TOPIC 7

Highway Location, Geometrics, & Drainage

TOPIC 7

Part 1

Highway Location

Introduction

Highway Location

- ❖ Selecting the location of a proposed highway is an important initial step in its design.
- ❖ It involves the acquisition of data concerning the terrain upon which the road will traverse and the economical siting of an alignment.
- ❖ Factors considered include:
  - earthworks,
  - geologic conditions, and
  - and land use
- ❖ The decision to select a particular location is usually based on:
  1. topography,
  2. soil characteristics,
  3. environmental factors such as noise and air pollution, and
  4. economic factors.
- ❖ The result of the economic evaluation aids in the decision to accept or reject that location

Principles of Highway Location

- The basic principle for locating highways is that roadway elements such as curvature and grade must blend with each other to produce a system that provides for the easy flow of traffic at the design capacity, while meeting design criteria and safety standards.
- The highway should also cause a minimal disruption to historic and archeological sites and to other land-use activities.
- Environmental impact studies are therefore required in most cases before a highway location is finally agreed upon.
- The highway location process involves four phases:
  1. Office study of existing information
  2. Reconnaissance survey
  3. Preliminary location survey
  4. Final location survey

Principles of Highway Location

Office study of existing information

- Involves examination of all available data of the area in which the road is to be constructed.
- Available data are collected and examined.
- These data can be obtained from existing engineering reports, maps, aerial photographs, and charts, which are usually available at one or more of the state's departments of transportation, agriculture, geology, hydrology, and mining.
- Data should be obtained on the following characteristics of the area:
  - Engineering - topography, geology, climate, and traffic volumes
  - Social and demographic - land use and zoning patterns
  - Environmental - types of wildlife; location of recreational, historic, and archeological sites; and the possible effects of air, noise, and water pollution
  - Economic - unit costs for construction and the trend of agricultural, commercial, and industrial activities

Principles of Highway Location

- Preliminary analysis of the data obtained will indicate whether any of the specific sites should be excluded from further consideration because of one or more of the above characteristics.
- For example, if it is found that a site of historic and archeological importance is located within an area being considered for possible route location, it may be immediately decided that any route that traverses that site should be excluded from further consideration.
- At the completion of this phase of the study, the engineer will be able to select general areas through which the highway can traverse.

Principles of Highway Location

Reconnaissance Survey

- ❖ Identifies several feasible routes, each within a band of a limited width of a few hundred feet
- ❖ When rural roads are being considered, there is often little information available on maps or photographs
- ❖ Therefore aerial photography is widely used to obtain the required information. Feasible routes are identified by a stereoscopic examination of the aerial photographs, taking into consideration factors such as: terrain and soil conditions, serviceability of route to industrial and population areas crossing of other transportation facilities, such as rivers, railroads, and highways directness of route.
- ❖ Control points between the two endpoints are determined for each feasible route.
- ❖ For example, a unique bridge site with no alternative may be taken as a primary control point.
- ❖ The feasible routes identified are then plotted on photographic base maps.

Principles of Highway Location

Preliminary Location Survey

- ❖ In this study, the positions of the feasible routes are set as closely as possible by establishing all the control points and determining preliminary vertical and horizontal alignments for each.
- ❖ Preliminary alignments are used to evaluate the economic and environmental feasibility of the alternative routes.
- ❖ **Economic evaluation** of each alternative route is carried out to determine the future effect of investing the resources necessary to construct the highway
- ❖ Environmental Evaluation considers the impact of the highway on its surroundings.
- ❖ This environment includes plant, animal, and human communities and encompasses social, physical, natural, and man-made variables
- ❖ It is therefore essential that the environmental impact of any alignment selected be fully evaluated

Principles of Highway Location

Preliminary Location Survey

- Governments have enacted laws that set forth the requirements of the environmental evaluation required for different types of projects.
- Generally, environmental impact statements for many projects should include:
  - A detailed description of alternatives
  - The probable environmental impact, including the assessment of positive and negative effects
  - An analysis of short-term impact as differentiated from long-term impact
  - Any secondary effects, which may be in the form of changes in the patterns of social and economic activities
  - Probable adverse environmental effects that cannot be avoided if the project is constructed
  - Any irreversible and irretrievable resources that have been committed

