ISTANBUL TECHNICAL UNIVERSITY DEPARTMENT OF GEOMATICS ENGINEERING

ENGINEERING SURVEYING

W-1 v3

Prof. Dr. Ergin TARI

translated by Res. Assist. Serpil ATEŞ

WHAT IS ENGINEERING SURVEYING?

Engineering surveying is one of the fundamental discipline of Geodesy. Therefore, the borders of the issues to be included in the engineering surveying must be specified in accordance with the definition and scope of the Geodesy. According to classical definition of F.R. Helmert (1880), **Geodesy** is the " **science of measurement and visualisation (portrayal) of the physical earth** " [Draheim; 1971], [Torge; 1975, s. 9].

After this definition in 1880, many scientists tried different definitions of Geodesy with different words, but main elements of the Helmert’s definition are never changed.

WHAT IS ENGINEERING SURVEYING?

Main elements of definition of the Geodesy

- **Physical earth**,
- **Measurement** ,
- **Visualisation**.

PHYSICAL EARTH AND THE AIM OF THE GEODESY

Physical earth which is the study field of Geodesy science, is defined as the intersection surface of the solid mass with the atmosphere and volumes filled with water such as sea and lake [Torge; 1975, s. 10].

The underground mines, tunnels, GPS satellites and similar applications show near space of the physical earth is in the study area of the Geodesy. The field of study is expanded to include the moon and other planets [Kaula, 1971].

PHYSICAL EARTH AND THE AIM OF THE GEODESY

The aim of Geodesy is to determine the shape (geometry) of physical earth. This intersectional surface that is the actual shape of the earth can not be expressed in mathematical functions because it has a lot of discontinuity and has highly irregular geometry (topography). The only way to define this geometry is to create spatial locations (space coordinates) of the sufficient number of ground points with appropriate distribution.

Therefore, a 3D coordinate system should be determined and time dependent changes of this coordinate system should be taken into account. In additon, a smooth surface (**model Earth-rotational ellipsoid**) which can be expressed in mathematical functions must be defined as well.

THE AIM OF THE GEODESY

a) Determination of space coordinate system according to time and specifying rotational ellipsoid parameters;

To realize this aim physics of earth must be taken into account. Such as, determination of earth rotation parameters and external gravity field of the earth and determination of the Geoid (a boundary value problem) is in the scope of the this task. Defining the best-fit rotational ellipsoid parameters is in the study field of Geodesy as well.

THE AIM OF THE GEODESY (Continue)

b) Establishing a set of points which has space positions on the physical earth:

As a result of rapid developments in the GPS, GLONASS, VLBI, SLR, LLR, DORIS measurement and positioning techniques, a set of points covering the whole earth (ITRF, IGS networks) was created by international organizations. Three-dimensional coordinates and the change of the coordinates by time (annual velocities) is calculated and serviced for all points.

Because the coordinates mentioned above does not have qualifications to meet demands of height applications, levelling networks are also required to meet these demands. In this context, there is no international initiative covering whole earth. This problem is solved in the national context because the European Levelling Network establishment project is not concluded.

THE AIM OF THE GEODESY (Continue)

c) The establishment of set of points at national level with known space coordinates:

Every country establishes a **National Horizontal Control Network** and a **National Vertical Control Network** that has sufficient point density.

Turkish National Fundemantal GPS Network (TUTGA) is connected to the international IGS network mentioned in slide 7). Because **International Vertical Control Network** is not established yet, **Turkish National Vertical Control Network (TUDKA)** is not connected to any network (Ayhan; v.d. ; 2002).

THE AIM OF THE GEODESY (Continue)

d) Determining geometry of the physical earth in detail (Map production):

This task can contain whole physical earth or a large part of this surface (a continent, a country) while a specific study area of an engineering service. In general, the map scale become larger as the task area smaller and geometric details are determined when the working area becomes smaller. In order to achieve the task, point densification in the control networks mentioned at task b and c is essential. Geometric details are determined with appropriate methods such as remote sensing, photogrammetry, GPS. A **digital map** [BÖHHBÜY, 2005] is produced with location information, geometric information and relationships between detail points. In addition a map can be converted to information systems by adding non-geometrical (attribute) information and query ability. Planar coordinates and level of the geometric detail points must be determined for map production. Maps can be divided into 2 groups such as thematic and topographic maps according to their purpose. Large scale topographic maps are the vital infrastructure for engineering services.

THE AIM OF THE GEODESY (Continue)

e) Transferring new geometries designed in the projects of the engineering structures to the physical earth – Layout (Set out)

The geometry of the part of the physical earth where the structure is established must be changed in accordance with the purpose. Transferring the new geometry designed at the project to the physical earth (layout), is one of the most important task of the geodesy (engineering surveying).

THE AIM OF THE GEODESY (Continue)

f) Monitoring the geometry changes at earth crust and structures – Deformation measurements:

Both the earth crust and the structures located on it has more or less geometry changes depending on the time; these changes can be referred as **time dependent deformation**.

Determination of movements of fault lines and continents, extending the life of important engineering structures and efficient management of these, determining the dangerous geometry changes on these structures on time and similar purpose deformation measurements are among the important tasks of the geodesy (engineering surveying).

