

Practical No-3

Design of Bench Terrace

Aim: Design of Bench Terrace

Theory:

Design basics

- Use simple arithmetic and a step-by-step approach to design.
- Design bench terraces such that the volumes of cut and fill are to be equal for minimizing construction cost.
- Design terraces according to the needs of farmers, crops, climate, and tools

to be used for farming

Design procedures and criteria

(1) Widths of Bench

In designing bench terraces, the width of the bench (flat part) needs to first be determined by the farmers according to crop needs, tillage tools, as well as their individual preferences. Field technicians or extension officers need to check soil depths and inform farmers that wide benches require deep soils and higher construction costs. Experience has shown that for hand cultivation 2.5 m to 5 m wide are appropriate widths whereas for mechanization 3.5 m to 8 m are proper where depth of soil does not constitute a limit.

(2) Slopes

Slopes can be measured by using a hand level or a clinometer. In design of terraces, a representative slope or a mode slope should be obtained from the field.

If the farmer will build terraces by hand, the appropriate slope range is from 7 degrees to 25 degrees (or 12.3% to 46.6%). If machines will be used for construction, the range is from 7 degrees to 20 degrees (or 12.3% to 36.4%) according to past experience. Slopes gentler than 7 degrees may best use simple conservation measures or agronomic measures. Using machines on a slope over 20 degrees is unsafe.

(3) Vertical Intervals

After the slope and the width are determined, the Vertical Interval (*VI*) can be calculated by a simple equation. *VI* is the elevation difference between two succeeding terraces. It is essential to calculate the *VI*; it not only shows roughly the height of future terraces but also provides the basis for further designing. The simple equation using slope and the width of the bench as the main inputs is as follows:

$$VI = (S \times Wb) / (100 - S \times U) \quad (1)$$

Where S is land slope in percent (%), Wb is the width of the bench, and U is the slope of the terrace riser or side slope. Use a horizontal to vertical ratio to put into the equation such as 1 for machine-built terraces, 0.75 for hand-made terraces, and 0.5 for stone terraces.

RELATIONSHIP BETWEEN LEVEL TERRACES
AND REVERSED SLOPED TERRACES

— To show VI does not change —

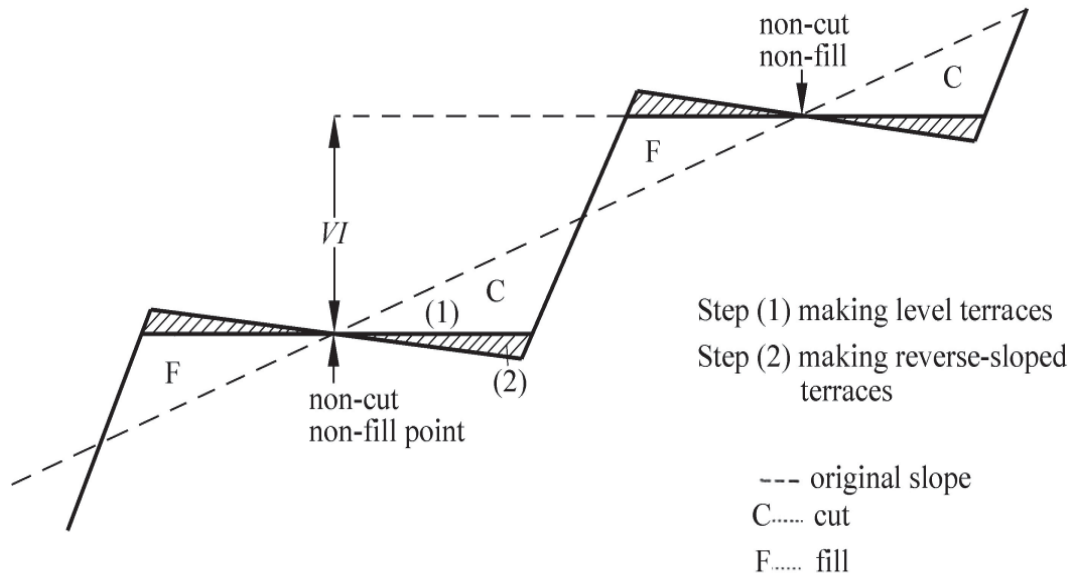


Fig.3.1

Same vertical interval (VI) between level and reverse sloped bench

Fig.1 Shows that VI does not change between level and reverse sloped terraces. For outward sloped type, the VI is also the same.

(4) Heights of Riser

After VI is obtained it is easy to figure out the height of riser of the terraces. For level terrace, VI equals the height of the riser. For rice paddies, a 15 cm dike may be added to the VI to get the total height. For reverse sloped terraces, the VI needs to add a reverse height to get the total height. The reverse height can be easily calculated by the following equation:

$$RH = Wb \cdot 0.05 \tag{3}$$

Where RH is reverse height, Wb is width of bench, 5% is the reverse slope. A five percent (5%) reverse slope is sufficient to keep runoff away from the riser and it does not interfere with farming operation. The height of riser (Hr) of reverse sloped terraces can therefore be obtained using the following equation:

$$Hr = VI + RH \quad (4)$$

Experience shows that the overall height of a riser should not exceed 1.8 m to 2 m; above that the maintenance work will become difficult.