Principles of Highway Location

Preliminary Location Survey

- In cases where an environmental impact study is required, it is conducted at this stage to determine the environmental impact of each alternative route.
- Such a study will determine the negative and/or positive effects the highway facility will have on the environment.
- For example, the construction of a freeway at grade through an urban area may result in an unacceptable noise level for the residents of the area (negative impact), or the highway facility may be located so that it provides better access to jobs and recreation centers (positive impact). Public hearings are also held at this stage to provide an opportunity for constituents to give their views on the positive and negative impacts of the proposed alternatives.
- The best alternative, based on all the factors considered, is then selected as the preliminary alignment of the highway.

Principles of Highway Location

Final Location Survey

- ❖ The final location survey is a detailed layout of the selected route.
- ❖ The horizontal and vertical alignments are determined, and the positions of structures and drainage channels are located
- ❖ The method used is to set out the points of intersections (PI) of the straight portions of the highway and fit a suitable horizontal curve between these
- ❖ This is usually a trial-and-error process until, in the designer's opinion, the best alignment is obtained, taking both engineering and aesthetic factors into consideration
- ❖ Splines and curve templates are available that can be used in this process
- ❖ The availability of computer-based techniques has significantly enhanced this process since a proposed highway can be displayed on a monitor, enabling the designer to have a driver's eye view of both the horizontal and vertical alignments of the road
- ❖ Detailed design of the vertical and horizontal alignments is then carried out to obtain both the deflection angles for horizontal curves and the cuts or fills for vertical curves and straight sections of the highway

Principles of Highway Location

Special Considerations

1. **Location of Recreational and Scenic Routes**
   - ❖ Follow the same steps as discussed earlier, but the designer of these types of roads must be aware of their primary purpose
   - ❖ For example, although it is essential for freeways and arterial routes to be as direct as possible, a circuitous alignment may be desirable for recreational and scenic routes to provide access to recreational sites (such as lakes or campsites) or to provide special scenic views.
   - ❖ The designer must realize, however, the importance of adopting adequate design standards
   - ❖ Design speeds are usually low, and therefore special provisions should be made to discourage fast driving, for example, by providing a narrower lane width

Principles of Highway Location

Special Considerations

2. Location of Highways in Urban Areas

- Urban areas usually present complex conditions that must be considered in the highway location process
- In addition to factors discussed, other factors that significantly influence the location of highways in urban areas include:
  - Connection to local streets
  - Right-of-way acquisition
  - Coordination of the highway system with other transportation systems
  - Adequate provisions for pedestrians

Principles of Highway Location

Special Considerations

3. Principles of Bridge Location

- ❖ The basic principle for locating highway bridges is that the highway location should determine the bridge location, not the reverse.
- ❖ When the bridge is located first, in most cases the resulting highway alignment is not the best
- ❖ When the waterway to be crossed requires a major bridge structure, however, it is necessary to first identify a narrow section of the waterway with suitable foundation conditions for the location of the bridge and then determine acceptable highway alignments that cross the waterway at that section. This will significantly reduce the cost of bridge construction in many situations.

Highway Surveys Methods

- ❖ Highway surveys involve measuring and computing horizontal and vertical angles, vertical heights (elevations), and horizontal distances.
- ❖ The surveys are then used to prepare base maps with contour lines (that is, lines on a map connecting points that have the same elevation) and longitudinal cross-sections
- ❖ Highway surveying techniques have been revolutionized due to the rapid development of electronic equipment and computers.
- ❖ Surveying techniques can be grouped into three general categories:
  1. Ground surveys
  2. Remote sensing
  3. Computer graphics

Highway Surveys Methods

1. **Ground surveys**

- Ground surveys are the basic location technique for highways.
- The total station is used for measuring angles in both vertical and horizontal planes, distances, and changes in elevation through the use of trigonometric levels; the level is used for measuring changes in elevation only.
- A summary of ground survey equipment include:
  - The Total Station
  - The Level
  - Measuring Tapes

Highway Surveys Methods

Digital Survey Advancements

- Significant advancements in survey technology have been made in recent years that reflect the worldwide revolution in wireless and communications technology
- **Survey data collectors** are devices that connect to any survey instrument (total station) through a cable or Bluetooth and allows a surveyor to secure information digitally as illustrated in the figure.