THE AIM OF THE GEODESY (Continue)

Determination of the external gravity field and rotation parameters of the earth, determination of the model earth (rotational ellipsoid) parameters, identifying three-dimensional coordinate system and locating according to earth, establishing international and national control networks, map production for culture and information, deformation measurements for fault lines and continental movements and similar tasks cause geodesy counted as **earth science**.

On the other hand, establishing control networks for engineering services and large scale topographic map production, layout surveys, deformation measurements for determining geometry changes of the structures and similar tasks cause geodesy counted as an **engineering science**.

SURVEYING SCIENCE AND ACCURACY CONCEPT

Surveying is the science of comparison of a quantity in nature and a quantity defined as same type of unit and determining how many units and fractions are found in this quantity.

In order to measure a quantity, first a measurement model should be designed, **measurement methods and and equipments having unit and fractions** will be developed according to the model. The foundation of the measurement model is **assumptions**. The differences between facts and assumptions lead to inevitable **measurement errors**.

SURVEYING SCIENCE AND ACCURACY CONCEPT (cont'd)

Intended products of the geodetic tasks are three-dimensional coordinates (length) or latitude, longitude, height (angle, length) and time. To access these products, horizontal and slope length, height difference, horizontal and vertical angle, slope, temperature, pressure, humidity, frequency, time difference, gravity, etc. are measured according to measurement model and method.

Because the measurement results can not be error free, **accuracy criterion** must be used to define accuracy of the measurement results and the quantities that produced from these results. Today **standart deviation (root mean square error)** is used as accuracy criterion [Kreyszig; 1979].

SURVEYING SCIENCE AND ACCURACY CONCEPT (cont’d)

Accuracy criterion derived from measurement results can be referred as **achieved accuracy**. There is not a limit value for achieved accuracy in geodetic actions within scope of earth sciences, higher achieved accuracy is always continuously intended.

In the scope of engineering sciences, to optimize geodetic actions, a priori accuracies of the engineering structures according to their qualification must be determined. The type of accuracy that is not depended on the surveying, only depended on the specifications of the engineering structures referred as **required accuracy** [Uren; Price; 2006, s. 553].

SURVEYING SCIENCE AND ACCURACY CONCEPT (cont'd)

If required and achieved accuracy of a quantity about engineering services referred as **μ** and **σ** standart deviation, respectively, optimization of geodetic actions to produce this quantity is realized with inequality (1.1);

$$|\mu| \geq |\sigma| \qquad (1.1)$$

In other words, geodetic control networks are designed taking into account of inequality (1.1) and measurement techniques and equipments are selected up on[Baykal; v.d. ; 2005].

VISUALISATION AND VISUAL PRODUCTS

Today, except for very small and simple ones, all large-scale topographic maps for engineering services and project are produced in computer. As the result, necessary and sufficient number of quantity (coordinate, length, angle, height, slope, etc.) are described numerically and used in subsequent operations.

However, human beings cannot sense the geometry that expressed on listed numerical quantities, so visualization of projects and maps is required. After visualization, **visual products** are acquired [Uren; Price; 2006, s. 7].

VISUALISATION AND VISUAL PRODUCTS (continue)

Visual Products are classified as;

- **horizontal projection products**: location plans, tematic maps, topographic maps
- **vertical projection products**: cross sections, profiles
- **three-dimensional** (perspective) images

Visualisation is carried out by drawing on a base such as tracing paper or displaying on the computer screen.

CONTENT OF THE ENGINEERING SURVEYING

The content is closely connected with engineering services and can be divided into four sections such as;

1. Geometric design and layout,
2. Mining surveying,
3. Hydrographic surveying,
4. Determination of structural deformations.

CONTENT OF THE ENGINEERING SURVEYING (Continue)

1. **Geometric design and layout**

The geometric design of engineering structure projects, layout computation, establishment of geodetic control networks according to inequality (1.1), selection of measurement methods and equipments and layout surveys.

2. **Mining Surveys**

Mining Surveys include, legal regulation about open and close mining and application of this regulations, measurement techniques and instruments especially designed for underground surveys [Randolph; 1983].

CONTENT OF THE ENGINEERING SURVEYING (Continue)

3. Hydrographic Survey

The subject of the hydrographic survey is determining bottom geometry of volumes filled with water such as sea and lake. In order to obtain this invisible geometry with sufficient accuracy special measuring methods and equipment have been developed [IHO; 2005], [U.S. Army; 2004].

4. Determination of structural deformations

The main topics are; inner and outer forces that affect engineering structures, modelling of force-strain relationship, required accuracy determination, establishing control networks according to optimization and selection of measuring methods and equipment, deformation measurements, evaluation and interpretation of the measurements results with statistical methods [U.S. Army; 2002].

CONTENT OF THE ENGINEERING SURVEYING (Continue)

- Hydrographic surveys, mining surveys and determination of structure deformations are separate topics of other courses and excluded from the scope of this course.

- In addition, the geometric design and the application topics are explained only for road and railway within the scope of this course.

end…