(5) Widths of Terraces

The width of a terrace can be obtained by adding the width of the bench (Wb) to the width of the riser (Wr). Wr is calculated by multiplying the height of the riser to a riser slope (U) which has been explained in Equation (1).

$$Wr = Hr U \quad (5)$$

Where Wr is the width of the riser, Hr is the height of the riser, and U is the slope of riser giving value 1 for machine-built terrace, 0.75 for handmade terrace, and 0.5 for stone made terrace. The total width of a terrace (Wt) is obtained as shown below:

$$Wt = Wr + Wb \quad (6)$$

(6) Lengths of Terraces

The length of a terrace is limited by the size and shape of the field and the degree of land dissection. Longer terraces will increase farming operation efficiency especially using machines for cultivation. However, too great a length in one direction in the case for drainage may cause accelerated runoff velocity and erosion. Based on past experience, 100 m in one inclined direction or 200 m in total is recommended for reverse sloped or drainage type terraces. The gradient for drainage is 0.5 % to 1 % according to soils and rainfall. Leaner length (L), expressed in meters (m) in a hectare (ha), can be calculated as follows:

$$L = 10,000 / Wt \quad (7)$$

Where Wt is the width of terrace which has been explained previously.

(7) Net Area

Farmers are interested in knowing the net area for cultivation when terraces are to be built. The net area (NA) in a hectare (ha) can be obtained easily by multiplying leaner length (L) to the width of the bench (Wb):

$$NA = L Wb \quad (8)$$

Consequently, the percent of net area or percent of benches (Pb) in a ha can thus be obtained, as follows

$$Pb(\%) = NA / 10,000 \cdot 100 \quad (9)$$

It is important to know that on the same slope, the percent of bench or net area does not change regardless the width of the bench. In other words, building a wide bench or a narrow bench will get same percentage or flat area for cultivation, though too narrow a terrace will be impractical whereas too wide a terrace will need to cut deeper and cost more.

(8) Volumes to be Cut and Filled

To build bench terraces, as mentioned previously, the volume of soil to be cut and filled has to be equal in order to minimize the cost. There should be no extra volume of soil to be disposed of or borrowed from other places. Therefore, when we calculate volumes, we need only to consider one volume (cut volume) that will eventually be moved down slope to form a terrace (See Fig. 1). Volumes can usually be obtained by multiplying an area to a length. In our case, the area is a triangle or the cross-section of the cut part (C). Therefore, multiplying C by the linear length, L, will obtain the volume. For level terraces, the equation for the cross-section (C) is simply as follows:

$$C = (Wb VI) / 8 \quad (10)$$

In case a small dike is needed, cross-section of the dike must be added to the above equation. For reverse sloped terraces, the cut and fill are more and its equation is shown below:

$$C = (Wb Hr) / 8 \quad (11)$$

The following figure (Fig. 2) shows the calculation of the cross-section (C) of the reverse sloped terraces.

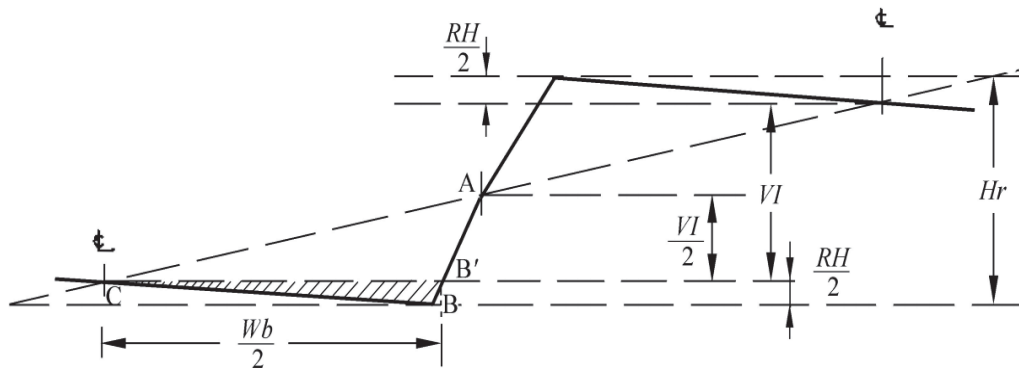


Fig 3.2

$$ABC = AB'C + B'BC$$

$$\begin{aligned}
& \frac{Wb}{2} \times \frac{VI}{2} + \frac{Wb}{2} \times \frac{RH}{2} \\
= & \frac{2}{2} + \frac{2}{2} \\
& \frac{Wb \times VI}{4} + \frac{Wb \times RH}{4} \\
= & \frac{4}{2} \\
& \frac{(Wb \times VI) + (Wb \times RH)}{4} \\
= & \frac{4}{2} \\
& \frac{(Wb \times VI) + (Wb \times RH)}{8} \\
= & \frac{Wb(VI + RH)}{8} \\
= & \frac{Wb \times Hr}{8}
\end{aligned}$$

Fig.3.2 Computation of cross-sectional area of reverse sloped bench terraces

After the cross-section, C , is obtained, the volume to be cut and filled in a ha can be quickly calculated:

$$V = C L \quad (12)$$

Where V is the volume, C is the cross-section, and L is the linear length per ha.

(9) Depths of Cut

To find out depth of cut is essential. It is needed to compare with the soil depth measured in the field. If the measured depth is insufficient, then the width of the bench needs to be reduced to fit the depth on site (Sheng, 2000). The following equations are used to calculate the depth of cut for level terraces (Eq.13) and reverse sloped terraces (Eq.14) respectively. All the abbreviations have been explained previously.

$$(Wb/2) (S/100) \quad (13)$$

$$(Wb/2) (S/100) + RH/2 \quad (14)$$

NUMERICAL

Question:

In a hilly region bench terracing work is proposed for cultivation purpose. The general land slope is 30%. Average soil depth is about 1.0m. riser is to be laid on 1:1 gradient. The critical length of terrace is equal to 125m. compute the following

i) Earthwork per ha and its cost @Rs. 2.5 per m^3

ii) Number of outlets

iii) Total cost of bench terracing including outlet and sodding