Lec. 24

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CE 371 Surveying

VOLUME CALCULATIONS

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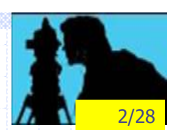

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Overview

- Purposes of Volume Computations
- Methods of Volume Computations
- Regular objects
- Cross-section method
- Borrow- pit method
- Contour-area method

Purposes of Volume Computations

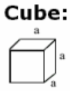
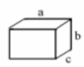
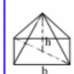
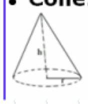
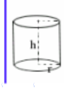
1. Determining volumes of earthwork (volume of cut and fill).
2. Determining the capacity of reservoirs and buildings.
3. Determining volumes of stockpiles of coal, gravel, and other materials.
4. Determining quantities of water discharged by rivers per unit time.

Methods of Volume Computations

Volumes are computed indirectly using measured lines and areas. Different methods of computing volumes will be presented here:

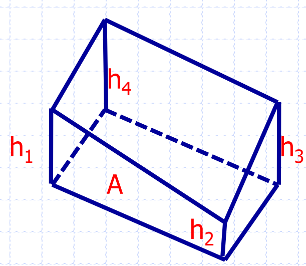
1. Regular objects
2. Cross-section method
   1. Average-end-area method.
   2. Prismoidal method.
3. Borrow- pit method (Unit-area method)
4. Contour-area method

Regular objects

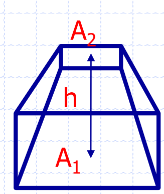
• **Cube:**  Volume = a^3	• **Sphere:**  Volume = (4/3) × pi × r^3
• **Rectangular Prism:**  Volume = a × b × c	• **Pyramid:**  Volume = (1/3) × b × h
• **Cone:**  Volume = (1/3) × pi × r^2 × h	• **Cylinder:**  Volume = pi × r^2 × h

Regular objects

- Irregular prism



- Frustum of pyramid

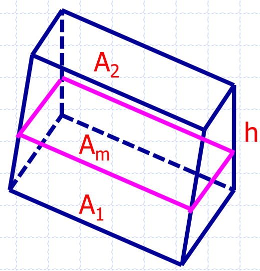


- $v = A(h_1+h_2+h_3+h_4)/4$
- A= base area

$V = 1/3\, h\, (A_1+A_2+\sqrt{A_1A_2})$

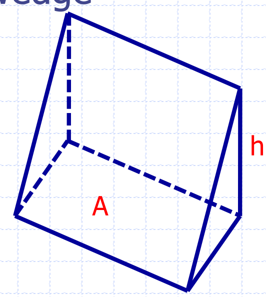
Regular objects

- Prismoidal



- $V = 1/6\ h\ (A_1 + A_2 + 4A_m)$
- $A_m \neq (A_1 + A_2)/2$

- Wedge

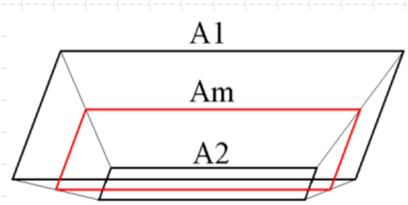


- $V = 1/2\ A\ h$

example

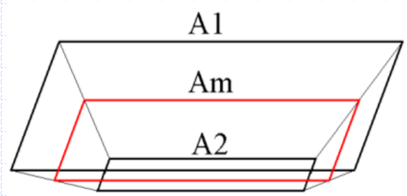
Compute the volume of water tank excavated in flat area of elevation 18 m, the top cross section is 50 x 20 m and the bottom cross section is 30 x 5 m. the elevation of the tank bottom is 10 m.

- Prismoidal rule
- $A_1 = 50 \times 20 = 1000\ m^2$
- $A_2 = 30 \times 5 = 150\ m^2$
- $A_m = (50+30)/2 \times (20+5)/2$
- $A_m = 40 \times 12.5 = 500\ m^2$
- $h = 18 - 10 = 8\ m$
- $\text{Volume} = 8/6 \times (1000+150+4 \times 500) = 4200\ m^3$



