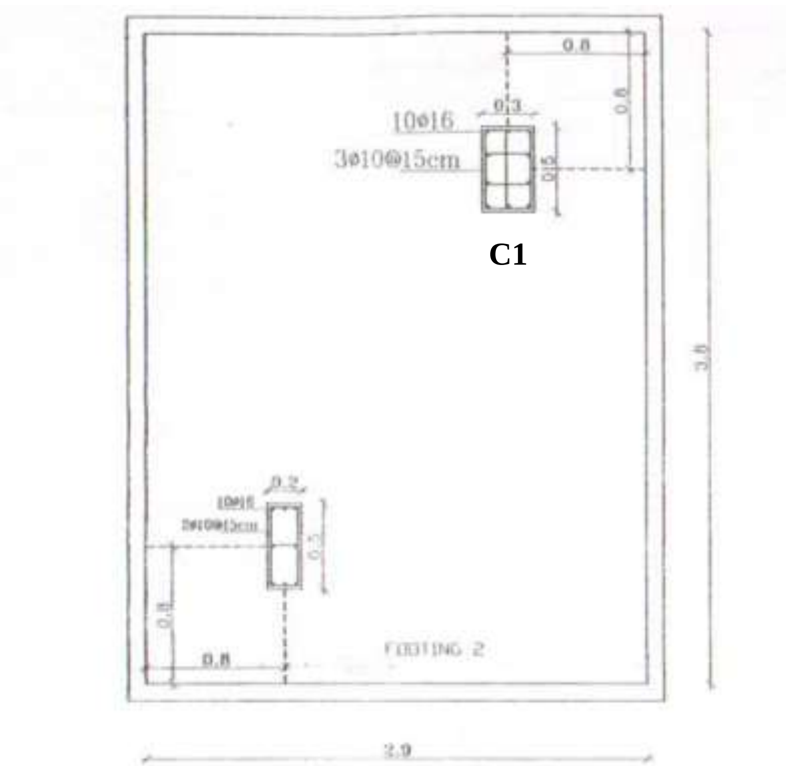
Example:

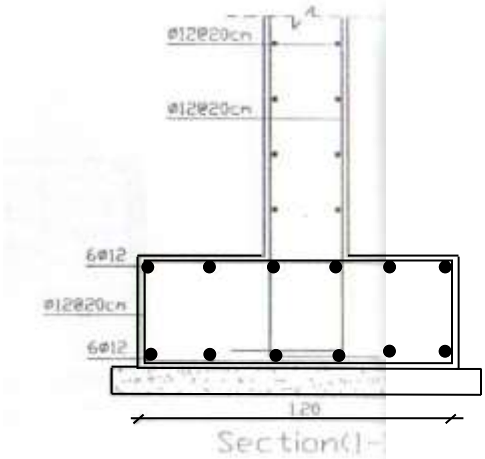
Find reinforcement bars quantities and weight for the following items:

1. Footings. 2. Walls. 3. Columns. 4. Slabs

Item	Work Description	Reinforcement Bar Shape	Bars Length	Number of Bars	Total Length	Weight per 1 m.r	Total Weight
1.1	Footing 2	Ø12	(3.8-.08+0.6-.08)x2+.2=7.24	(2.9-.08)/.15+1=20 20x1=20	144.8	0.888	128.6 kg
		Ø12	(2.9-.08+0.6-.08)x2+.2=6.88	(3.8-.08)/.15+1=26 26x1=26	178.9	0.888	158.8 kg
1.2	Continuous footing section 1-1 (30 m)		6	30/(6-50x.012)=5.5 5x12=60	360	0.888	319.7 kg
			30-(5.4x5)=3 m 3+0.6=3.6 m	12	43.2	0.888	38.4 kg
			(1.2-.08+.6-.08)x2 +.2 = 3.5 m	30/.2=150	525	0.888	466.2 kg
2.	Walls (length 30 m x height 4 m x thickness 0.3 m)	Ø12	4 +.55+.6 =5.15	2x 30/.2=300	1545	0.888	1,372.0 kg
		Ø12	6	2 x (4/.2 +1)=42 42x5.5= 231	1386	0.888	1,230.8 kg
3.	Columns C1 (height 4 m, 2 columns)	10Ø16	4+.55+.6=5.15	10x2= 20		1.58	

	C1 Stirrups		(.45+.25)x2+.1= (.15+.25)x2 +.1= (.45+.13)x2 +.1=	4/.15=		0.617	
4.	**Slabs**						
	Solid Slab	Ø12 10Ø	3.1+.3+.12+.12= 3.8+.3+.12+.12=	2x 3.8/.15= 2x 3.1/.15=		0.888	
	Ribbed Slab (B,C)	2Ø10 T 10Ø	10-.3+.1+.1= 10+3.7-.3+.1+.1=	2 x 4 = 2 x 12 =		0.617	
		2Ø14 T					
		10Ø 2Ø12 B					
		2Ø14 B					
		2Ø12 B					
	Ribbed Slab (D,E)						
	B1						
	B2						
	B4						
	CR						
	DR						



