Chapter One

Basic concepts

1.1 Introduction to *Surveying and Mapping*

This chapter will define surveying and some of the essential terms used in surveying.

Surveying may be simply defined as the art of making measurements. Surveying involves the measurements of distances, angles and elevations. It also involves staking out the lines and grades needed for the construction of buildings, roads, dams, and other engineering structures. In addition to the field measurements, surveying includes the computation of areas, volumes, and other quantities, as well as the preparation of necessary maps and diagrams. Surveying has many industrial applications: for example, setting equipments, assembling aircrafts, laying out assembly lines, and so on. In addition, it includes the processing of converting the measurements in to positional information such as maps and coordinates. The survey activities are not limited to the surface of the earth but extend to the sea and deep underground, as well as extraterrestrial space.

More precisely, Surveying can be defined as the art and science of determining the relative positions of various points on, above or below the surface of the earth.

When we say the relative positions of points it means that determining the relative positions of points in reference to another point or reference point/station. For example, Bule hora town is found at about 465 kilometers south of Finfinne (Addis Ababa), again you may say Bule hora University is found at about 1 km west of Bule hora twon. In this example, it is obvious that the (relative position) location of Bule hora town is described in reference to Finfinne (Addis Ababa) and that of Bule hora University is in reference to Bule hora town.

The Art and Science of Surveying

Surveying is the art and science of measuring and locating points and angles on, above, and below the surface of the earth. In this definition, the terms “art” and “science” are used because good surveying is both. Webster defines art as “skill acquired by experience, study, or observation” and “the conscious use of skill and creative imagination especially in the production of aesthetic objects. “An example of the art of

surveying is being able to reconnoiter a site and determines the "best" instruments and methods to use to collect the desired data. Best is a very subjective term. What is best for one individual, crew, or site may not be the best if the conditions change, such as moving to a different site, completing a different type of survey, or working for a different government agency. The best instruments and methods produce the required data with the least consumption of resources. This includes determining what data needs to be collected, the most appropriate surveying method to use, the best location of the instruments, and so on. For professional surveyors, and for commercial construction operations, time is money. An experienced surveyor can look at a site and determine the best method for collecting the necessary data. This ability is an art because it cannot be learned from a textbook or in a classroom. This "art" is developed through natural abilities and from experience. In many cases, standards and procedures have been developed to provide guidance in this area. For example, if the purpose of a survey is to establish the legal description of a parcel of land, then standard procedure requires that an instrument that measures angles with known and verified accuracy be used. Distances must also be measured within the stated limits and a procedure called "balancing the traverse" should be used.

Surveying is also a science. Webster defines science as, "*knowledge covering general truths or the operation of general laws especially as obtained and tested through scientific method*." This definition is appropriate for many aspects of surveying. The principles and practices that have been developed to collect accurate data provide an example of the use of science in surveying. Accurate data is valuable in surveying, while inaccurate data can be costly because it may result in design errors. A rule to remember is that bad data is worse than no data. Procedures have been developed and tested over time that, if followed, control errors. These include procedures to set up and use the instruments, record data, and perform mathematical procedures used to complete the calculations.

Simply stated, surveying involves the measurement of distances and angles. The distances may be horizontal or vertical in direction. Simply, the angles may be measured in a horizontal or vertical plane. Frequently distances are measured on a slope, but they must eventually be converted to a corresponding horizontal distance. Vertical distances

are also called elevations. Horizontal angles are used to express the directions of land boundaries and other lines.

There are two fundamental purposes for measuring distances and angles. The first is to determine the relative positions of existing points or objects on or near the surface of the earth. The second is to layout or mark the desired positions of new points or objects which are to be placed or constructed on or near the surface of the earth. The survey measurements must be made with precision in order to achieve a maximum of accuracy with a minimum expenditure of time and money.

- ☑ Surveying involves the measurements of distances, angles and elevations.
- ☑ In addition, it includes the processing of converting the measurements in to positional information such as maps and coordinates (i.e. Mapping).

Generally, the practice of surveying is an art, because it is dependent upon the skill, judgment, and experience of the surveyor and an applied science, because field and office procedures rely up on a systematic body of knowledge, related primarily to mathematics and physics.

1.2 Primary Division of Surveying

Primary divisions of surveying are made on the basis whether the curvature of the earth is considered or the earth is assumed to be a flat plane. Because of the curvature of the earth's surface, the measured distances on earth are actually curved. However, when the distances are small, compared with the radius of the earth, there is no significant difference between the curved distances and the corresponding straight – line distances, and the curvature of the earth can be neglected.