Highway Surveys Methods

Digital Survey Advancements

- ❖ The data collector converts the survey instrument's raw data string into coordinates and elevations.
- ❖ The raw data string includes bearing, angle, distance, slope distance, zenith, and more.
- ❖ Each point stored on the data collector has an XYZ value that it calculates from the occupied location of the survey instrument.
- ❖ The data collector can then be attached to a desktop or laptop computer through IR, serial, or USB ports, and the information can then be processed into a CADD file.
- ❖ This allows for more accurate three-dimensional surfaces to be created. The triangulated surface created is called a TIN File (Triangulated Irregular Network).

Highway Surveys Methods

Digital Survey Advancements

- **The Global Positioning System** (GPS) is a satellite-based system that uses a constellation of 28 satellites to give a user an accurate position
- GPS surveying is an evolving technology that was originally designed for military use at any time anywhere on the surface of the earth
- The first two major civilian applications to emerge were in marine navigation and surveying.
- Now applications include in-car navigation, truck fleet management, and automation of construction machinery.
- Accuracy expectations range from sub-centimeter with static surveys to plus or minus 2 cm using Real-Time Kinematic (RTK) methods

Highway Surveys Methods

2. Remote sensing

- ❖ Remote sensing is the measurement of distances and elevations by using devices located above the earth, such as airplanes or orbiting satellites using Global Positioning Satellite systems (GPS)
- ❖ The most commonly used remote-sensing method is photogrammetry, which utilizes aerial photography.
- ❖ Photogrammetry is the science of obtaining accurate and reliable information through measurements and interpretation of photographs, displaying this information in digital form and/or map form.
- ❖ This process is fast and economical for large projects but can be very expensive for small projects.
- ❖ Difficulties will arise when it is used for terrain with areas of thick forest, Areas that contain deep canyons or tall buildings, and areas that photograph as uniform shades, such as plains and some deserts

Highway Surveys Methods

3. Computer Graphics

- ❖ Computer graphics, when used for highway location, is usually the combination of photogrammetry and computer techniques.
- ❖ With the use of mapping software, line styles, and feature tables, objects and photographic features can be recorded digitally and stored in a computer file.
- ❖ This file can then either be plotted out in map form or sent on to the design unit

Highway Earthworks And Final Plans

- ❖ The final element in the location process is to establish the horizontal and vertical alignments of the highway project and to prepare highway plans and specifications for estimating project costs and preparation of bids by contractors
- ❖ The final result of the location process is a highway plan used in estimating quantities and computing the overall project cost.

Highway Grades and Terrain

- ❖ One factor that significantly influences the selection of a highway location is the terrain of the land, which in turn affects the laying of the **grade line**
- ❖ The primary factor that the designer considers on laying the grade line is the amount of earthwork that will be necessary for the selected grade line
- ❖ One method to reduce the amount of earthwork is to set the grade line as closely as possible to the natural ground level
- ❖ This is not always possible, especially in undulating or hilly terrain. The least overall cost also may be obtained if the grade line is set such that there is a balance between the excavated volume and the volume of embankment

Highway Earthworks And Final Plans

Highway Grades and Terrain

- ❖ Another factor that should be considered in laying the grade line is the existence of fixed points, such as railway crossings, intersections with other highways, and in some cases existing bridges, which require that the grade be set to meet them.
- ❖ When the route traverses flat or swampy areas, the grade line must be set high enough above the water level to facilitate proper drainage and to provide adequate cover to the natural soil.
- ❖ The height of the grade line is usually dictated by the expected floodwater level. Grade lines should also be set such that the minimum sight distance requirements are obtained.
- ❖ The amount of earthwork associated with any grade line influences the decision on whether the grade line should be accepted or rejected