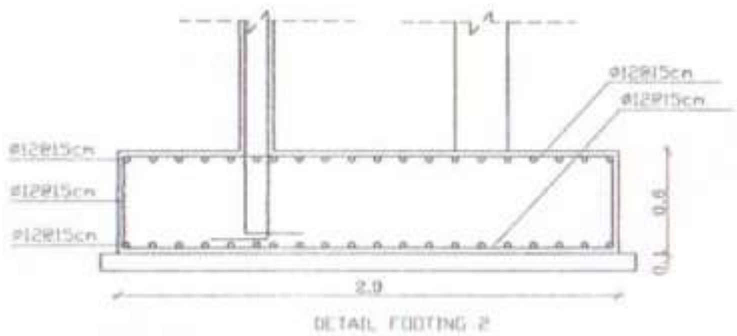


Assume the length of continuous footing is 30 m.

Assume required reinforcement overlapping equals 50 times the bar diameter.

For Ø12mm it equals 0.60 m

Assume concrete covering is 4cm.



Chapter 3: Project Scheduling

A schedule is the conversion of a project action plan into an operating timetable. As such, it serves as the basis for monitoring and controlling project activity and, taken together with the plan and budget, is probably the major tool for the management of projects. In a project environment, the scheduling function is more important than it would be in an ongoing operation because projects lack the continuity of day-to-day operations and often present much more complex problems of coordination.

The basic approach of all scheduling techniques is to form a network of activity and event relationships that graphically portrays the sequential relations between the tasks in a project. Tasks that must precede or follow other tasks are then clearly identified, in time as well as function. Such a network is a powerful tool for planning and controlling projects.

The most common approaches to project scheduling, which will be discussed in this chapter, are the use of network techniques such as PERT and CPM, and the use of Gantt charts.

3.1 Network Techniques

Two methods of network techniques are commonly used for project scheduling:

1. activity-on-node (AON) network:

Rectangles (nodes) represent the activities connected with arrows to show relationships.

2. activity-on-arrow (AOA):

The activities are shown on the arrows and the (circular) nodes represent events.

Events: The result of completing one or more activities.

Example:

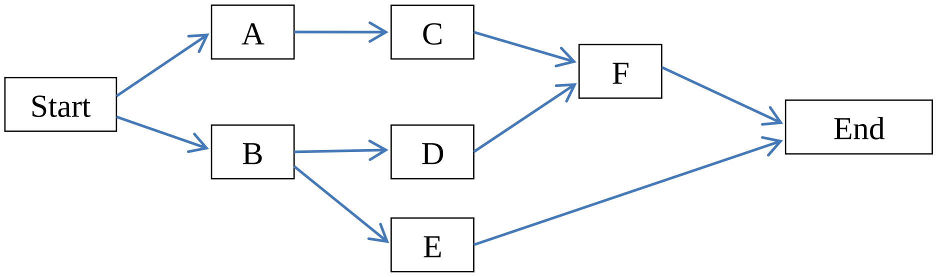
The following table lists all activities that must be undertaken in order to complete a specified task, the time each activity is expected to take, any nonroutine resources that will be used by the activity, and the predecessor activities for each activity. Construct AON and AOA Network schedule.

Tasks	Precedence	Time (Days)	Cost	Who Does
A	-	5	-	-
B	-	4	-	-
C	A	6	-	-
D	B	2	-	-
E	B	5	-	-
F	C,D	8	-	-

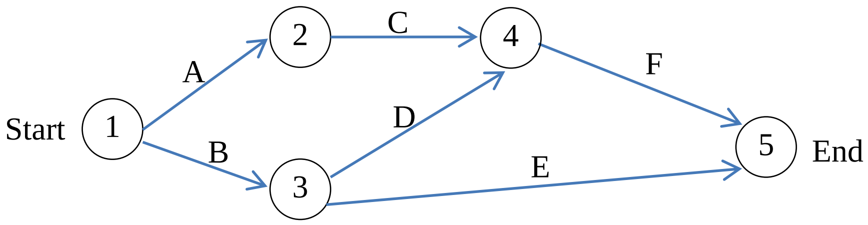
Sample action plan

Solution:

AON Network Schedule



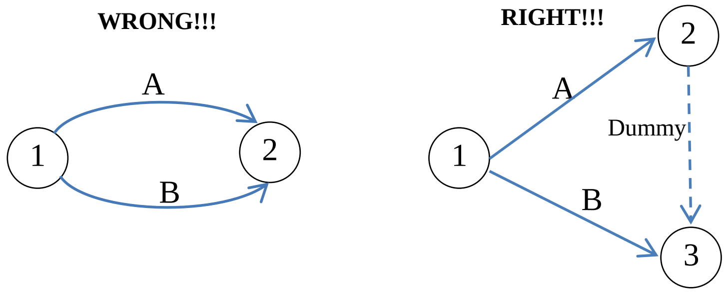
AOA Network Schedule



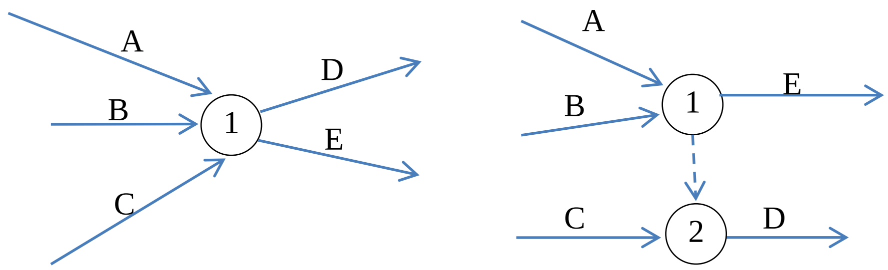
The following figures illustrate why to use a dummy activity for AOA networks.

An activity is identified by its starting and ending nodes as well as its “name.” Many computer programs that are widely used for finding the critical path and time for networks require the nodes to identify which activity is which.

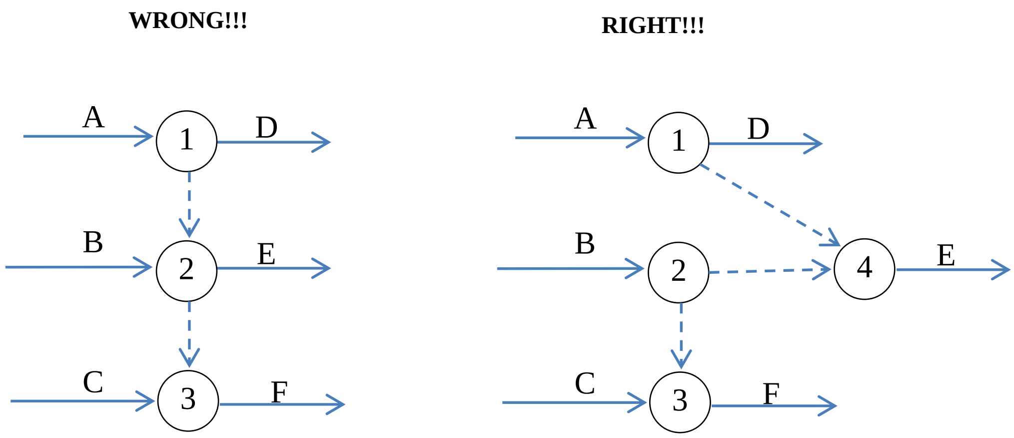
If two activities occur between the same two events.

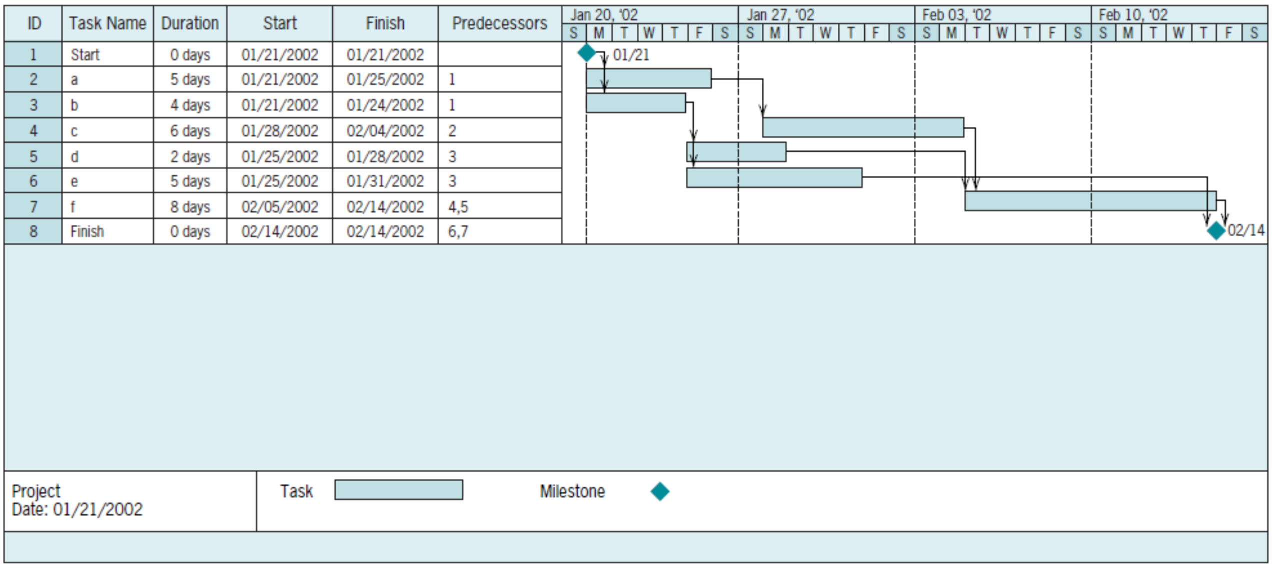


Activity C not required for E!!!