Surveying is thus primarily divided in two types:

1. Plane surveying
2. Geodetic Surveying

1. **Plane surveying-** is the type of surveying in which the curvature of the earth is neglected and it is assumed to be a flat surface. All horizontal distances and horizontal angles are assumed to be projected on a horizontal plane. A horizontal plane at a point is the plane, which is perpendicular to the vertical line at that point.

2. **Geodetic Surveying:** is the type of surveying in which the curvature of the earth is taken in to consideration and a very high standard of accuracy is maintained. The main objective of geodetic surveying is to determine the precise location of a system of widely spaced points on the surface of the earth.

1.3 Importance of Surveying

Surveying plays an essential role in the planning, design, layout and construction of our physical environment and infrastructure. The term infrastructure is commonly used to present all the constructed facilities and systems which allow human communities to function. Surveying is the link between design and construction. Roads, Bridges, Buildings, water supply sewerage, drainage systems and many other essential public works, projects could never be built without surveying technology.

In addition to its customary applications in construction and land-use projects, surveying is playing an increasingly important role in modern industrial technology.

Most commonly for ordinary local projects the surveying process starts with the reconnaissance survey i.e. on arrival at the site the survey team simply walks over the area with a view to establish the best sites for survey stations, and other purposes need to be considered.

Next the necessary data for the project will be collected by the principle of basic measurements in surveying, then computations of the collected data has to be done to produce plans or topographic maps depending up on the objectives of the project. The produced plans or maps are used for planning Engineering projects, marking boundary corners or lines, computations of areas & volumes and other purposes. Surveying also includes the art of setting out the new points on the ground from the plans or maps according to the design of the project.

To summarize; the first stage in all big projects is generally to survey the area and prepare plans or maps which will be used in the preparation of detailed drawings, design and cost estimation of the project .After finalizing the design or detail drawing, setting out will be done.

1.4 Classifications of Surveying

1.4 .1 Based on application area

As we mentioned at the beginning, the two fundamentals purposes for surveying are to determine the relative positions of existing points and to mark the positions of new points on or near the surface of the earth .within this frame work, many different kinds of surveys are performed. Some specific applications or types of surveys are outlined briefly as follows:

i. Property survey

A property survey is performed in order to establish the positions of boundary lines and property corners. It is also referred to as a land survey or a boundary survey. Property surveys are usually performed when ever land ownership is to be transferred or when a large tract of land is to be subdivided in to smaller parcels for development. Also before the design and construction of any public or private land- use project can get underway, it is necessary to accurately establish the legal boundaries of the proposed project site. Constructing a structure on what later is found to be property that belongs to someone else can be a very expensive mistake.

Any survey for establishing or describing land boundaries must be performed under the supervision of a licensed land surveyor. Land surveys in urban areas must be conducted with particular care, due to the very high cost of land. In rural areas less accuracy may be accepted. Land surveys done to actually mark property corners with permanent monuments are sometimes informally referred to as ‘’stakeout’’ ‘’out bound’’ or ‘’bar job’’ surveys.

ii. Topographic Survey

A topographic survey is performed in order to determine the relative positions (horizontal and vertical) of existing natural and constructed features on a tract of land. Such features include ground elevations, bodies of water, vegetation, rock out crops, roads, buildings, and so on.

A topographic survey provides information on the ‘’shape of the land’’ Hills, valleys, ridges, and the general slope of the ground can be depicted graphically. The data obtained from a topographic survey are plotted and drawn as a suitably scaled map called a topographic map, or topo map.

The shape of the ground is shown with contours, or lines of equal elevation. Since a topo map is always needed before the engineering and architectural design of any building or other project can begin, a topo survey may also be referred to as a preliminary survey. Of course an accurate property survey must always precede the topo survey, to establish the boundaries of the project site.

iii. **Construction Survey**

A construction survey, also called a layout or location survey is performed in order to mark the position of new points on the ground. These new points represent the location of building corners, road center lines, and other facilities that are to be built. These positions are shown on a site plan, which is essentially a combination of the property survey and topo survey, along with the newly designed facilities. This also may be called a plot plan.

A site plan shows the location dimensions which are to be measured with reference to boundaries or other control points. Vertical heights are given by elevations. Some times horizontal positions may be given by coordinates. Wooden stakes are used by the surveyors to mark the positions of the building, roads, and other structures. An example of a drawing which includes location dimensions is shown below figure 1.1 below.

