HIGHER LEVEL

Skew Boreholes

It is possible to determine the strike, dip and thickness of a stratum of ore using only two non-parallel boreholes. The pictorial diagram, Fig. 19.29, shows two skew boreholes (skew means non-parallel, non-intersecting lines) intersecting a vein of ore. Borehole A intersects the top surface, the headwall, at A_H and exits the stratum through the footwall at A_F. Similarly borehole B enters the headwall at B_H and exits through the footwall at B_F. A straight line joining A_H and B_H will run along the headwall for its entire length. The line $A_F B_F$ lies on the footwall. By finding a view that shows $A_H B_H$ and $A_F B_F$ appearing parallel, an edge view of the stratum can be seen.

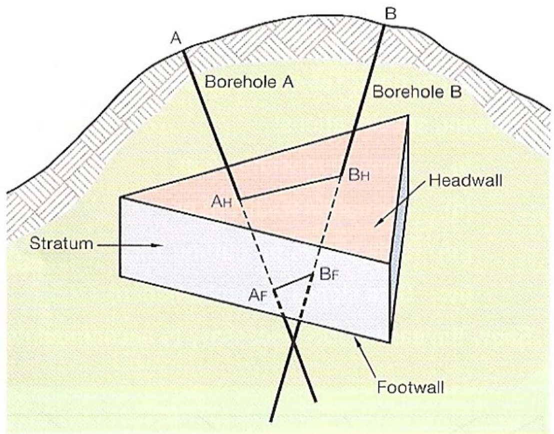


Fig. 19.29

On a contour map, A and B are two points whose altitudes are 80 m and 100 m respectively. On the map, B is located 80 m east of A. A skew borehole at A is drilled in a southerly direction in plan and has an actual inclination of 45° to the horizontal plane. It reveals the top and bottom surfaces of the stratum at altitudes of 65 m and 25 m respectively.

A skew borehole at B is drilled in a north-westerly direction in plan and has an actual inclination of 65° to the horizontal plane. It reveals the top and bottom surfaces of the stratum at altitudes of 80 m and 45 m.

Find the strike, dip and thickness of the stratum.

Scale 1:1,000

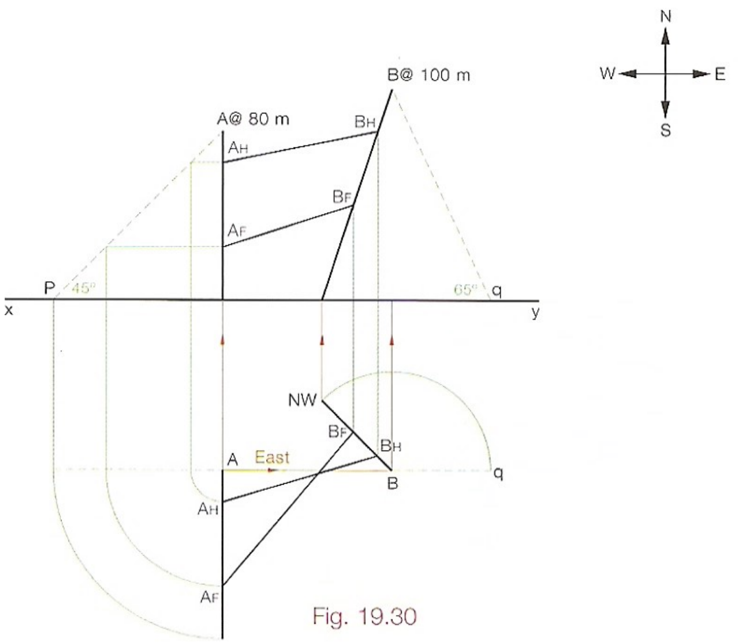


Fig. 19.30

(1) Draw the xy line. In plan choose a position for borehole A. Borehole B is located 80 m east of A. It is always advisable to draw a directional compass to reduce the chances of errors.

(2) Project points A and B to elevation and measure vertically to the specified altitudes of 80 m and 100 m.

(3) Borehole A is bored at an angle of 45° to the HP and in a southerly direction. The borehole is constructed first in a westerly or easterly direction and then rotated to a southerly direction. Draw a line from A at 45° to the xy line. Where this line meets the xy line at p, project down to a horizontal from A in plan. This 'constructed' borehole can now be swung around into a southerly direction. The borehole is drawn in bold in both views.

(4) This borehole reveals the top and bottom of the stratum at altitudes of 65 m and 25 m. An altitude is a vertical measurement. Vertical distances of 65 m and 25 m above the xy line are found on the borehole giving A_H and A_F.

(5) A_H and A_F are found in plan by projecting the two points onto the constructional borehole, projecting to plan and rotating onto the actual borehole.

(6) The construction of borehole B is the same. It is bored at an angle of 65° in a north-westerly direction. Draw a line from B at an angle of 65° to the xy line. Where this line meets the xy line at q, project down to a horizontal from B in plan. The constructional borehole is rotated about B into a north-westerly direction and drawn in bold. Find this borehole in elevation.

(7) B_H and B_F have altitudes of 80 m and 45 m respectively. Project these heights onto borehole B in elevation and project to plan.

(8) Join A_H to B_H and also A_F to B_F. The first of these skew lines lies on the headwall and the second on the footwall.

(1) Fig. 19.31 shows that by getting a view showing A_HB_H and A_FB_F appearing as parallel, the strike, dip and thickness of the stratum can be found.
Draw a level line in elevation from one of the points, e.g. A_H From B_H in elevation draw a line parallel to A_FB_F to intersect the level line at O.

(2) From B_H in plan draw a line parallel to A_FB_F. This line intersects the projection line from O in elevation to find point O in plan.

(3) Join O back to A_H. View along A_HO which is the strike. An auxiliary projected in this direction shows the skew lines appearing parallel and thus reveals the thickness and dip of the stratum.

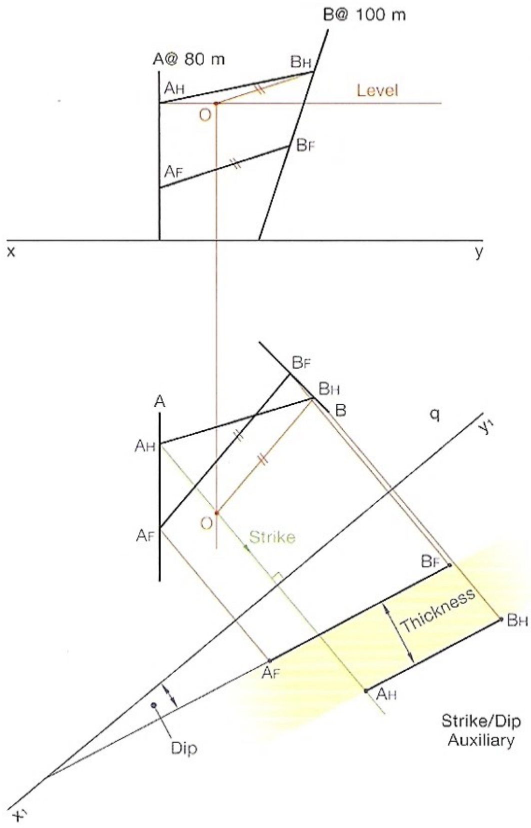
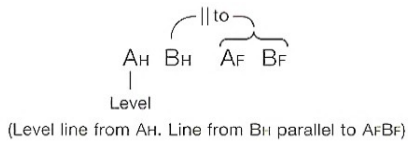


Fig. 19.31



On a contour map A and B are two points whose altitudes are 70 m and 90 m respectively. On a map, B is located 90 m south-east of A. A skew borehole at A is drilled in a north-westerly direction in plan and has an actual inclination of 50° to the horizontal plane. It reveals the top and bottom surfaces of the stratum at distances of 35 m and 65 m respectively from A.