A precedes D; A and B precede E; B and C precede F (A does not precede F).





ID	Task Name	Duration	Start	Finish	Predecessors
1	Start	0 days	01/21/2002	01/21/2002	
2	a	5 days	01/21/2002	01/25/2002	1
3	b	4 days	01/21/2002	01/24/2002	1
4	c	6 days	01/28/2002	02/04/2002	2
5	d	2 days	01/25/2002	01/28/2002	3
6	e	5 days	01/25/2002	01/31/2002	3
7	f	8 days	02/05/2002	02/14/2002	4,5
8	Finish	0 days	02/14/2002	02/14/2002	6,7

Figure 8-11 MSP plan and Gantt chart for sample project in Figure 8-4.

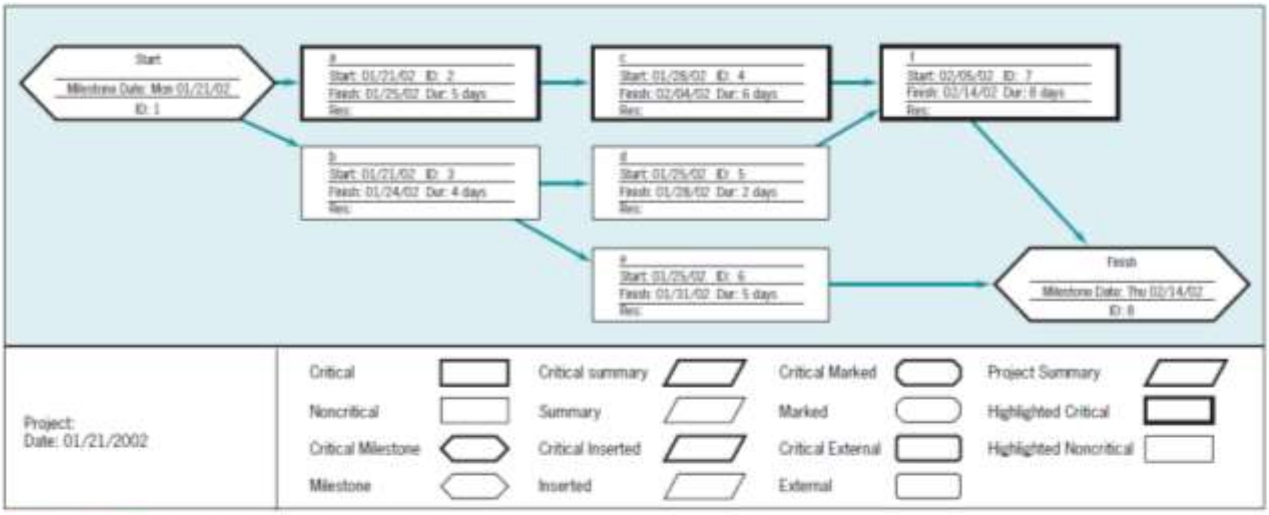


Figure 8-12 An MSP AON network for sample project in Figure 8-4.

3.2 Solving the Network

The following table lists activities, their most likely completion times, and the activities that must precede them. The table also includes optimistic and pessimistic estimates of completion time for each activity in the list.

Table 8-1. Project Activity Times and Precedences

Activity	*Optimistic Time*	*Most Likely Time*	*Pessimistic Time*	*Immediate Predecessor Activities*
a	10	22	22	—
b	20	20	20	—
c	4	10	16	—
d	2	14	32	a
e	8	8	20	b, c
f	8	14	20	b, c
g	4	4	4	b, c
h	2	12	16	c
i	6	16	38	g, h
j	2	8	14	d, e

The next step is to calculate expected activity completion times from the data in Table 8-1.

The "most likely" time, m, for the activity is the mode of the distribution.

The PM, or whoever is attempting to estimate a and b, is asked to select a such that the actual time required by the activity will be a or greater about 99 percent of the time. Similarly, b is estimated such that about 99 percent of the time the activity will have a duration of b or less.

The **expected time, TE**, is found by

$$TE = (a + 4m + b) / 6$$

where

a = optimistic time estimate

b = pessimistic time estimate

m = most likely time estimate, the mode

TE is an estimate of the mean of the distribution. It is a weighted average of a, m, and b with weights of 1-4-1, respectively.