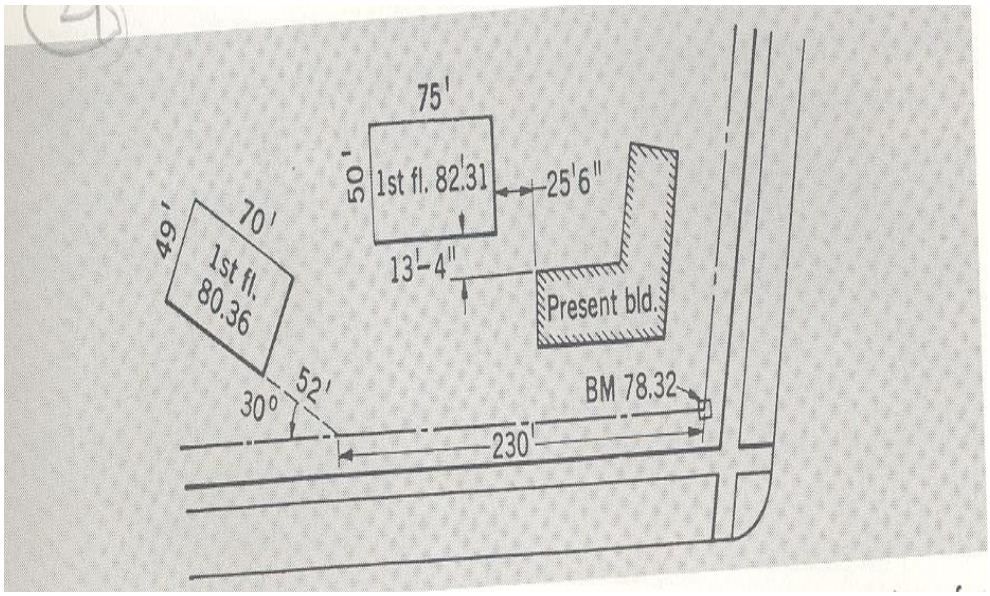

Fig-1.1- Typical location dimension found on engineering or architectural plans, for use during a stake out survey.

The wooden stakes serve as reference points for the construction contractor who actually builds the project. They may be centerline stakes, offset stakes, or grade stakes. Carpenters, masons, and other skilled professionals transfer measurements directly from the survey points. The procedure of placing the markers is called staking out. Another term used, especially for pipelines and roads, is giving line and grade.

iv. Control Survey

There are two kinds of control surveys horizontal and vertical. In a horizontal control survey, several points are placed in the ground by the surveyor, using wooden stakes, or more permanent markers such as iron bars and concrete monuments. These points, called *stations*, are arranged throughout the site or area under study so that they can be easily seen and surveyed. The relative horizontal positions of these points are established, usually with a very high degree of precision and accuracy; this is done using traverse, triangulation, or trilateration survey methods.

In a vertical control survey, the *elevations* of relatively permanent reference points are determined by precise leveling methods. Marked or monumental points of known elevation are called elevation bench marks (BMs). Boundary surveys or construction surveys can be tied in to near by control surveys stations and Bench Marks. This minimizes the accumulation of errors and the cost of making all the measurements precise.

