VII

Surveying Engineering

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SURVEYING IS ONE OF THE OLDEST ACTIVITIES of the civil engineer, and remains a primary component of civil engineering. It is also one field that continues to undergo phenomenal changes due to technological developments in digital imaging and satellite positioning. These modern surveying tools are not only revolutionizing regular surveying engineering tasks but are also impacting a myriad of applications in a variety of fields where near-real-time positioning is of great value.

Surveying and engineering are closely related professional activities. The area of surveying and mapping is in many countries a discipline by itself, and taken in total, it is almost as broad in scope as civil engineering. In the U.S., surveying engineering has been historically allied to civil engineering. Engineering surveying is defined as those activities involved in the planning and execution of surveys for the location, design, construction, operation, and maintenance of civil and other engineered projects. Such activities include the preparation of survey and related mapping specifications; execution of photogrammetric and field surveys for the collection of required data, including topographic and hydrographic data; calculation, reduction, and plotting of survey data for use in engineering design; design and provision of horizontal and vertical control survey networks; provision of line and grade and other layout work for construction and mining activities; execution and certification of quality control measurements during construction; monitoring of ground and structural stability, including alignment observations, settlement levels, and related reports and certifications; measurement of material and other quantities for inventory, economic assessment, and cost accounting purposes; execution of as-built surveys and preparation of related maps and plans and profiles upon completion of construction; and analysis of errors and tolerances associated with the measurement, field layout, and mapping or other plots of survey measurements required in support of engineering projects. Engineering surveying may be regarded as a specialty within the broader professional practice of engineering and, with the exception of boundary, right-of-way, or other cadastral surveying, includes all surveying and mapping activities required to support the sound conception, planning, design, construction, maintenance, and operation of engineered projects. Engineering surveying does not include surveys for the retracement of existing land ownership boundaries or the creation of new boundaries.

Modern surveying engineering encompasses several specialty areas, each of which requires substantial knowledge and training in order to attain proper expertise. The most primary area perhaps is plane surveying because it is so widely applied in engineering and surveying practice. In plane surveying, we consider the fundamentals of measuring distance, angle, direction, and elevation. These measured quantities are then used to determine position, slope, area, and volume — the basic parameters of civil engineering design and construction. Plane surveying is applied in civil engineering projects of limited areal extent, where the effects of the earth's curvature are negligible relative to the positional accuracy required for the project.

Geodesy, or higher surveying, is an extensive discipline dealing with mathematical and physical aspects of modeling the size and shape of the earth, and its gravity field. Since the launch of earth-orbiting satellites, geodesy has become a truly three-dimensional science. Terrestrial and space geodetic measurement techniques, and particularly the relatively new technique of satellite surveying using the Global Positioning System (GPS), are applied in geodetic surveying. GPS surveying has not only revolutionized the art of navigation but has also brought about an efficient positioning technique for a variety of users, prominent among them the engineering community. GPS has had a profound impact on the fundamental problems of determining relative and absolute positions on the earth, including improvements in speed, timeliness, and accuracy. It is safe to say that any geometry-based data collection scheme profits to some degree from the full constellation of 24 GPS satellites. In addition to the obvious applications in geodesy, surveying, and photogrammetry, the use of GPS is applied in civil engineering areas such as transportation (truck and emergency vehicle monitoring, intelligent vehicle and highway systems, etc.) and structures (monitoring of deformation of structures such as water dams). Even in other areas such as forestry and agriculture (crop yield management) GPS provides the geometric backbone of modern (geographic) information systems.

Photogrammetry and remote sensing encompass all activities involved in deriving qualitative and quantitative information about objects and environments from their images. Such imagery may be acquired at close range, from aircraft, or from satellites. In addition to large-, medium-, and small-scale mapping, many other applications such as resource management and environmental assessment and monitoring rely on imageries of various types. Close-range applications include such tasks as accident reconstruction, mapping of complex piping systems, and shape determination for parabolic antennas. Large-scale mapping (including the capture of data on infrastructure) remains the primary civil engineering application of photogrammetry. Recent evolution toward working with digital imagery has brought about the increasing acceptance of the digital orthophoto to augment or supplant the planimetric map. Digital image processing tools offer the probability of great increases in mapping productivity through automation. For small- and medium-scale mapping, the increasing availability of satellite image data offers an alternative to chemical photography. Commercially available satellite data with spatial resolutions of 1 to 3 meters, proposed for the near future, would have a profound impact on all mapping activities within civil engineering. Inclusion of GPS in photogrammetric and remote sensing acquisition platforms will lead to substantial improvements in accuracy, timeliness, and economy.

For centuries, maps have provided layered information in graphical form and have been used as legal documents and as tools to support decision making for applications such as urban planning. Recently, geographic information systems (GIS) have broadened the role played by all types of maps to encompass a total system of hardware, software, and procedures designed to capture, manage, manipulate, and produce information in a spatial context. GIS applications are broad indeed; they include land record management, base mapping, infrastructure maintenance, facilities management, and many others.

A driving force behind the move toward integrating mapping and other spatially oriented data has been the various utility industries and municipalities who need to plan and manage their infrastructure facilities and property assets. This automated mapping/facilities management, or AM/FM, concept is being used successfully today by many cities, counties, and utility industries, who may have embarked on the transition as much as 15 years ago. Successful practitioners of GIS can satisfy the needs of a broad spectrum of users with a single system, minimizing the duplication of resources required to support historically independent user groups.

All other components of surveying engineering contribute to the construction of a GIS. The range of survey methods, from classical to modern geodesic and space-based technologies, provide the required reference framework. Digital mapping provides an efficient technology to populate the GIS with spatial information. Remote sensing techniques applied to the earth and its environment provide the various thematic layers of information.

Scope of This Section of the Handbook

The scope of Section VII, Surveying Engineering, in this handbook is to present the reader with the basic information involved in the performance of different surveying engineering projects. As was mentioned earlier, this is a discipline of many areas, each of which will be covered in a separate chapter. The underlying mathematical concepts used by the different areas of surveying engineering are covered first in Chapter 53, followed by four chapters covering, in sequence, plane surveying, geodesy, photogrammetry and remote sensing, and geographic information systems. Of particular importance is the topic on measurements, their errors, and least squares adjustment of redundant data. Since surveying is fundamentally a measurement science, all phases are covered: preanalysis (design), data acquisition (observations), data preprocessing, data adjustment, and postadjustment analysis of the results (quality assessment). Each engineering surveying project must properly execute these phases.