The uncertainty for the duration of each activity, the variance, σ^2 , is calculated as,

$\sigma^2 = ((b-a)/6)^2$

Standard Deviation: $\sigma = \sqrt{\sigma^2}$

Table 8-2. Expected Activity Times (TE), Variances (σ^2), and Standard Deviations (σ)

Activity	*Expected Time, TE*	*Variance, σ^2*	*Standard Deviation, σ*
a	20	4	2
b	20	0	0
c	10	4	2
d	15	25	5
e	10	4	2
f	14	4	2
g	4	0	0
h	11	5.4	2.32
i	18	28.4	5.33
j	8	4	2

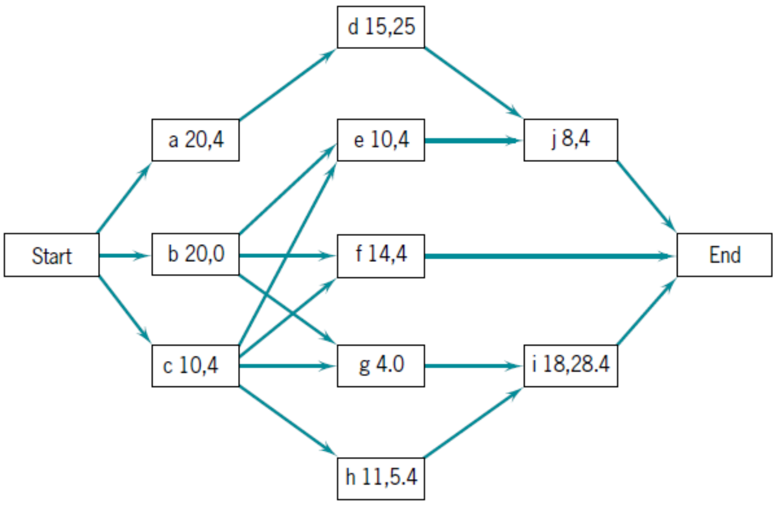


Figure 8-15 The AON network from Table 8-1, showing activity durations and variances.

As can be seen, the longest of the paths through the network is a-d-j using 43 days, which means that 43 days is the shortest time in which the entire network can be completed. This is called the critical time of the network, and a-d-j is the critical path, usually shown as a heavy line.