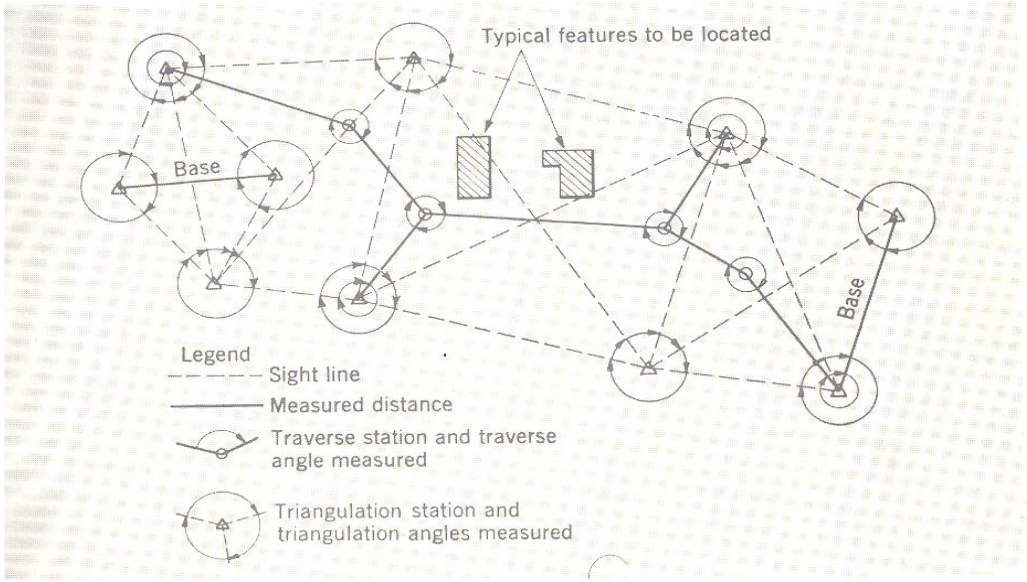

Fig-1.2-A horizontal control survey network showing traverse and triangulation station points and course lines

v. Route Survey

A route survey is performed in order to establish horizontal and vertical control to obtain topographic data and to lay out the positions of highways, *rail ways, streets, pipelines* or any other ‘’linear’’ project. In other words, the primary aspect of a route survey is that the project area is very narrow compared with its length, which can extend from many kilometers and miles

vi. City surveys

These surveys are conducted within the limits of a city for urban planning. These are required for the purpose of layout of streets, buildings, sewers, pips, etc.

vii. **Mine surveys**

These surveys are conducted to determine the relative positions and elevations of Mines, shafts, bore holes etc for underground works. Mine surveys are useful to plan the working of mines and to compute volumes of materials in mines.

viii. Hydrographic surveys

These surveys are conducted on or near the body of water, such as lakes, rivers, bays, and harbors.

ix. **Engineering surveys**

Engineering surveys are conducted to collect data for the designing and planning of engineering works such as building, roads, bridges, dams, reservoirs, sewers and water supply lines. These surveys generally include surveys discussed above.

x. Astronomic surveys

These surveys are conducted for the determination of latitudes, Azimuths, local time etc. for various places on the earth by observing heavenly bodies (the sun or stars).

xi. **Satellite surveys**

These surveys are conducted to obtain intercontinental, interdatum and interisland geodetic ties the entire world over by artificial earth’s satellites.

xii. **Geological surveys**

Geological surveys are conducted to obtain information about different strata of the earth’s surface for geological studies

1.4.2 Based on instruments used

Based on the instruments used surveys can be classified as under

i. **Chain surveying**: is the simplest type of surveying in which linear measurements are taken with a chain or tape

ii. **Compass surveying**: In this type of surveying, the horizontal angles are measured with the help of a magnetic compass, in addition to the line or measurements with a chain or a tape.

iii. **Leveling**: this is a type of survey in which a leveling Instrument is used for determination of relative elevations (levels) of various points on, above or below the surface of the earth

iv. **Theodolite survey:** In this survey Theodolite is the main instrument used. It is used for measuring both horizontal and vertical angles.

v. **Tachometric Survey:** This is a rapid and economical survey by which the horizontal distances and the difference in elevation are determined indirectly using a Theodolite and a graduated rod.

vi. **Photogram metric survey:** Photogrammetry is a science of taking measurements with the help of photographs. Photogrammetric surveys are generally used for topographic mapping of vast areas.

1.5. Basic measurements in Surveying

Introduction as it is defined in section 1.1 generally surveying can be define as the art and science of determining the relative position of various points on, above or below the surface of the earth. These relative positions of points or the position of one point to another point or the reference point can be defined by making some kind of measurements of these measurements the basic ones are classified in to four:

1. Horizontal distance 2. Vertical Distance

3. Horizontal Angles and 4. Vertical Angles

1. Horizontal Distance

Most surveying data are eventually plotted and drawn as a boundary plat, a topographic map, a building site plan, a profile of the ground along a route or a series of route cross-sections. With the exception of the last two types of drawings, the lines shown on the paper represent projections of points on to a flat and horizontal surface. The drawing

paper represents the level reference plane. The scaled length of any line on the drawing is proportional to the actual horizontal distance between its end points on the earth.

The tasks of determining the horizontal distance between two existing points and of setting a new point at a specified distance from some other fixed position are fundamental surveying operations. The surveyor must select the appropriate equipments and apply suitable field procedures in order to determine or set and mark distances with the required degree of accuracy. The most common methods for measuring horizontal distances include: pacing, stadia, taping, and electronic distance measurement (EDM).