example

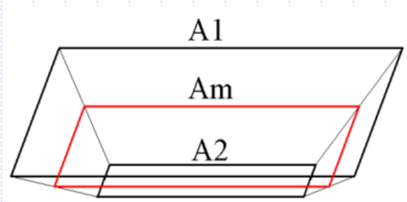
- Frustum of pyramid



- $A_1 = 50x20 = 1000\ m^2$
- $A_2 = 30x5 = 150\ m^2$
- $h = 18-10 = 8\ m$
- Volume $= 8/3\ x(1000+150+\sqrt{1000x150}) = 4099.46\ m^3$

example

- Average end area

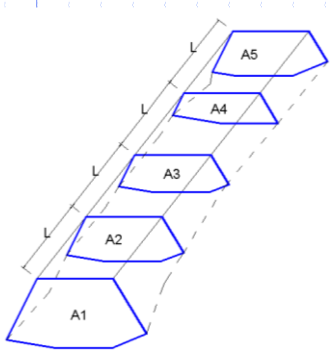


- $A_1 = 50x20 = 1000\ m^2$
- $A_2 = 30x5 = 150\ m^2$
- $h = 18-10 = 8\ m$
- Volume $= 8/2\ x(1000+150) = 4600\ m^3$

Cross-section method

- This method is mostly employed in highway design and construction.
- Two rules can be used
  - Average end area rule
  - Prismoidal rule

Average end area

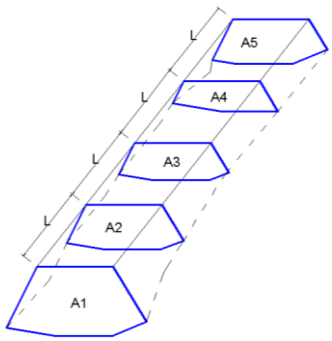


- Volume between every two sections=
- $L/2\ (A_1+A_2)$
- Volume for n number of sections

- $L/2\ \{(A_1+A_{n+1})+2(A_2+A_3+.....+A_n)\}$

Example

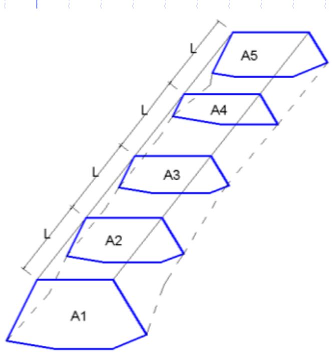
- Compute the volume from the following cross sections
- L=30 m



Cross sec.	Area (m^2)
A1	120.23
A2	98.56
A3	92.78
A4	76.46
A5	105.37

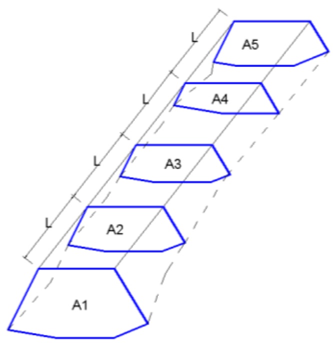
- Volume= 30/2{(120.23+105.37) +2(98.56+92.78+76.46)}
- Volume= 15 x(225.6 + 535.6) = 11418 m^3

Prismoidal rule (for even number of spaces)



- Volume between every 3 sections
- $L/3\ (A_1 + 4A_2 + A_3)$
- Volume for n number of sections
- $L/3\ \{(A_1+A_{n+1})+2(\Sigma A_{odd}) + 4(\Sigma A_{even})\}$

Example



- Compute the volume from the following cross sections
- L=30 m

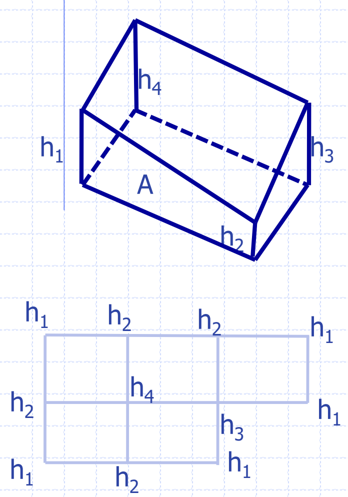
Cross sec.	Area (m^2)
A1	120.23
A2	98.56
A3	92.78
A4	76.46
A5	105.37

- Volume= 30/3{(120.23+105.37) +2(92.78) +4(98.56+76.46)}
- Volume= 10 x(225.6 + 185.56 + 700.08) = 11112.4 m^3

Borrow- pit method

- This method is mostly used in borrow-bit leveling to compute volumes of earth, gravel, or other material excavated or filled on a construction project.