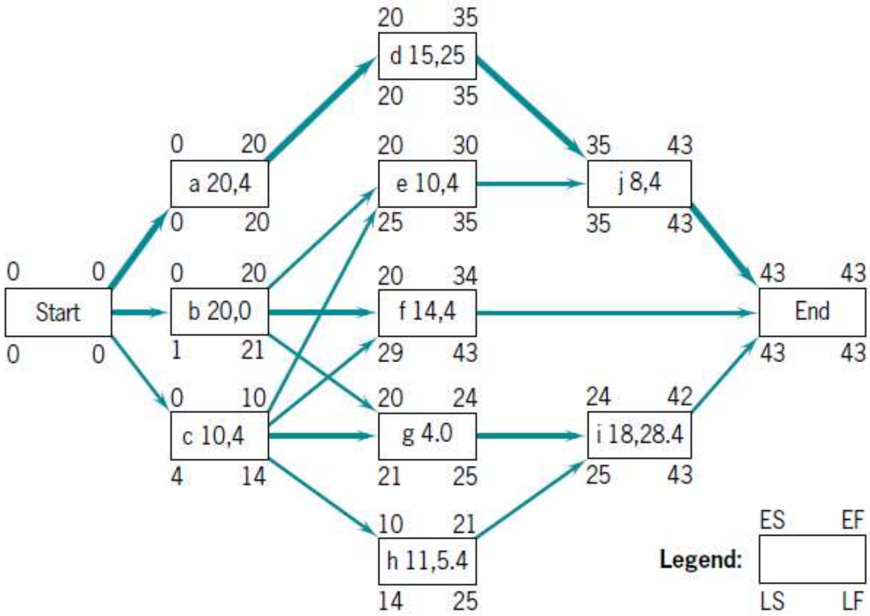


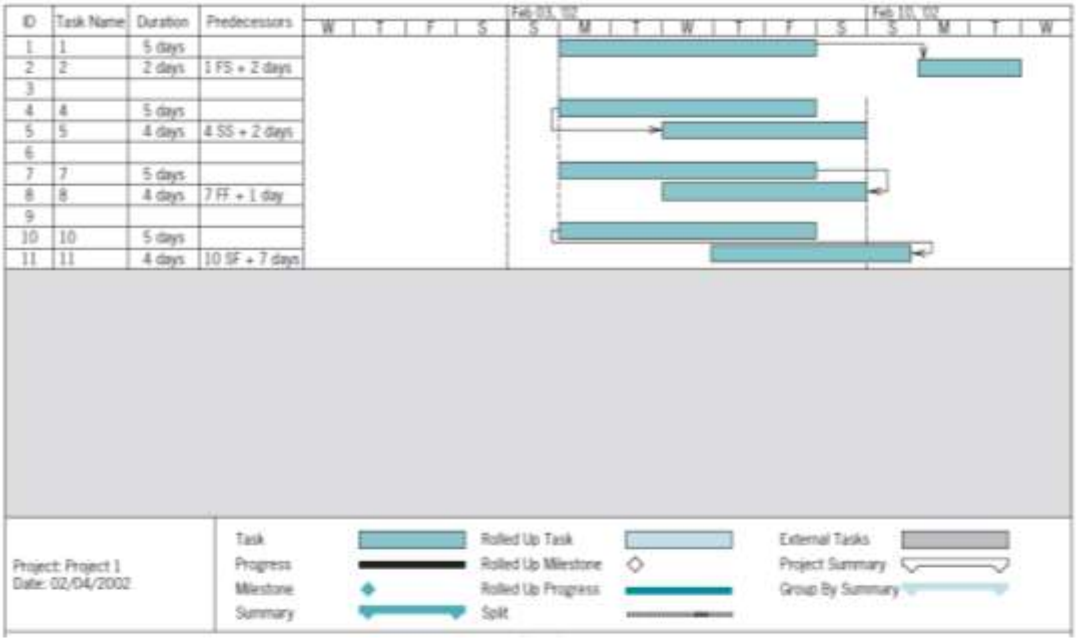
Figure 8-16 AON network showing earliest and lastest start and finish times, and critical path.

Activity f has slack of LS - ES = 29 - 20 = 9 days

Table 8-3. Times and Slacks for Network in Figure 8-16

Activity	*LS*	*ES*	*Slack*
a	0	0	0
b	1	0	1
c	4	0	4
d	20	20	0
e	25	20	5
f	29	20	9
g	21	20	1
h	14	10	4
i	25	24	1
j	35	35	0

Precedence types and Lags:



Finish to Start: Activity 2 must not start before Activity 1 has been completed. If the predecessor information had been written 1FS + 2 days, Activity 2 would be scheduled to start at least two days after the completion of Activity 1. For instance, if Activity 1 was the pouring of a concrete sidewalk, Activity 2 might be any activity that used the sidewalk.

Start to Start: Activity 5 cannot begin until Activity 4 has been underway for at least two days. Setting electrical wires in place cannot begin until two days after framing has begun.

Finish to Finish: Activity 7 must be complete at least one day before Activity 8 is completed. If Activity 7 is priming the walls of a house, Activity 8 might be the activities involved in selecting, purchasing, and finally delivering the wallpaper. It is important not to hang the paper until the wall primer has dried for 24 hours.

Start to Finish: Activity 11 cannot be completed before 7 days since the start of Activity 10. The S–F relationship is rare because there are usually simpler ways to map the required relationship.

Table 8-4. MSP Gantt Chart Version of Project Described in Table 8-1.

ID	*Task Name*	*Predecessors*	*Duration*	*Optimistic Duration*	*Expected Duration*	*Pessimistic Duration*
1	Start		0 days	0 days	0 days	0 days
2	a	1	20 days	10 days	22 days	22 days
3	b	1	20 days	20 days	20 days	20 days
4	c	1	10 days	4 days	10 days	16 days
5	d	2	15 days	2 days	14 days	32 days
6	e	3, 4	10 days	8 days	8 days	20 days
7	f	4, 3	14 days	8 days	14 days	20 days
8	g	3, 4	4 days	4 days	4 days	4 days
9	h	4	11 days	2 days	12 days	16 days
10	i	9, 8	18 days	6 days	16 days	38 days
11	j	5, 6	8 days	2 days	8 days	14 days
12	Finish	10, 11, 7	0 days	0 days	0 days	0 days