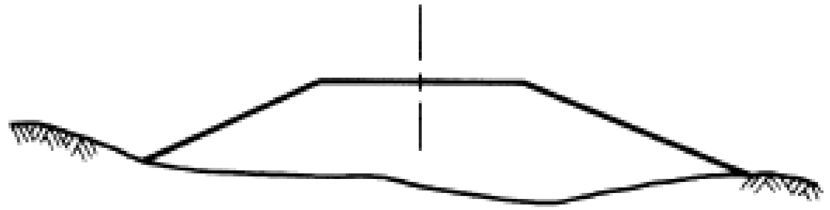
Highway Earthworks And Final Plans

Computing Earthwork Volumes

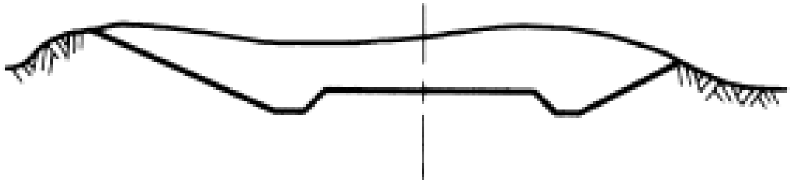
- ❖ One of the major objectives in selecting a particular location for a highway is to minimize the amount of earthwork required for the project.
- ❖ Therefore, the estimation of the amount of earthwork involved for each alternative location is required at both the preliminary and final stages.
- ❖ To determine the amount of earthwork involved for a given grade line, cross sections are taken at regular intervals along the grade line. The cross sections are usually spaced 15 m apart, although this distance is sometimes increased for preliminary engineering.
- ❖ These cross sections are obtained by plotting the natural ground levels and proposed grade profile of the highway along a line perpendicular to the grade line to indicate areas of excavation and areas of fill