Generally, we can define horizontal distance between two points is the distance measured between the points which are in a horizontal plane, the plane which is perpendicular to the vertical direction at a point or direction of gravity at the points or the horizontal projection of the slope distance between points which are on a slopping ground.

- More precisely, horizontal distance is the distance measured between points which are in a horizontal plane or the horizontal projection of the slope distance between points on a sloping ground. In surveying the distance between two points means a horizontal distance.
- Measurement of horizontal distance or making linear measurements is required in chain surveying, traverse surveying, and other types of surveying.
- When slope distances are measured in the field, are always reduced to the equivalent horizontal distances for preparation of map.

There are, in general, three methods of making linear measurements:

1. **Direct methods**: the distance is actually measured in the field using a tape.
2. **Optical methods:** the distance is not actually measured in the field. It is computed indirectly (for example: stadia tachometry, $HD=K(U-L)\cos^2 v$).
3. **E.D.M. methods:** use light or radio waves for measurement of distance.

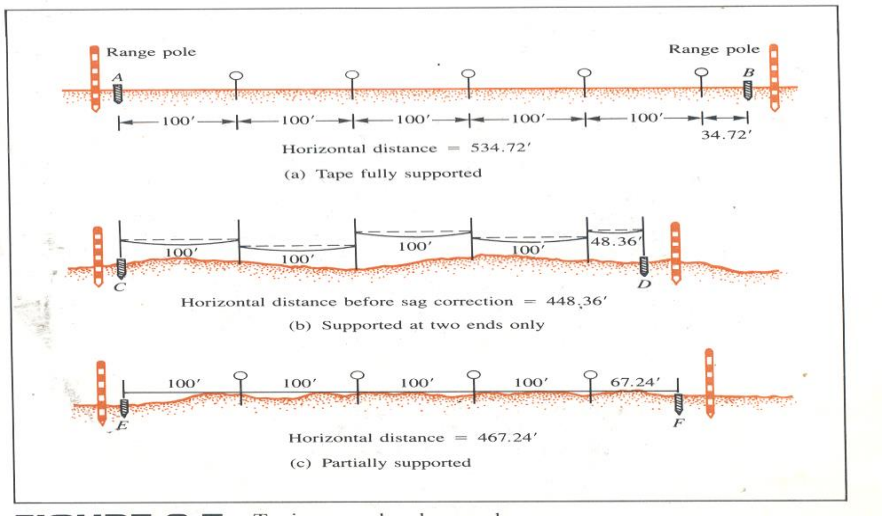

Fig 1.3-horizontal distance measurement over level ground

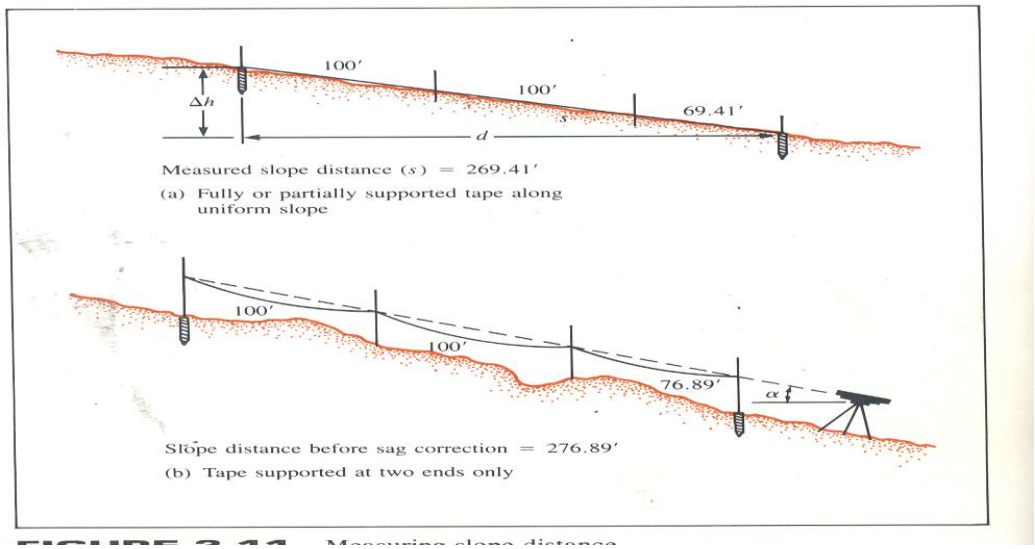

Fig-1.4-Measuring slope distance

OTHER METHODS (ROUGH DISTANCE MEASUREMENT)

- **Approximate methods commonly used in reconnaissance surveying for the measurement of horizontal distances .**
  1.Pacing
  2.Measuring wheel

In certain surveying applications, only a rough approximation of distance is necessary; a method called pacing, or the use of a simple measuring wheel, may be sufficient in these instances.