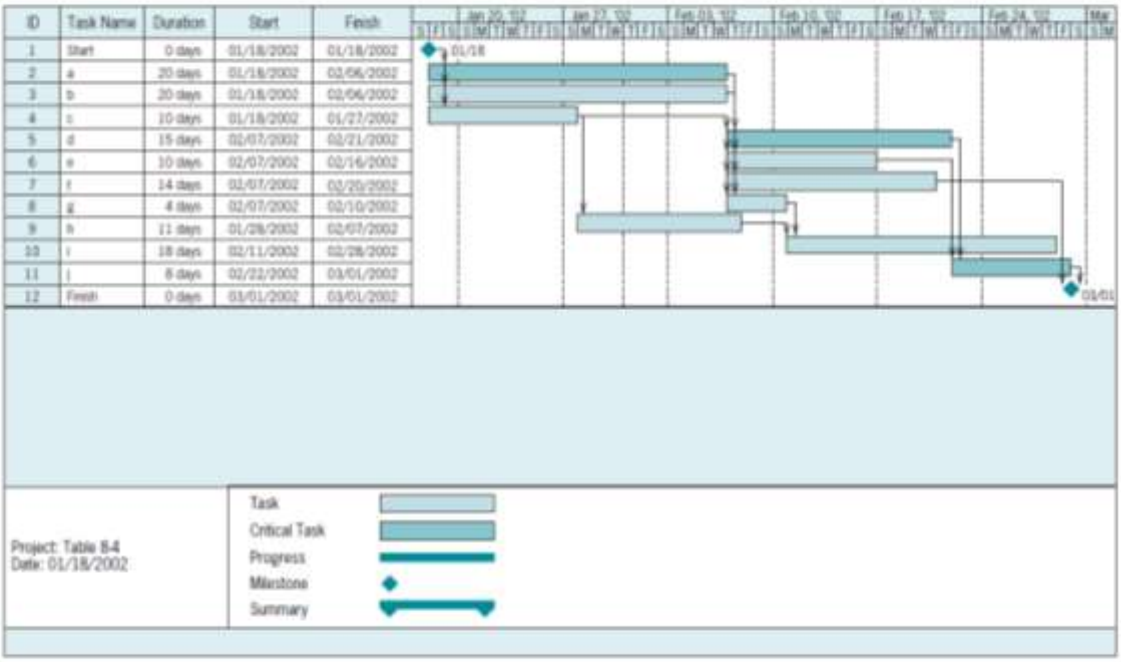


Figure 8-18 Gantt Chart of Table 8-4.

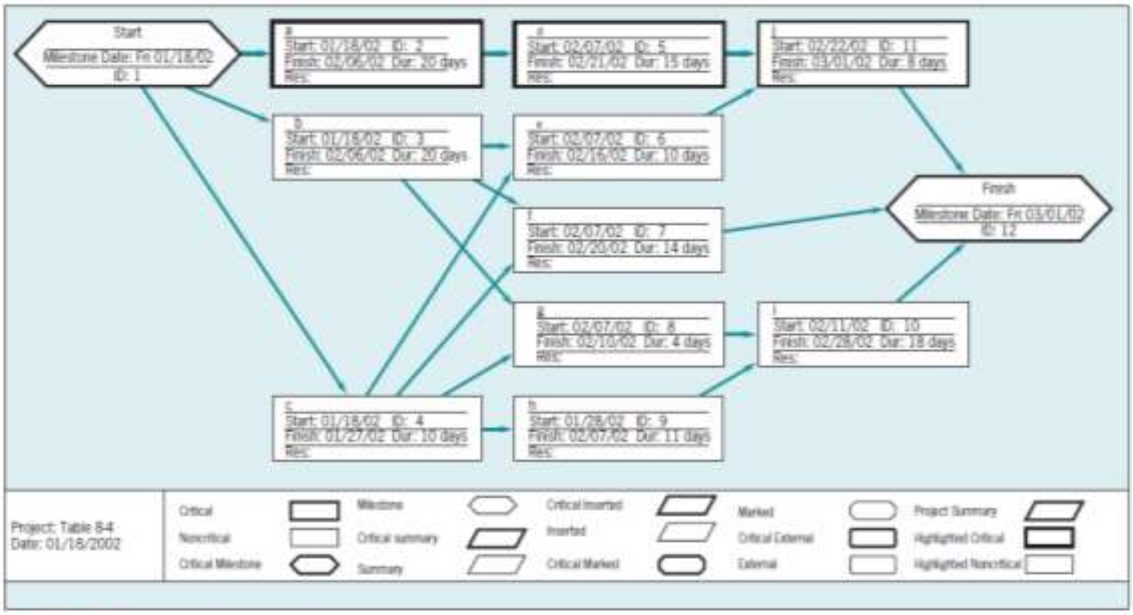


Figure 8-19 AON network of Table 8-4.

Uncertainty of Project Completion Time:

PM should try to determine the probability that a project will be completed by the suggested deadline—or find the completion time associated with a predetermined level of risk.

Assume that the PM has promised to complete the project in 50 days. What are the chances of meeting that deadline? We find the answer by calculating Z, where

$$Z = (D - \mu)/\sqrt{\sigma_\mu^2}$$

and

D = the desired project completion time

μ = the critical time of the project, the sum of the TEs for activities on the critical path

σ_μ^2 = the variance of the critical path, the sum of the variances of activities on the critical path

Z = the number of standard deviations of a normal distribution (the standard normal deviate)

Z, as calculated above, can be used to find the probability of completing the project on time.

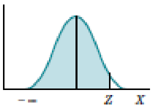
Using the numbers in our example, D = 50, μ= 43, and σ_{μ}^{2}= 5.745,

we have

Z = (50 – 43) / 5.745 = 1.22 standard deviations

We turn now to Table 8-5, which shows the probabilities associated with various levels of Z.