Borrow- pit method

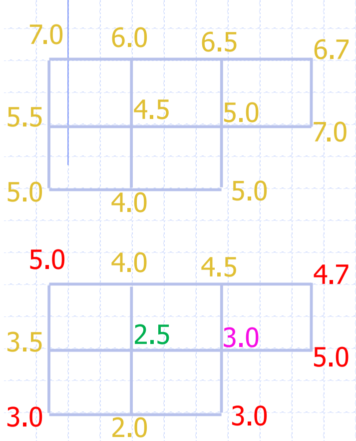


- volume= A $(h_1+h_2+h_3+h_4)/4$
- A= unit area
- In case of the full area is cut or fill

- $V = A/4(\Sigma h_1+2\Sigma h_2+3\Sigma h_3+4\Sigma h_4)$
- h_1 : heights used once
- h_2: heights used two times
- h_3: heights used three times
- h_4: heights used four times

Example

h1	h2	h3	h4
5.0	4.0	3.0	2.5
4.7	4.5		
5.0	2.0		
3.0	3.5		
3.0			
20.7	14	3.0	2.5



- Compute earthwork volume to level the shown area to +2 m. cell size 30 m.

- Compute cut height at each point

- V= (30x30)/4 x(20.7 +2x14 +3x3 + 4x2.5)
- V= 225 x 67.7 = 15232.5 m^3

Four Corner Method

$$L = \text{Grid Interval}$$

$$H_{CUT} = \sum \text{of Heigths of CUT at Corners}$$

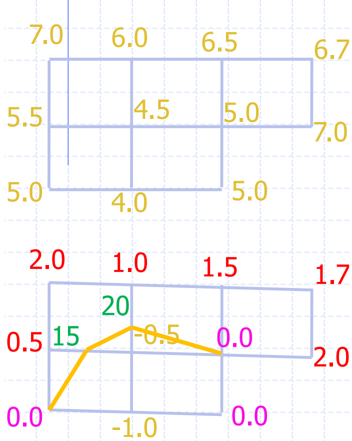
$$H_{FILL} = \sum \text{of Heights of FILL at Corners}$$

$$V_{CUT} = \frac{L^2 \times H_{CUT}^2}{4 \times \left(H_{CUT} + H_{FILL} \right)}$$

$$V_{FILL} = \frac{L^2 \times H_{FILL}^2}{4 \times \left(H_{CUT} + H_{FILL} \right)}$$

Four corner

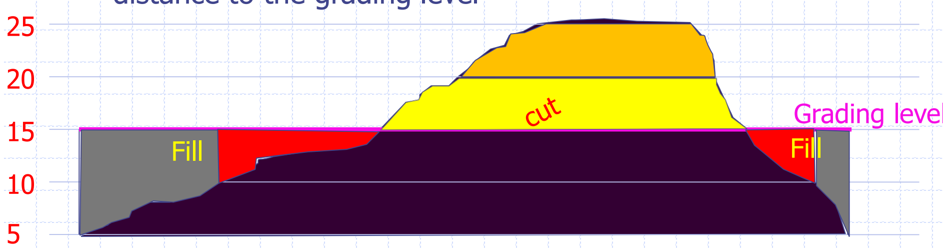
- Compute earthwork volume to level the shown area to +5 m. cell size 30 m.
- Compute heights of cut and fill



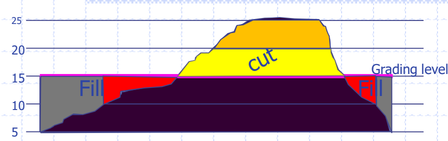
Cell	H_{cut}	H_{Fill}	V_{cut}	V_{Fill}
1	5.2	0	1170	0
2	2.5	0.5	468.75	18.75
3	3.5	0.5	689.06	14.06
4	0.5	1.5	28.13	253.13
5	0	1.5	0	337.5
Σ			2355.94	623.44

Contour-area method

- Volumes can be obtained from contour maps by measuring the area enclosed within each contour then
- Compute volume between each successive contour lines, then the sum.
- V_{cut}= average of two contours areas x contour interval
- V_{fill} = difference between two contours areas x average distance to the grading level