A skew borehole at B is drilled in a north-easterly direction in plan and has an actual inclination of 60° to the horizontal plane. It reveals the top and bottom surfaces of the stratum at altitudes of 70 m and 35 m respectively.

(i) Determine the strike, dip and thickness of the stratum.

(ii) A second skew borehole from A is drilled in a southerly direction and has an actual inclination of 60° to the horizontal plane. Determine the altitude at which this borehole touches the bottom surface of the stratum and also the inclination of the borehole to the stratum.

Scale 1:1,000

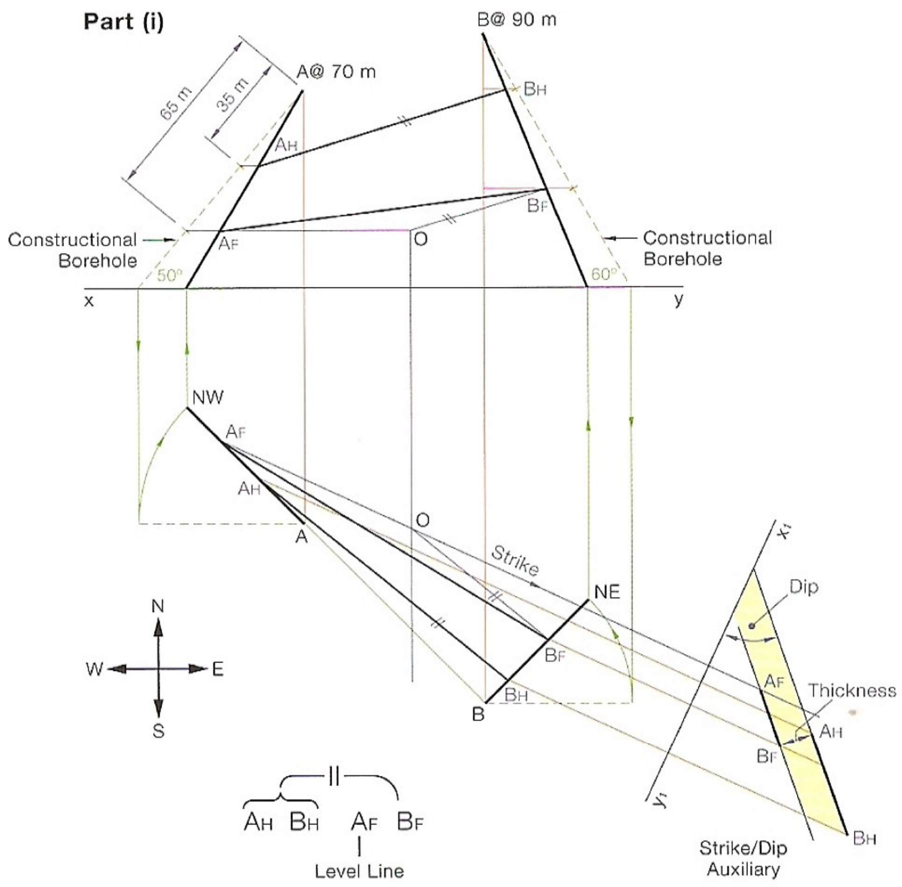


Fig. 19.32

(1) Set up the problem as explained in the previous example. Points A and B are fir[st] found in plan. B is 90 [m] away from A and at a 45° angle in a south-easterly direction.

(2) Project the two point[s] to elevation and at th[e] required elevation.

(3) Draw the borehole A [at] a 50° angle in elevatio[n] drop it to plan and rotate to a north-westerly direction. Project the rotated borehole to elevation.

(4) This borehole reveals [the] top and bottom surfac[es] of the stratum at distances of 35 m and 65 m respectively from A. **These two distances must be measured down from A, along the constructional borehole.** This constructional borehole shows true angles and true lengths. As this borehole is rotated into position the points move horizontal[ly] thus locating A_H and A_F on the actual borehole. These may be projected down to plan.

(5) Borehole B is found in a similar fashion. The points on the headwall and footwall are given as altitudes. These vertical heights are projected horizontally onto the actual borehole and then down to plan.

(6) A_HB_H and A_FB_F are treated as skew lines. The strike dip and thickness are found as explained in Fig. 19.30.

The second part of the question refers to a new borehole from A, bored in a southerly direction. In order to see this new borehole as a true length and with a true angle, it is viewed perpendicularly. A vertical section is taken along the new borehole to see the position of the stratum at that particular place.

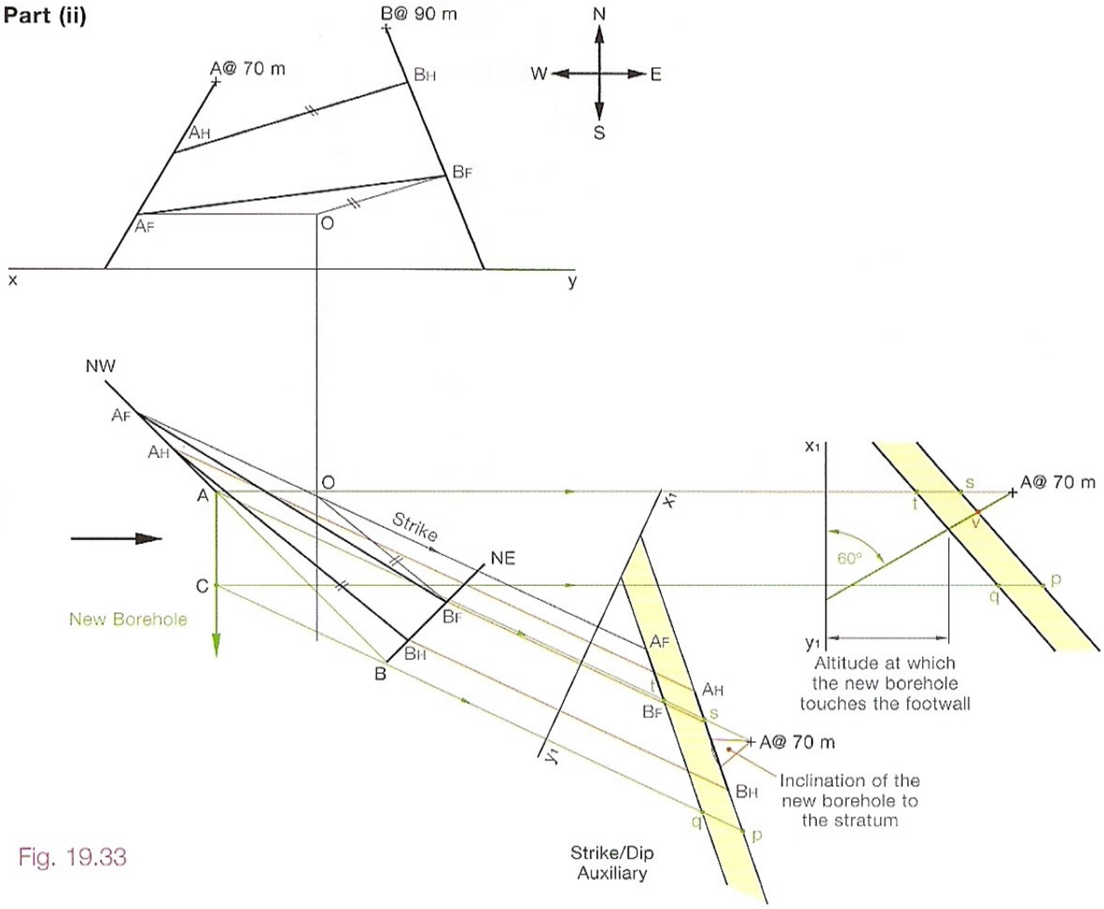


Fig. 19.33

(1) Draw the new borehole from A in plan in a southerly direction.