Table 8-5. Cumulative (Single Tail) Probabilities of the Normal Probability Distribution (Areas under the Normal Curve from $-\infty$ to Z)



Example: the area to the left of Z = 1.34 is found by following the left Z column down to 1.3 and moving right to the .04 column. At the intersection read .9099. The area to the right of Z = 1.34 is 1 − .9099 = .0901. The area between the mean (center line) and Z = 1.34 is .9099 − .5 = .4099.

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
.7	.7580	.7611	.7642	.7673	.7704	.7734	.7764	.7794	.7823	.7852
.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8880
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	.9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9932	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	.9987	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990
3.1	.9990	.9991	.9991	.9991	.9992	.9992	.9992	.9992	.9993	.9993
3.2	.9993	.9993	.9994	.9994	.9994	.9994	.9994	.9995	.9995	.9995
3.3	.9995	.9995	.9995	.9996	.9996	.9996	.9996	.9996	.9996	.9997
3.4	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9998

The probability value of Z = 1.22 shown in the table is 0.8888, or almost 89 percent, which is the likelihood that we will complete the critical path of our sample project within 50 days of the time it is started.

We can work the problem backward, too. What deadline is consistent with a .95 probability of on-time completion?

First, we go to Table 8-5 and look through the table until we find .95. The Z value associated with .95 is 1.645.

We know that μ is 43 days, and that

$\sqrt{\sigma_{\mu}^{2}}$ is 5.745.

Solving the equation for D, we have

D = μ + 5.745 (1.645)

= 43 + 9.45 = 52.45 days

Thus, we conclude that there is a 95 percent chance of finishing the project by 52.45 days.

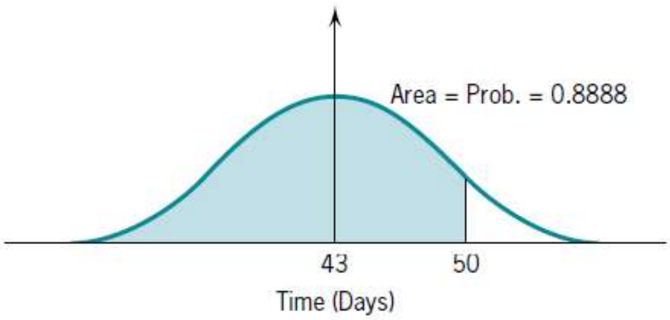


Figure 8-25 Probability distribution of project completion times.

Solved Problem

Consider the following project (times given in days).

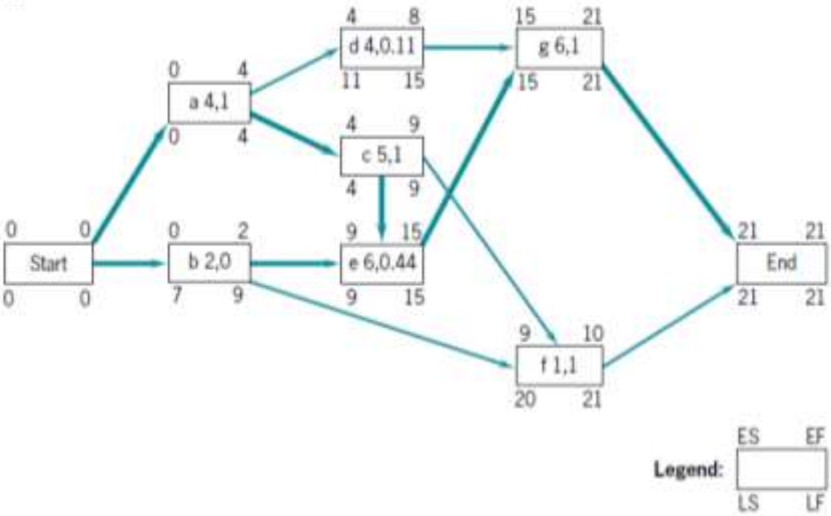
Activity	*a*	*m*	*b*	*Predecessors*
a	1	4	7	—
b	2	2	2	—
c	2	5	8	a
d	3	4	5	a
e	4	6	8	c,b
f	0	0	6	c,b
g	3	6	9	d,e

Find:

1. The network.
2. All expected activity times, variances, and slacks.
3. The critical path and expected completion time.
4. The probability the project will be done in 23 days.
5. The completion time corresponding to 95% probability.

Answer

1.



2. Activity	TE	σ^2	Slack
a	4	1.00	0
b	2	0	7
c	5	1.00	0
d	4	0.11	7
e	6	0.44	0
f	1	1	11
g	6	1	0

3. Critical path is a-c-e-g for a time of 21 days.
4. $z = (23 - 21)/\sqrt{3.44} = 1.078$ for a probability of 85.9%.
5. P = 0.95 corresponds to $z = 1.65 = (T - 21)/1.855$, or T = 24.06 days.