Pacing

• Practical measure of distance.
• Don't try to pace out one meter with every step. Walk casually over 100 m counting the number of steps. Work out the length of a casual step and use this instead.
• Varies with uphill, downhill, and your age.

• Low accuracy
• No equipment needed

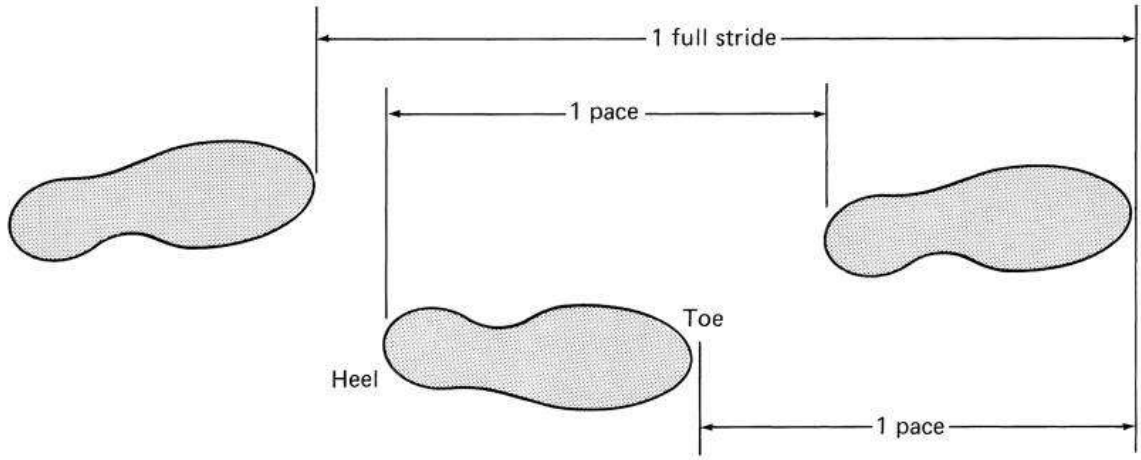

FIGURE -1. Pacing provides a simple yet useful way to make rough distance measurements.

All surveyors and construction technicians should know their own personal unit pace value.

Ex. The approximate distance between two points is 0. 512km.A person measured this distance by using pacing 531 paces. What is the pace length of a person in meter?

solution

pl=md/no of p

=512/531

=0.964m

2. Vertical Distances

The vertical direction is parallel to the direction of gravity; at any point, it is the direction of a freely suspended plum bob cord or string. The vertical distance of a point above or below a given reference surface is called the elevation of the point.

The most commonly used reference surface for measuring vertical distance is mean sea level (MSL). (The words altitude & height are some times used in place of elevation)

Vertical distance between two points or between the point and reference surface is the distance measured between the points which are in a vertical plane or a plane which is parallel to the direction of gravity at that point and passing through the point or points