(2) View perpendicular to this to get the auxiliary view. Point A is projected onto this view to an altitude of 70 m. The borehole is now drawn in the auxiliary making an angle of 60° to the horizontal plane (from question).

(3) The stratum is found by taking a vertical section along the new borehole and projecting it onto the new auxiliary. A vertical borehole is drilled from point A in plan and a second vertical borehole is drilled from a point C anywhere along the new borehole.

(4) **Vertical boreholes will appear perpendicular to the horizontal plane in all elevations.** Draw these vertical boreholes in the new elevation. These two vertical boreholes will hit the stratum at points s, t, p and q (Fig. 19.33). The heights of these four points are found by projecting the same vertical boreholes, A and C, onto the strike/dip auxiliary.

(5) When the points s, t, p and q have been located the vertical section through the stratum can be drawn. The required altitude and inclination can then be clearly seen.

(6) To find the true inclination of the borehole to the stratum, the length Av (which is a true length) is taken on a compass. Use this, as a radius, in the strike/dip auxiliary. With A as centre, scribe an arc to hit the headwall in two places. The inclination of the borehole can then be seen.

On a contour map A and B are two points whose altitudes are 120 m and 100 m respectively. On the map. B is located 95 m north-east of A. A skew borehole at A is drilled in a north-easterly direction in plan and has an actual inclination of 60° to the horizontal plane. It reveals the top and bottom surfaces of a stratum at distances of 45 m and 100 m respectively from A.

A skew borehole at B is drilled in a southerly direction in plan and has an actual inclination of 50° to the horizontal plane. It reveals the top and bottom surfaces of the stratum at altitudes of 60 m and 45 m respectively.

(i) Determine the strike, dip and thickness of the stratum.

(ii) Another skew borehole at B is drilled in a south-westerly direction in plan and meets the top surface of the stratum at a distance of 55 m from B. Determine the altitude at which this borehole hits the bottom surface of the stratum and the length of the borehole as it passes through the stratum.

Scale 1:1,000

(1) Set up A and B in plan and elevation.

(2) Draw the constructional borehole for each point and rotate them into their proper positions.

(3) Locate A_H and A_F noting that the **distances** from A are given. These must be measured **down** from A along the constructional borehole which shows the borehole as a true length.

(4) Locate B_H and B_F by measuring vertical heights above the xy line. Borehole B is in a southerly direction and therefore is only seen as a vertical line in elevation. To find B_H and B_F in plan they must be projected across to the constructional borehole, dropped vertically to plan and rotated into place.

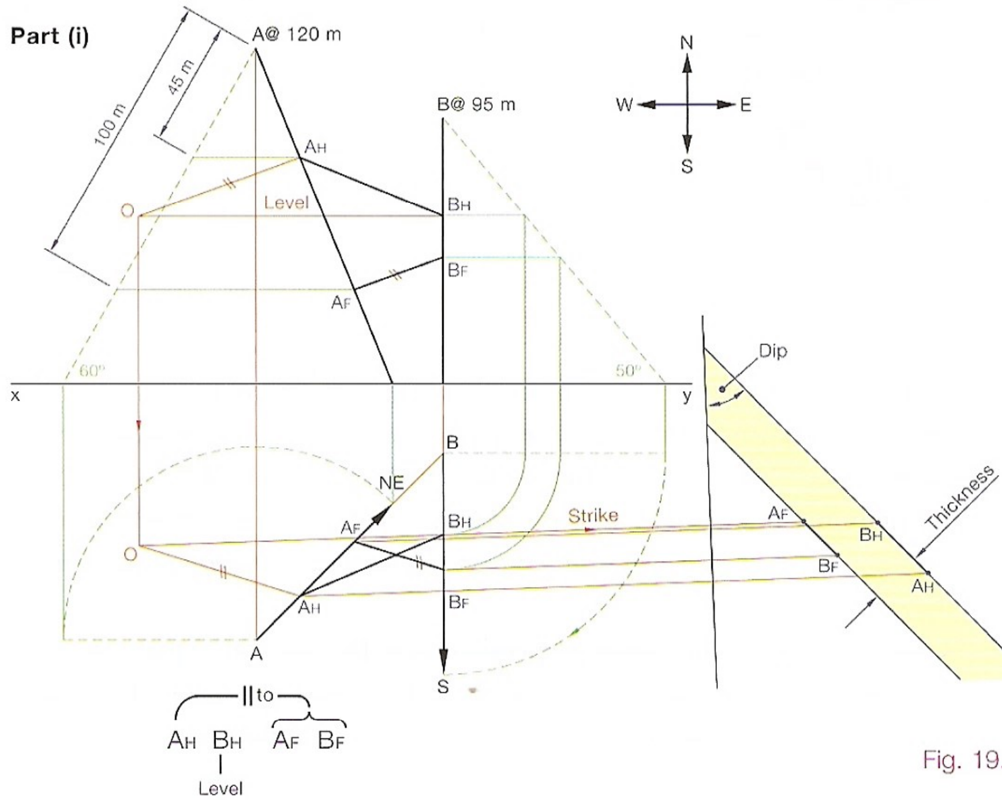


Fig. 19

(5) To find the strike, a level line is drawn from one of the points, e.g. B_H. From the other end of this line on the headwall a line is drawn parallel to A_FB_F to intersect the level line at O. Point O is projected to plan and is found exactly by drawing a line from A_H in plan, parallel to A_FB_F in plan. The level line in elevation B_HO, when found in plan, is the strike.

(6) Project the auxiliary and show the dip and thickness of the stratum.

The new borehole is in a south-westerly direction. A vertical section is taken along this borehole and a sectional elevation projected.

(1) Draw xy parallel to the new borehole.

(2) Project point B onto the new elevation.

(3) The stratum is found. Both A_H and A_F are along the new borehole and can therefore be projected to the new elevation. A further point on the headwall and on the footwall are needed. A vertical borehole is bored at B. Vertical boreholes project perpendicular to the horizontal plane in all elevations. Projected to the strike/dip auxiliary it passes through the stratum at s and t. These two points can now be found in the new auxiliary. Points A_F and s are on the footwall. Points A_H and t are on the headwall.