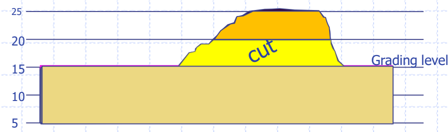
example



- The area of contour lines were as follows
- C_{25}= 100 m^2, C_{20} =150 m^2, C_{15}= 210 m^2, C_{10}= 320 m^2, C_5=450 m^2
- Compute cut and fill to grad the area at 15 m
- solution
- Cut = (100+150)/2 x 5 + (150+210)/2 x 5
- = 625 + 900 = 1525 m^3

- Fill = (320-210) x (5+0)/2 + (450-320) x (10+5)/2
- = 275 + 975 = 1250 m^3

Example 2



Compute the volume of a cylinder that contains the fill area and subtract the earth's volume from it

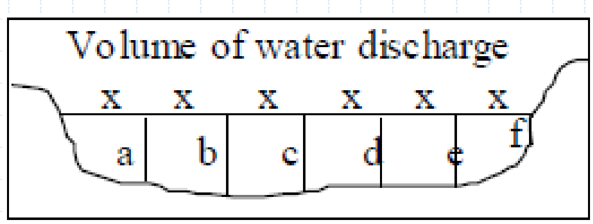
- The former example
-
- Cut = (100+150)/2 x 5 + (150+210)/2 x 5
- = 625 + 900 = 1525 m^3
- Fill
- Cylinder= 450 x 10 = 4500 m^3

Mass= (320+210)/2 x 5 + (450+320)/2 x 5 = 3250 m^3

Fill = = 4500 - 3250 = 1250 m^3

Volume of Water Discharge

- Volumes of water discharge in streams and rivers are determined as follows:
- 1)Divide the stream cross-section into equally spaced vertical sections **x.**
- 2)Measure depth of cross-sections (a, b, c, d, e, and f) by a graduated rod or by a sounding device called "Fathometer".



Volume of Water Discharge

- 3)Measure current velocity for each vertical section using a current meter device at 0.2 and 0.8 of the depth. For example: $\mathbf{vel_{0.2b}}$ and $\mathbf{vel_{0.8b}}$ at the depth 0.2b and 0.8b of section b.
- 4)Compute average of the two velocities at each section. For section b:

$$Average\ current\ velocity\ at\ b = vel_b = \frac{1}{2}(vel_{0.2b} + vel_{0.8b})$$

- Compute volume of water discharge at each section. For section b:

$$Volume\ of\ water\ at\ b = V_b = vel_b \cdot b \cdot x$$

- Compute total volume **V** of water discharge by summing volumes of all **n** sections, or:

$$Total\ volume\ V = x[(a \cdot vel_a) + (b \cdot vel_b) + \cdots + (n \cdot vel_n)]$$

example

- Example:
- (a) Compute the total cross-sectional area shown in the figure above if x =10.0 m, a=3.0 m, b=4.0 m, c=5.0 m, d=4.5 m, e=3.5 m, and f=1.0m.
- (b) Compute the total volume discharge if at each section measured current velocities (meter/sec) at 0.2 and 0.8 depths are as follows: a=(2.7,1.7),b=(2.9,1.8), c=(3.1,1.9), d=(2.9,1.7), e=(2.6,1.5), and f=(2.0,1.0).

- **Solution:**
- Total Area= 10/2[(0+1) +2x(3.0 + 4.0 + 5.0 + 4.5 + 3.5)] = 205 m2
- vel_a =(2.7+1.7)/2 = 2.2 m/sec,
- vel_b=(2.9+1.8)/2 = 2.4 m/sec,
- vel_c=(3.1+1.9)/2 = 2.5 m/sec,
- vel_d=(2.9+1.7)/2 = 2.3 m/sec,
- vel_e=(2.6+1.5)/2 = 2.1 m/sec,
- vel_f=(2.0+1.0)/2 = 1.5 m/sec.
- V = 10[3(2.2)+4(2.4)+5(2.5)+4.5(2.3)+3.5(2.1)+1(1.5)] = 479 m3/sec
- Total volume of water discharged per second V = 479 m3/sec.

Summary

- Purposes of Volume Computations
- Methods of Volume Computations
- Regular objects
- Cross-section method
- Borrow- pit method
- Contour-area method