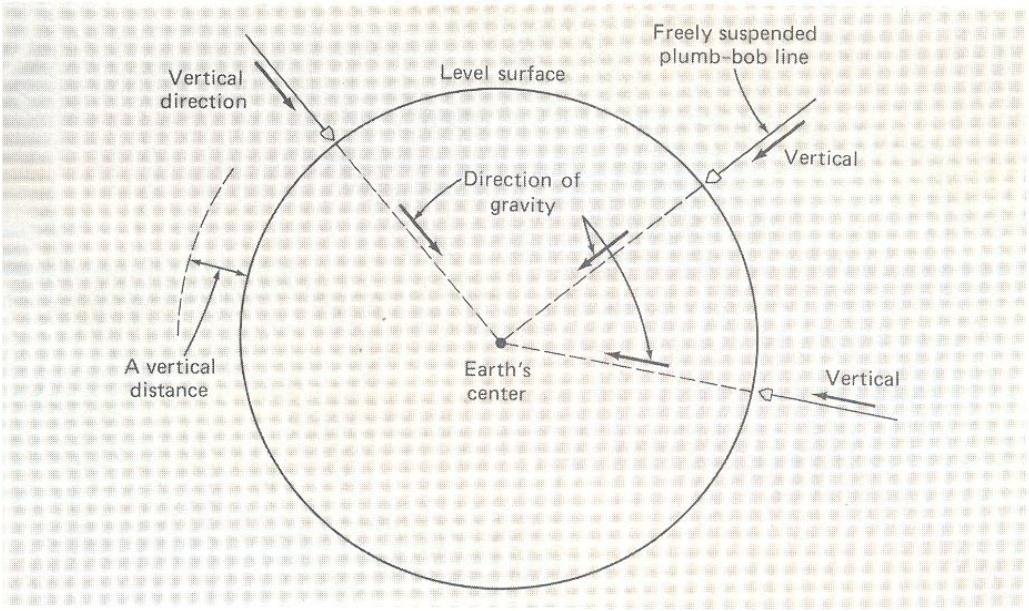

Fig –1.5-The relationship between vertical distance and direction of force of gravity.

3. Horizontal Angle

One of the basic purpose of surveying is to determine the relative positions of points on or near the earth's surface. Assigning coordinates to a given point is a useful and common way to indicate its position.

Horizontal angles are measured between two intersecting lines in a horizontal plane. They are usually expressed in terms of degrees, minutes, and seconds of arc.

The horizontal angle between a given line and a specified reference line is called the direction of the line. The reference line is called **meridian**. An angle measured between two intersecting lines in a horizontal plane is called **horizontal angle.**

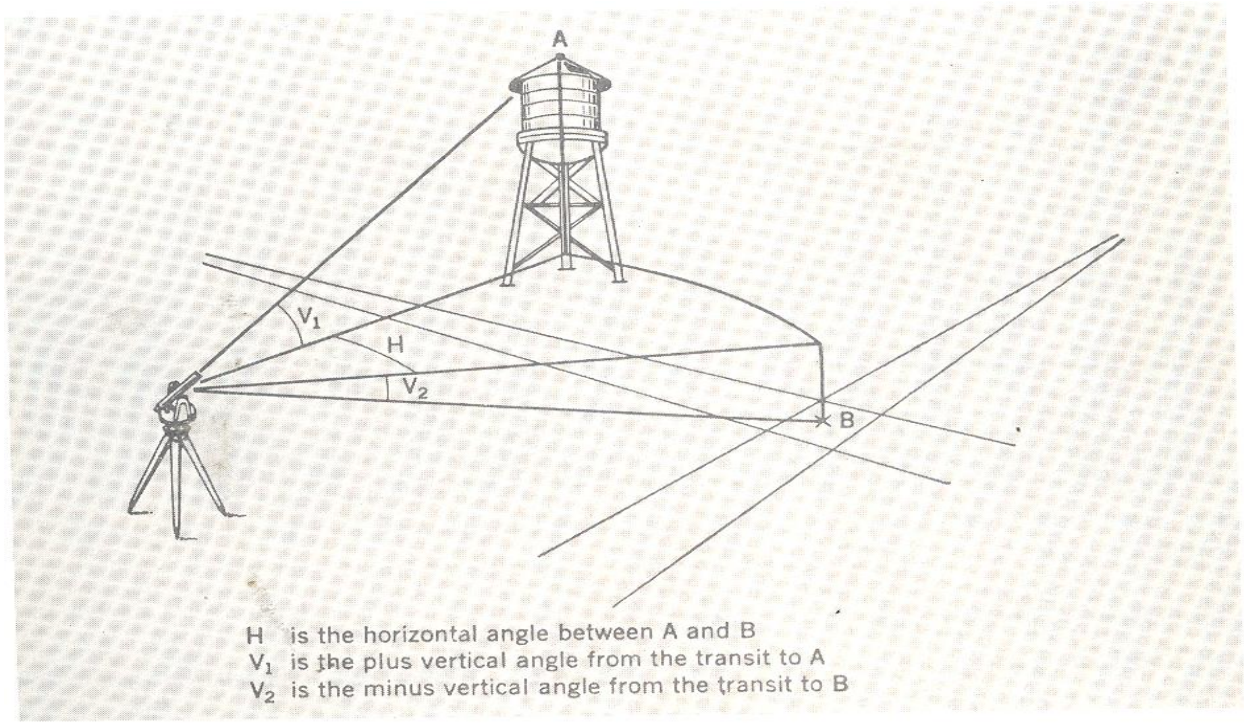

Fig-1.6-Measurment of horizontal and vertical angles.