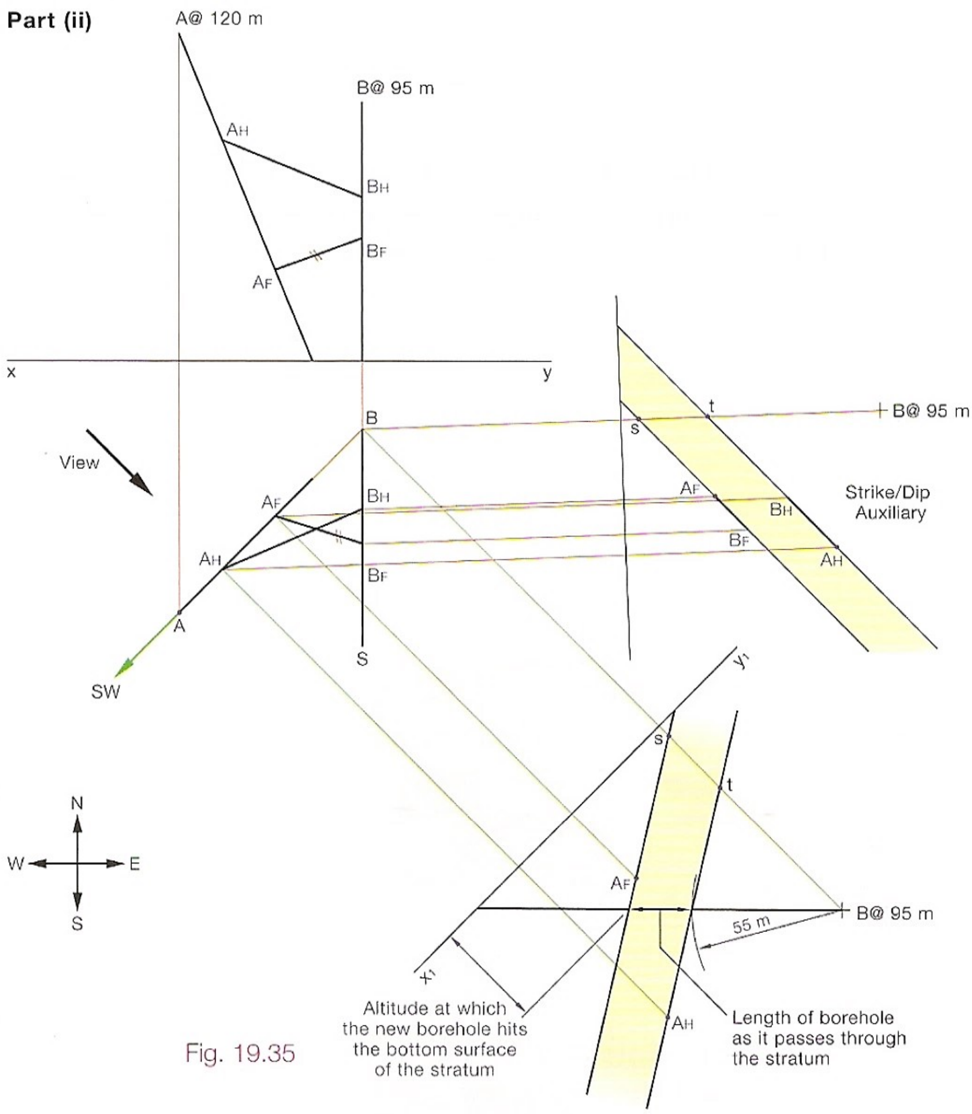


Fig. 19.35

(4) The new borehole is located by swinging an arc of 55 m length from point B.

(5) The length of the borehole as it passes through the stratum and the altitude at which it hits the bottom surface of the stratum are clearly seen, see Fig. 19.35.

True Dip and Apparent Dip

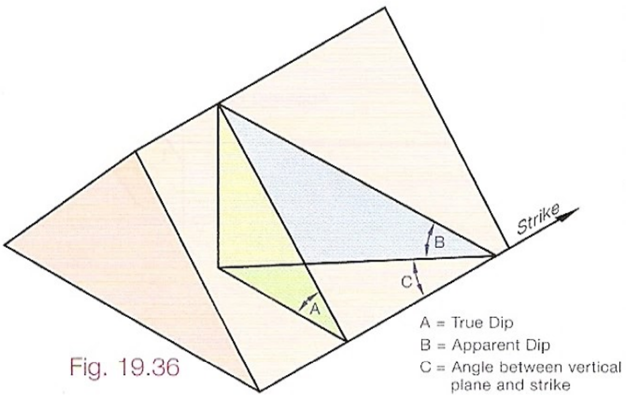


Fig. 19.36

The true dip of a stratum, which is what we have been finding up to this stage, is taken perpendicular to the strike. It can be taken from an edge view of the stratum plane(s) or as a vertical section taken perpendicular to the strike direction. Consider a vertical section taken at a different angle. This will show the layer(s) apparently at a lesser dip. This angle is the apparent dip.

Consider the practical example of a pitched roof. If you walk directly down the roof, taking the shortest route from ridge to eaves, then that is the steepest slope down the roof. By walking at an angle, the journey will be longer but not as steep. This is the essence of apparent dip. Any plane surface can have only one true dip angle but can have multiple apparent dip angles depending at which angle the section plane is taken.

If a vertical sectional plane is taken perpendicular to the strike of a stratum, then the dip is at its maximum, the true dip of the stratum is found. When the angle between the cross-section and the strike is anything less than 90° then the apparent dip is some value less than the true dip.

The apparent dip of a bed in any desired direction may be calculated from the true dip by the equation:
tan (apparent dip) = tan (true dip) × sin (angle between the strike of the stratum and the direction of the apparent dip)
Referring back to Fig. 19.36.

tan B = tan A × sin C

The apparent dip can also be easily established by graphical means.

On a contour map A and B are two points whose altitudes are 85 m and 110 m respectively. On the map, B is located 70 m north of A. A skew borehole at A is drilled in a south-westerly direction in plan and has an actual inclination of 55° to the horizontal plane. It reveals the top and bottom surfaces of a stratum at altitudes of 60 m and 40 m respectively. A skew borehole at B is drilled in a south-easterly direction in plan and has an actual inclination of 60° to the horizontal plane. It reveals the top and bottom surfaces of the stratum at altitudes of 90 m and 10 m respectively.

(i) Determine the strike, dip and thickness of the stratum.

(ii) Determine the apparent dip of the stratum on a vertical section through A that trends in a southerly direction.

Scale 1:1,000

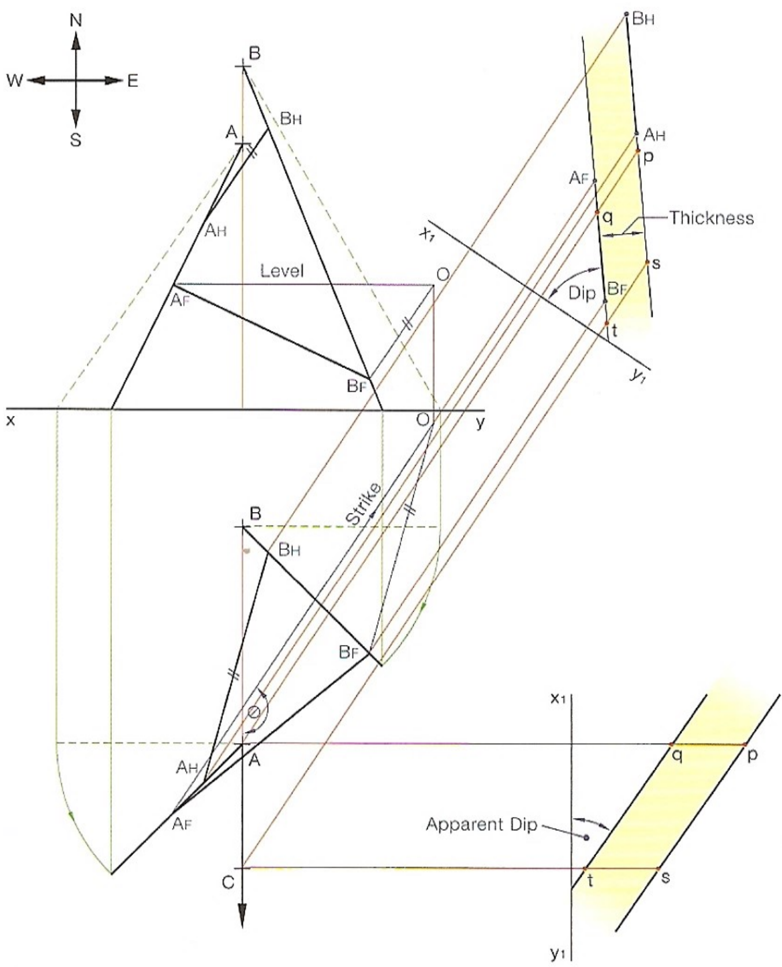


Fig. 19.37

(1) Set up the problem and find the strike, dip and thickness of the stratum in the usual way.