Highway Earthworks And Final Plans

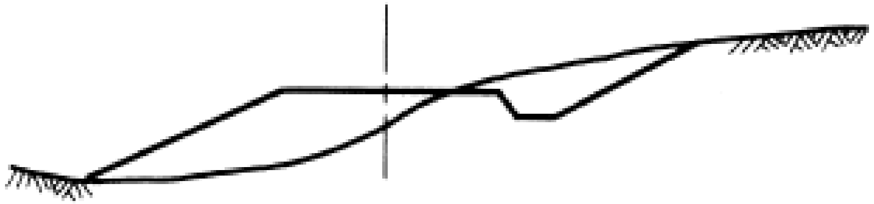
- **Computing Earthwork Volumes**



(a) Fill



(b) Cut



(c) Fill and cut

Highway Earthworks And Final Plans

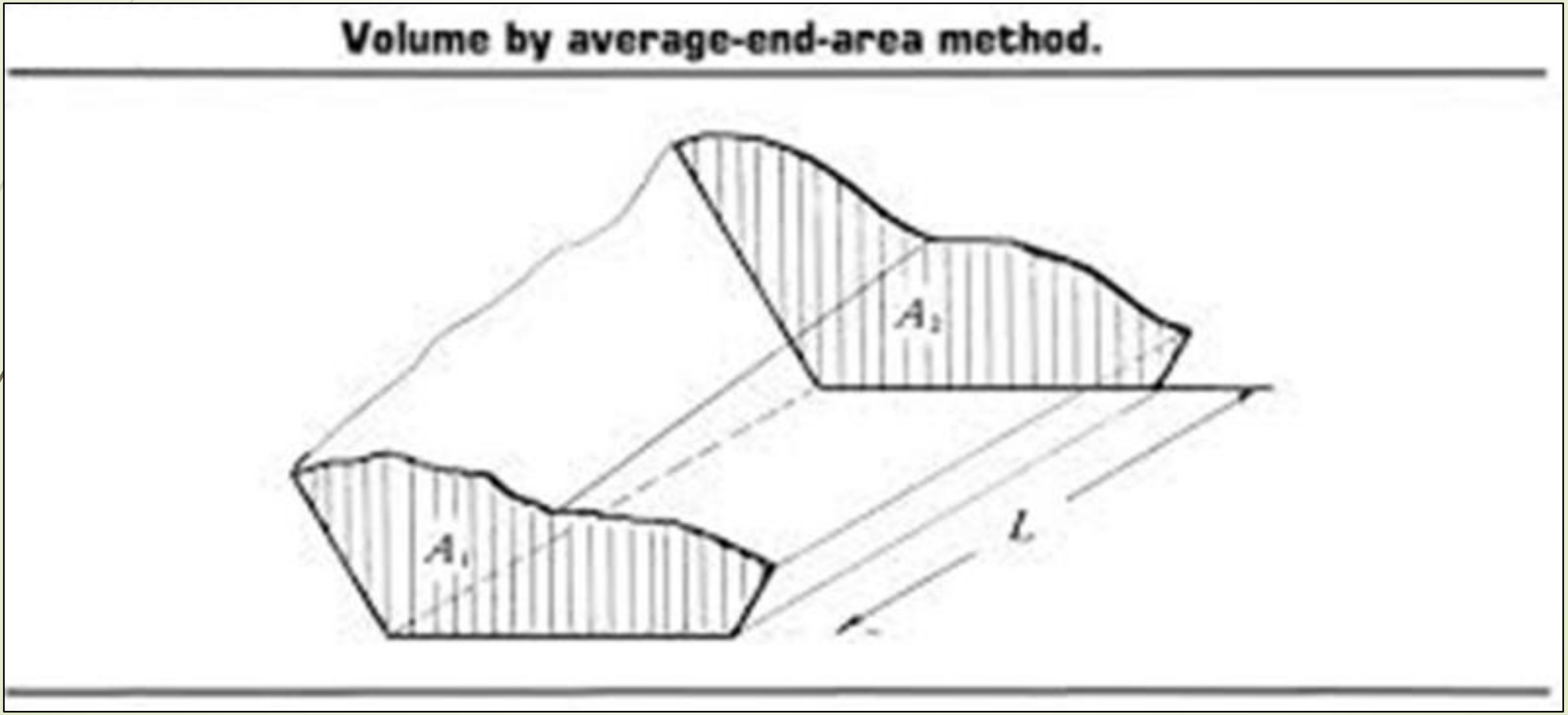
Computing Earthwork Volumes

- Surveying books document the different methods for area computation.
- The volume of earthwork is then computed from the cross-sectional areas and the distances between the cross sections.
- A common method of determining the volume is that of **Average End Areas**.
- This method is commonly used to determine the volume bound by two cross sections or 'end areas'
- This procedure is based on the assumption that the volume between two consecutive cross sections is the average of their areas multiplied by the distance between them, computed as follows.

$$V = \frac{L}{2}\,(A_1 + A_2);\ A_1, A_2 = End\ Areas\ in\ m^2\ and\ L = distance\ between\ A_1\ \&\ A_2\ in\ m$$

Highway Earthworks And Final Plans

Computing Earthwork Volumes



Highway Earthworks And Final Plans

Computing Earthwork Volumes

- The average end-area method has been found to be sufficiently accurate for most earthwork computations, since cross sections are taken 15 to 30 m apart, and minor irregularities tend to cancel each other.
- When greater accuracy is required, such as in situations where the grade line moves from a cut to a fill section, the volume may be considered as a pyramid or other geometric shape.
- It is common practice in earthwork construction to move suitable materials from cut sections to fill sections to reduce to a minimum the amount of material borrowed from borrow pits.
- When the materials excavated from cut sections are compacted at the fill sections, they fill less volume than was originally occupied.
- This phenomenon is referred to as shrinkage and should be accounted for when excavated material is to be reused as fill material.

Highway Earthworks And Final Plans

Computing Earthwork Volumes

- ❖ The amount of shrinkage depends on the type of material. Shrinkages of up to 50 percent have been observed for some soils. However, shrinkage factors used are generally between 1.10 and 1.25 for high fills and between 1.20 and 1.25 for low fills.
- ❖ These factors are applied to the fill volume in order to determine the required quantity of fill material.

Mass Diagram

- ❖ The mass diagram is a series of connected lines that depicts the net accumulation of cut or fill between any two stations. The ordinate of the mass diagram is the net accumulation in cubic meters (m^3) from an arbitrary starting point
- ❖ Thus, the difference in ordinates between any two stations represents the net accumulation of cut or fill between these stations.
- ❖ If the first station of the roadway is considered to be the starting point, then the net accumulation at this station is zero.