4. Vertical Angles

A vertical angle between two lines of sight is measured in a plane that is vertical at the point of observation. In modern surveying Instruments the up ward vertical direction is usually used as a reference for measuring vertical angles, instead of the horizontal. That direction is called the zenith direction, and the angle measured with respect to it is called a **zenith angle**.

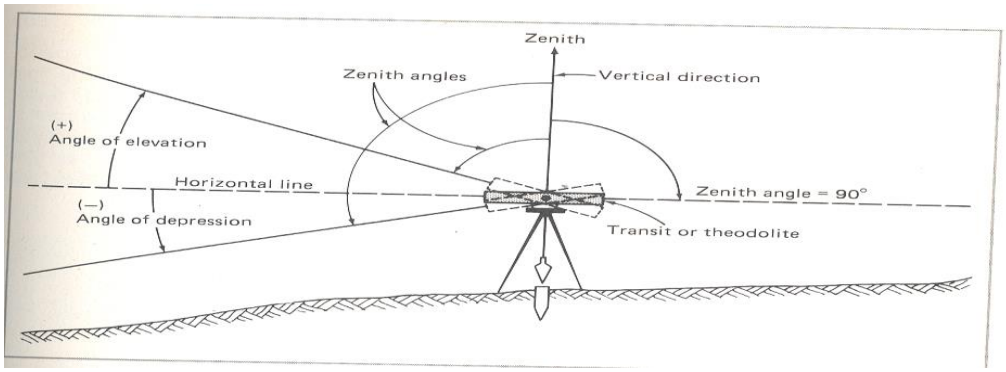

Fig-1.7- Designation of Vertical angles or Zenith Angles

Relationship between Zenith and Vertical Angle.

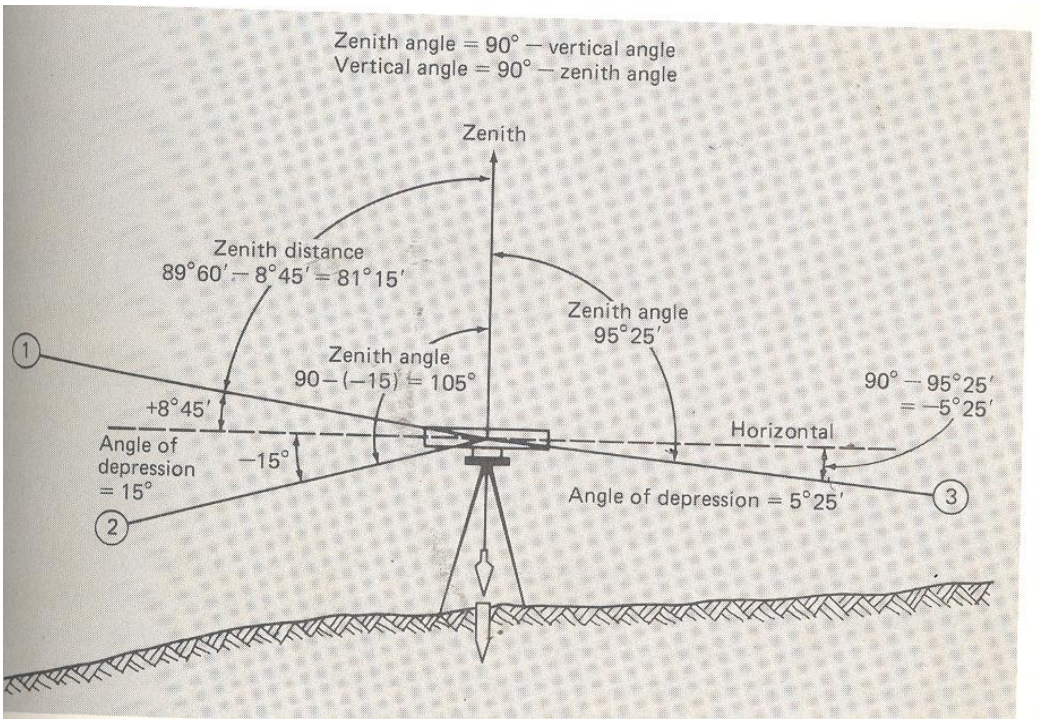

Fig- 1.8- Relationship between Zenith and Vertical Angle

*In Surveying, angles as well as linear distances are usually measured in order to compute the coordinates of any particular point.