(2) To find the apparent dip, a vertical section is taken in a southerly direction from A. Two vertical boreholes are introduced on this southerly plane, one at A and another at C.

(3) Draw a new auxiliary to show the sectional view. The vertical boreholes are projected to the strike/dip auxiliary and to this new auxiliary. Heights p, q, s and t are found from the strike/dip auxiliary and transferred to the new auxiliary. The apparent dip can be measured from the new auxiliary.

(4) The apparent dip can be calculated once the strike and dip are known.

tan (apparent dip) = tan (true dip) × sin (angle between strike and direction of apparent dip)

tan (apparent dip) = tan 47° × sin Θ

tan (apparent dip) = tan 47° × sin 149°

tan (apparent dip) = 1.07 × 0.52

tan (apparent dip) = 0.56

Apparent dip = 29°

Earthworks for Inclined Roads

The earthwork problems that we have dealt with so far have involved level stretches of road and level, car parking sites. On a variable height site it is often more practical to design a sloping road because it can often reduce the amount of earth to be moved. By closely balancing the amount of cut and fill it can mean that the material removed in the cut can be used to build up the fill.

HIGHER LEVEL

Plotting of Fill for a Sloping Road

Fig. 19.38 shows a road rising at a steep gradient. The road is to be built on a level plane. It can be seen that the amount of fill needed increases as the road rises. It can also be seen that the level lines along the embankment are parallel to each other but are not parallel to the side of the formation. They splay away from the road as it rises. The slope of the fill remains constant, so for a straight stretch of road it may be considered as a plane. This plane leans against the fill cone at the high end of the road and is tangential to it.

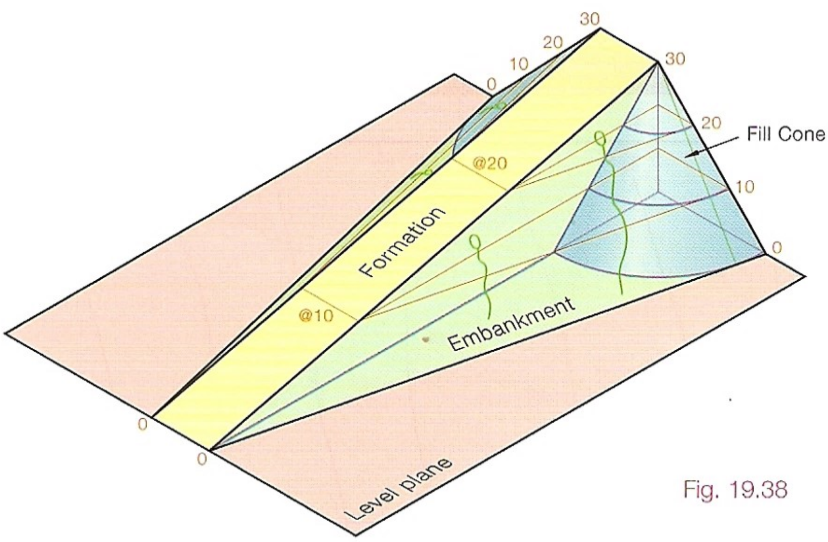


Fig. 19.38

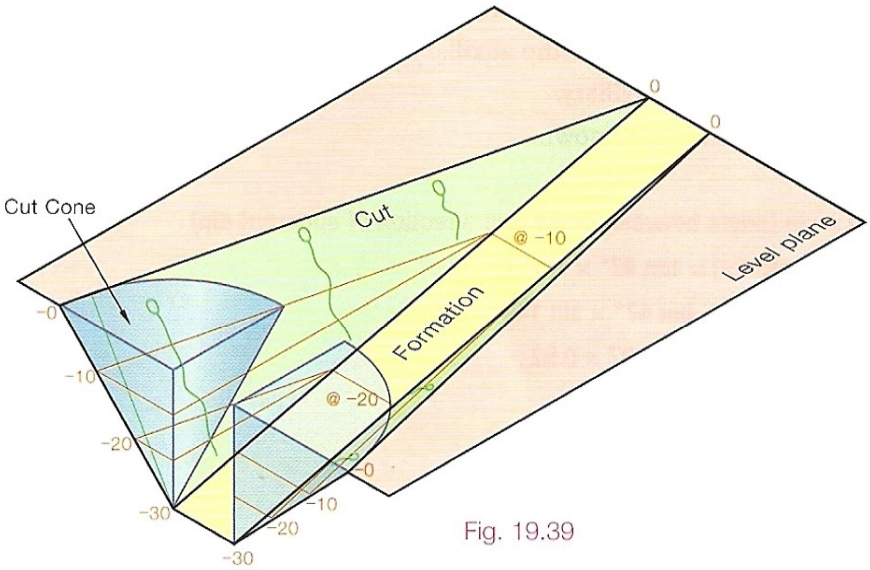


Fig. 19.39

Plotting of Cut for a Sloping Road

The diagram Fig. 19.39 shows a road sloping downwards into a level plane. The cutting needed increases as the road level drops. Level lines along the cutting are parallel to each other but are not parallel to the sides of the formation. They splay away from the road as it falls. The cut can be considered to be a plane when the road is straight. This plane is tangential to the cut cone. The cut cone is an inverted cone as shown.

Fig. 19.40a shows ground contours at 5 m vertical intervals. AB is the line of a proposed roadway. The road has the following specifications.

- **(i) Formation width is 12 m.**
- **(ii) Formation level at A is 70 m.**
- **(iii) Gradient A to B is 1 in 15 rising.**
- **(iv) Side slopes for cuttings 1 in 2.**
- **(v) Side slopes for embankments 1 in 1.5.**

On the drawing supplied, show the earthworks necessary to accommodate the roadway.