Highway Earthworks And Final Plans

Computing Earthwork Volumes – Example 1

A roadway section is 600 m long (20 stations). The cut and fill volumes are to be computed between each station. The table below lists the station numbers (column 1) and lists the end area values (m^2) between each station that are in cut (column 2) and that are in fill (column 3). Material in a fill section will consolidate (known as shrinkage), and for this road section, the shrinkage is 10 percent.

Question : Compute Fill and Cut Volumes and Mass Diagram Ordinates

Highway Earthworks And Final Plans

Station	End Area Cut (m^2)	End Area Fill (m^2)	Total Cut Volume (m^3)	Fill Volume (m^3)	Apply 10% Shrinkage to Fill Volume (m^3)	Total Fill Volume (m^3)	Net Volume Fill (-) (m^3)	Net Volume Cut (+) (m^3)	Mass Diagram Ordinate (m^3)
0	0.3	1.7	7	95	9	104	-97		0
1	0.2	4.6	6	205	20	225	-220		-97
2	0.2	9.0	8	316	32	348	-340		-317
3	0.4	12.1	17	252	25	277	-261		-657
4	0.7	4.7	67	134	13	147	-80		-917
5	3.7	4.2	118	91	9	100	19		-998
6	4.2	1.9	174	35	3	38	136		-979
7	7.4	0.5	281	10	1	11	271		-843
8	11.3	0.2	351	3	0	3	348		-572
9	12.1	0.0	376	0	0	0	376		-224
10	13.0	0.0	334	4	0	5	330		152
11	9.3	0.3	251	46	5	51	200		482
12	7.4	2.8	216	70	7	77	139		682
13	7.0	1.9	174	98	10	107	67		822
14	4.6	4.6	98	181	18	199	-102		889
15	1.9	7.4	42	251	25	276	-234		787
16	0.9	9.3	14	307	31	337	-323		553
17	0.0	11.1	4	334	33	368	-364		229
18	0.3	11.1	60	237	24	261	-201		-134
19	3.7	4.6	98	111	11	123	-25		-335
20	2.8	2.8							-360

Highway Earthworks And Final Plans

Computing Earthwork Volumes – Example 1

Sample Calculations: From Station 0 to Station 1

Cut Volume

1. Cut End Area 1, $A_1 = 0.3\ m^2$ (Given)
2. Cut End Area 2, $A_2 = 0.2\ m^2$ (Given)
3. Total Cut Volume, $V_{cut} = \frac{L}{2}(A_1 + A_2) = \frac{30}{2}(0.3 + 0.2) = 7.0\ m^3$

Fill Volume

1. Fill End Area 1, $A_1 = 1.7\ m^2$ (Given)
2. Fill End Area 2, $A_2 = 4.6\ m^2$ (Given)
3. Fill Volume, $V_{fill} = \frac{L}{2}(A_1 + A_2) = \frac{30}{2}(1.7 + 4.6) = 95\ m^3$
4. Apply 10% Shrinkage, $V_{shrink} = 10\% * 95\ m^3 = 9\ m^3$
5. Total Fill Volume = $V_{fill} + V_{shrink} = 95 + 9 = 104\ m^3$

Highway Earthworks And Final Plans

Computing Earthwork Volumes – Example 1

Net Volume:

Net Volume $V_{net} = V_{cut} - V_{fill}$

Net Volume $V_{net} = 7 - 105 = -97\ m^3$ (Fill)