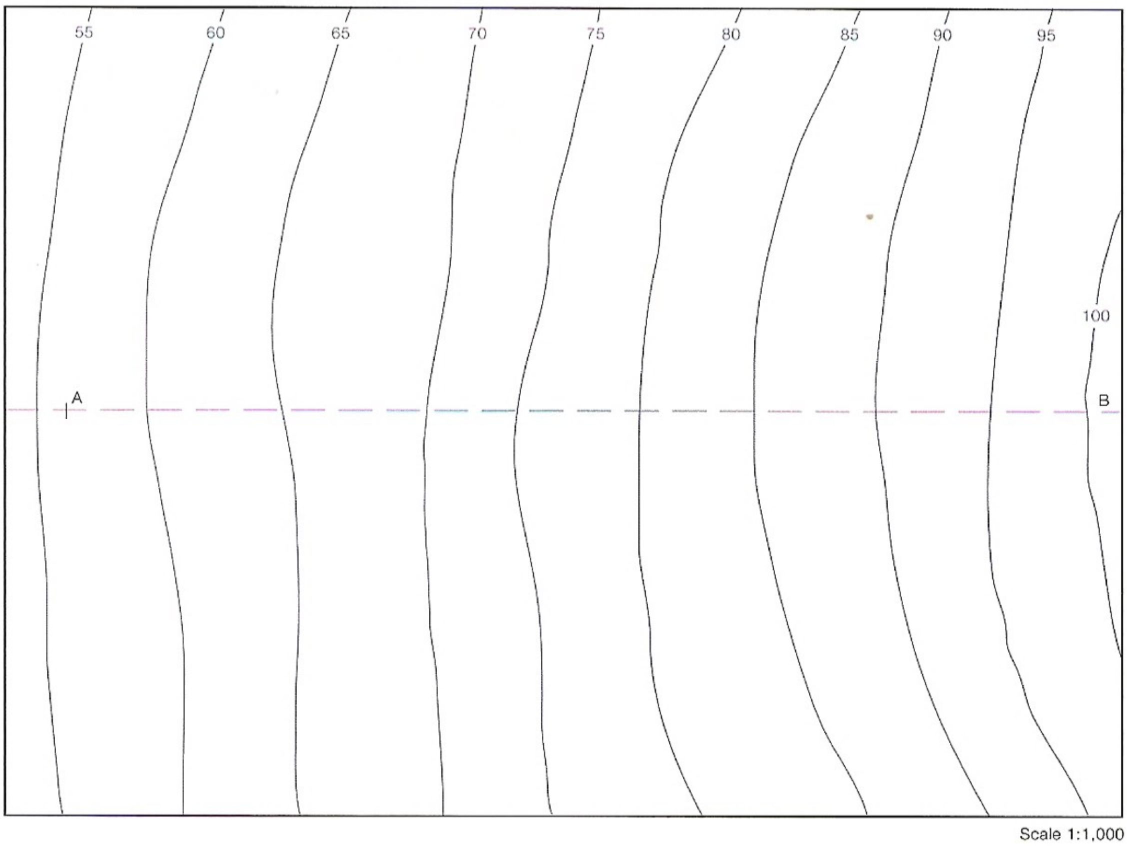


Fig. 19.40a

(1) Draw in the formation sides 6 m each side of the centre line.

(2) The road is level from side to side so the 70 m level from A is projected to the sides of the formation.

(3) The road rises at 1:15. Travelling from A to B the road rises by 1 m for every 15 m travelled on the map. For the purpose of solving these problems we are only interested in altitudes that correspond to contour levels.

Locate a point C along the road that produces a rise of 5 m or 10 m or 15 m (a multiple of 5 m). By measuring 150 m from point A, a point C is found that has an altitude 10 m greater than A.

(4) Project C to the sides of the formation. The fill cones are drawn. These appear as semicircles on the map. The radius in this example will be 15 m. **Fill cones are drawn at the high end of the formation.**

The 15 m is calculated by looking at the change in altitude and relating it to the embankment ratio. For a rise of 1 m a horizontal distance of 1.5 m is travelled away from the formation side. For a rise of 1 m a horizontal distance of 1.5 m is travelled away from the formation side.

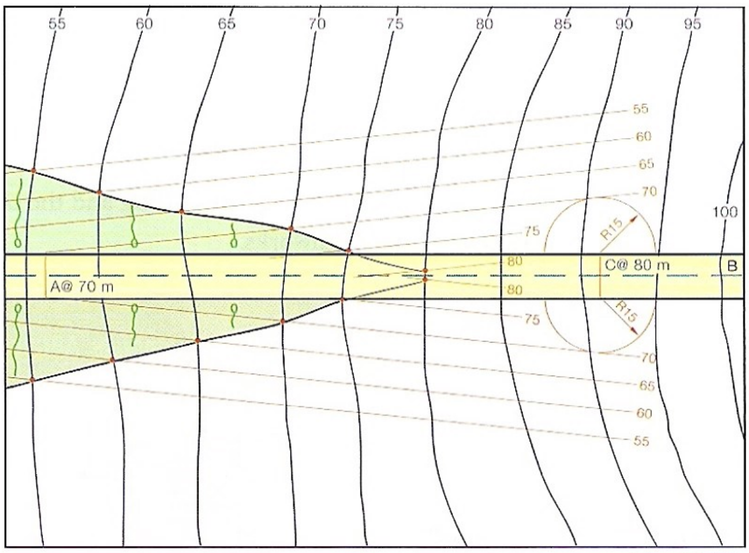


Fig. 19.40b

Fig. 19.41

Fig. 19.42

(5) Join the 70 m level on the side of the road as a tangent to the fill cone circle. This is a 70 m contour line along the embankment.

(6) Subsequent contour lines on the embankment will be parallel to this and 7.5 m apart on the map. Again, the figure of 7.5 m has been calculated from the fill ratio. The contours on the map are at 5 m intervals. To match these, the fill contours must be at 5 m intervals. A 5 m rise produces a 7.5 m horizontal spacing.

(7) Where the corresponding fill contours and map contours intersect gives points on the embankment edge.

(8) Note how the embankment point on the 80 m contour line was found to help locate the exact point where the fill edge hit the road.

Moving out from the side of the road, we move down the bank and the fill contours must drop.

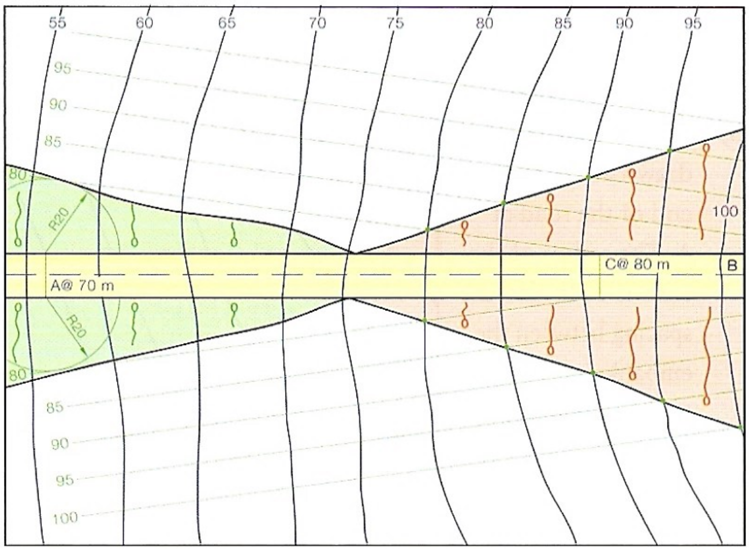


Fig. 19.43

HIGHER LEVEL

Cuttings

(9) The cutting cone is drawn at the low end of the formation. This cone will have a 20 m radius in plan. The 20 m is calculated by slotting the fall from C to A into the cutting ratio. 1:2 = 10:20

(10) Join the 80 m level at C as a tangent to the cut cone. This line forms the 80 m contour line on the cutting.

(11) Draw subsequent contour lines on the cutting parallel to this first line and 10 m apart.

1:2 = 5:10

Height between contours on map. / \ Width between cutting contours.

(12) Moving out from the road we move up the cutting and the cut contours must rise.

(13) Complete the outline of the earthworks.

Fig. 19.44a, shows ground contours at 5 m vertical intervals. ABC is the line of a proposed roadway. The road has the following specifications:

(i) Formation width is 12 m.