Negative = Fill

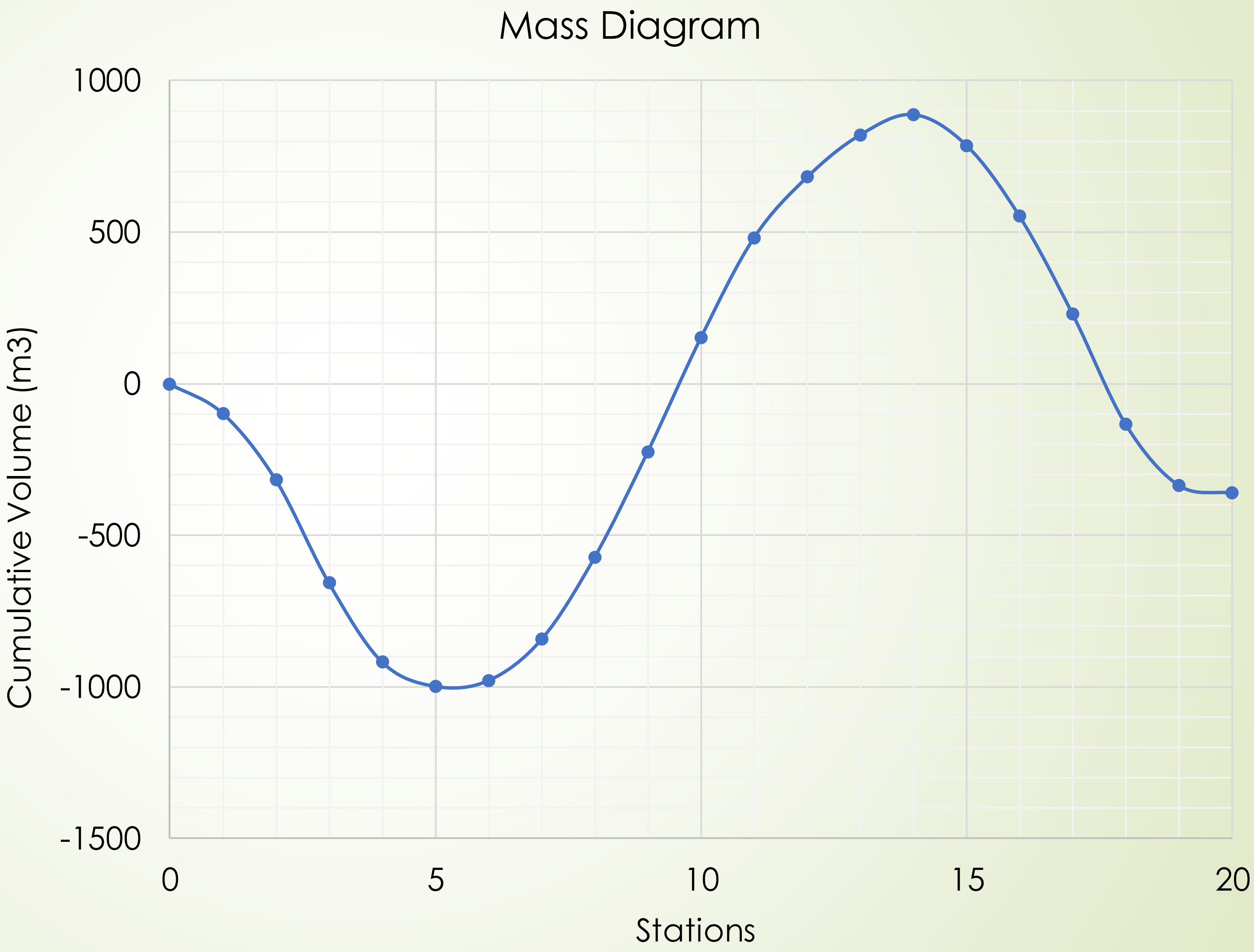
Positive = Cut

Highway Earthworks And Final Plans

- **Computing Earthwork Volumes – Example 1**

Mass Diagram

- Computer programs are now available that can be used to compute crosssectional areas and volumes directly from the elevations given at cross sections.
- Some programs will also compute the ordinate values for a mass diagram and determine the overhaul, if necessary.



Highway Earthworks And Final Plans

Preparation of Highway Plans

- Once the final location of the highway system is determined, it is then necessary to provide the plans and specifications for the facility.
- The plans and specifications of a highway are the instructions under which the highway is constructed.
- They are also used for the preparation of engineers' estimates and contractors' bids.
- When a contract is let out for the construction of a highway, the plans and specifications are part of the contract documents and are therefore considered legal documents.
- The plans are drawings that contain all details necessary for proper construction, whereas the specifications give written instructions on quality and type of materials
- Highway plans usually consist of horizontal alignment, vertical alignment (sometimes called the profile), and the typical cross sections and specific features such as pipe culverts and concrete box culverts

Thank You!!!