(ii) Formation level at A is 50 m.

(iii) Gradient A to B to C is 1 in 15 falling.

(iv) Side slopes for cutting 1 in 1.5.

(v) Side slopes for fill 1 in 1.

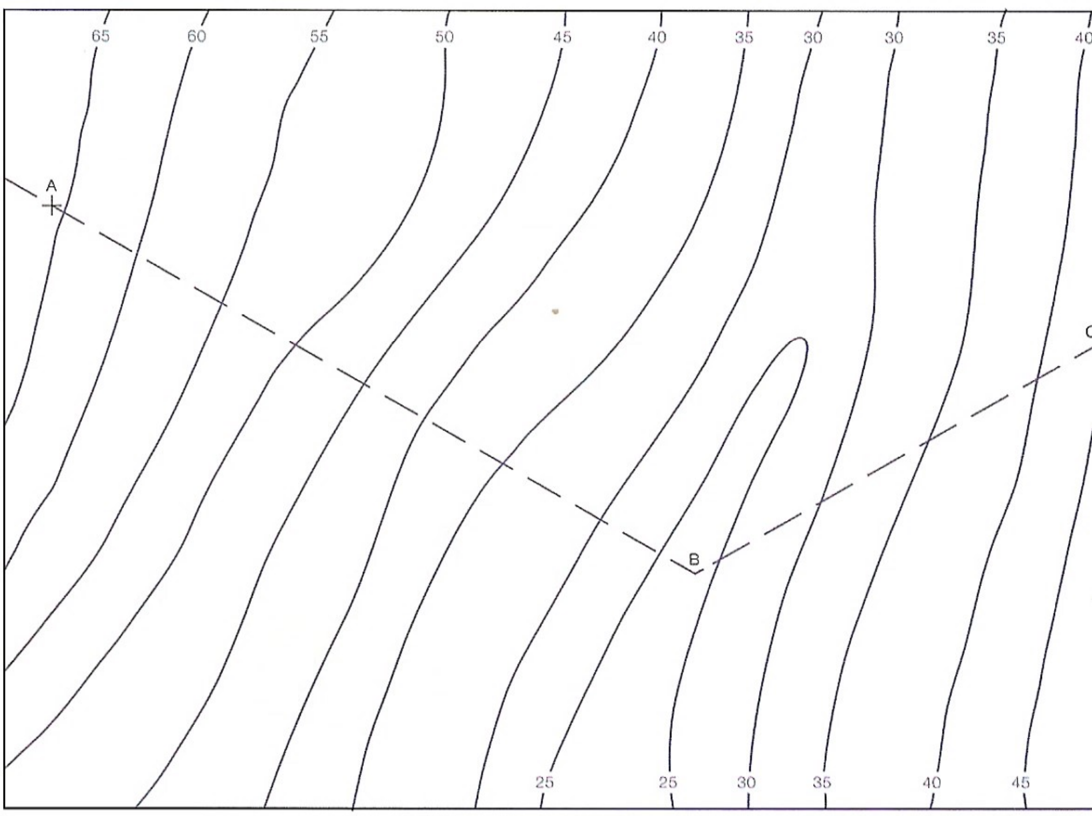
On the drawing, show the earthworks necessary to accommodate the road.

HIGHER LEVEL

(1) Draw in the formation sides 6 m each side of the centre line.

(2) The road is falling 1:15 from A to B to C. We ignore the bend in the road and treat the straight stretch A to B. If we travel from A, a distance of 150 m, we will locate point D and will have fallen in altitude by 10 m.

(3) The fill cone is drawn at the high end of the road at A. The radius of the cone is 10 m and the spacing between the embankment contours will be 5 m.



Scale 1:1,0

Fig. 19.44

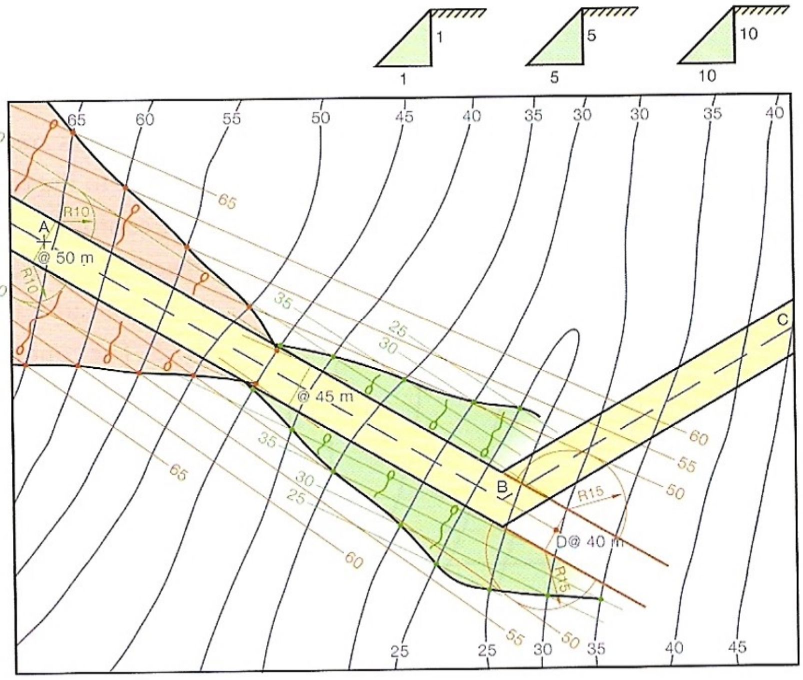


Fig. 19.44b

(4) The cut cone is always drawn at the lower end of the road. The cut cone will have a radius of 15 m and the spacing between the cutting contours will be 7.5 m.

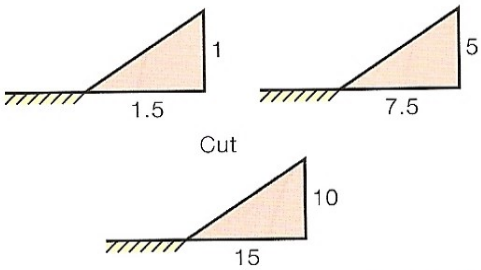


Fig. 19.44c

(5) Draw in the cut and fill for the first section of road A to D.

(6) Rotate point D about the corner O onto the other section of road. D is at an altitude of 40 m.

(7) Locate point E at an altitude of 45 m. D and E will be 75 m apart.

(8) Set up the cut and fill cones. The fill cone will be at the high end of the road, at E, and will have a radius of 5 m. The cutting cone will be at the lower end of the road and will have a radius of 7.5 m. Both of these are calculated from the cut and fill ratios.

Altitude difference between D + E = 5 m

Fill 1:1 = 5:5

Cut 1:1.5 = 5:7.5

(9) Complete the earthworks.

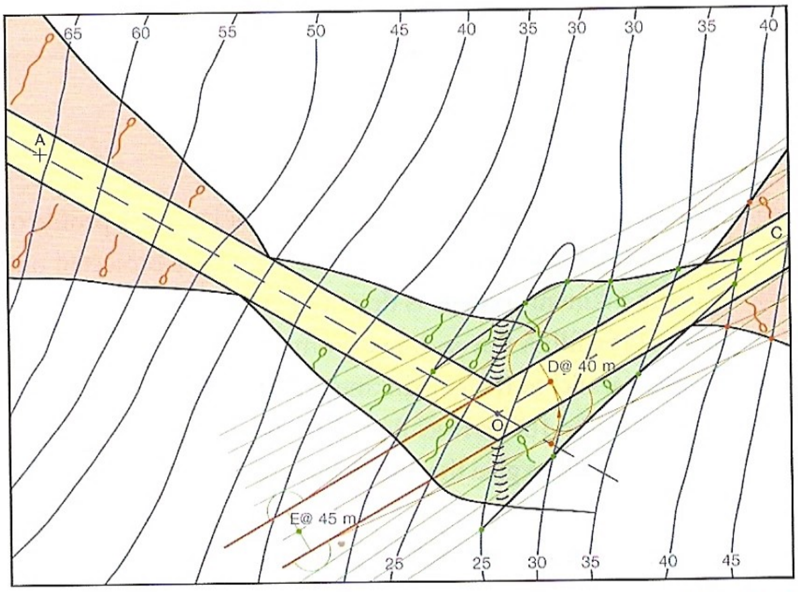


Fig. 19.45

Fig. 19.46a shows ground contours at 5 m vertical intervals. ABC is a roadway which widens onto a car parking area on one side. The road has the following specifications:

- **(i) Formation width 12 m.**
- **(ii) Formation level at A is 100 m.**
- **(iii) A to B is level, B to C is 1 in 10 rising.**
- **(iv) Side slopes for cutting 1 in 1.5.**
- **(v) Side slopes for embankments 1 in 1.**

On the drawing show the earthworks necessary to accommodate the road and car park.

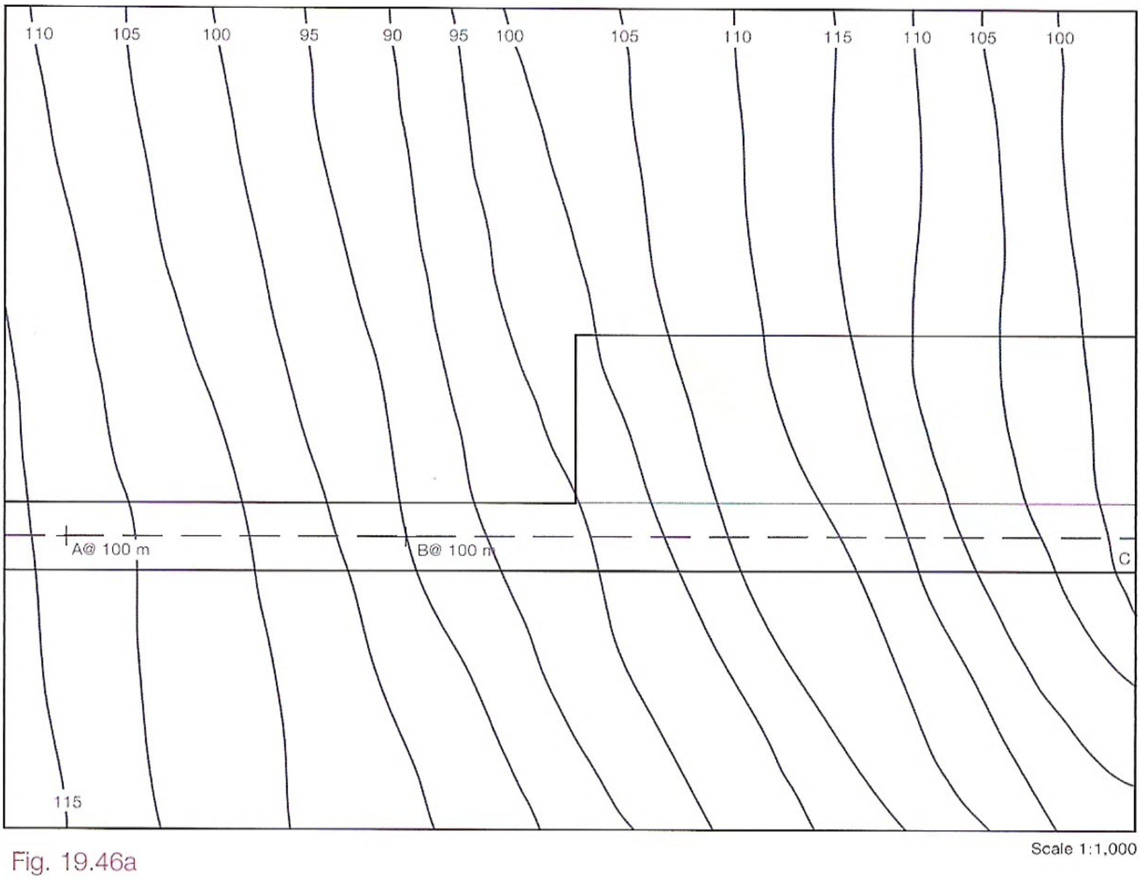


Fig. 19.46a

(1) A to B is level at 100 m. For level roads the cut and fill contours are parallel to the road. The contour spacing for the cut is 7.5 m. Cut 1:1.5 = 5:7.5. The contour spacing for the embankment is 5 m. Fill 1:1 = 5:5.

(2) The side of the car park, st, will also be level. By looking at the levels it can be seen that fill will be required. The difficulty is that since B to C is rising 1:10, the level of edge st is not known.

(3) Measure 100 m from point B to locate D@110 m. A profile of the road and car park are taken between B and D. The gradient is drawn in and points s and t are projected onto the sloping line.

(4) An embankment triangle is drawn to show the slope of the fill. A line is drawn from st in the profile, parallel to the embankment slope. This line strikes the 100 m level lines. This is projected back to give the 100 m level on the fill.

(5) Other fill contour lines will be parallel to this and at 5 m spacings.

(6) All remaining sides of the formation are sloping. Set up the cut and fill cones at B and D. Fill cone at high end of formation and of radius 10 m. Cut cone at low end of formation and of radius 15 m. Spacing of contours 5 m for fill and 7.5 m for cut.

(7) Complete the earthworks as shown.

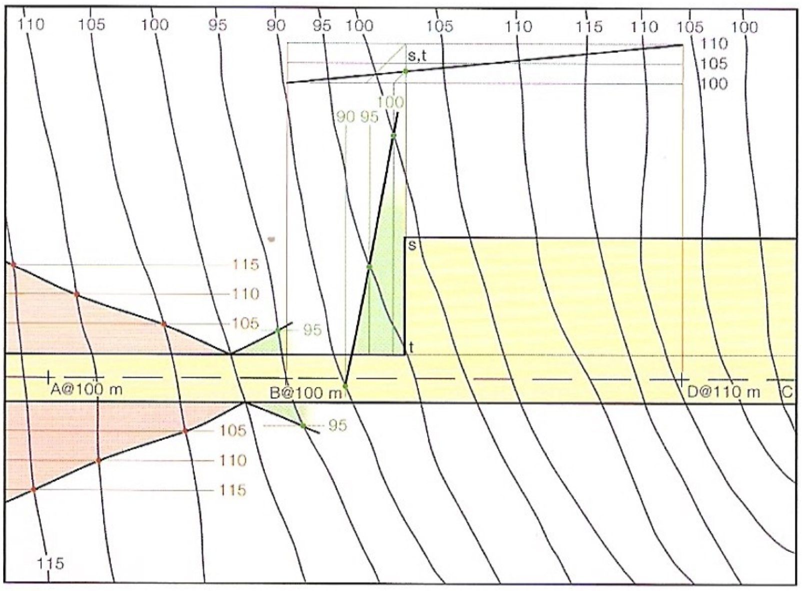


Fig. 19.46b