Chapter 5: Total Station and GPS Surveying

Introduction

Modern surveying has witnessed a revolutionary transformation with the advent of electronic and satellite-based instruments. Two significant innovations—**Total Station** and **Global Positioning System (GPS)**—have largely replaced conventional instruments in the field of geospatial data acquisition. This chapter delves into the components, principles, methodologies, and applications of Total Station and GPS, which are vital tools in the domain of Geo-Informatics and Civil Engineering surveying tasks.

5.1 Total Station

5.1.1 Definition and Overview

A **Total Station** is an integrated surveying instrument that combines the functions of an electronic theodolite, an electronic distance measuring device (EDM), and a microprocessor. It is capable of measuring horizontal and vertical angles as well as sloping distances from the instrument to a particular point.

5.1.2 Components of a Total Station

- **Electronic Theodolite**: Measures horizontal and vertical angles.
- **EDM (Electronic Distance Measurement)**: Measures the distance using electromagnetic waves.
- **Microprocessor and Memory**: Processes and stores the observed data.
- **Display and Keyboard**: For inputting commands and viewing data.
- **Optical Plummet**: For centering over the ground station mark.
- **Battery Pack**: Provides power for operation.
- **Tribrach and Levelling Screws**: Used for precise leveling and centering.

5.1.3 Working Principle

The Total Station works by measuring angles and distances electronically. It sends a modulated infrared or laser signal to a prism located at the surveyed point. The EDM unit calculates the time it takes for the signal to return and computes the slope distance. With internal trigonometric functions, it converts slope distance and angles into horizontal and vertical distances.

5.1.4 Features and Capabilities

- Measurement of horizontal and vertical angles.
- Distance measurement with high precision (up to 1 mm + 1 ppm).

- Onboard computation for coordinate calculation.
- Capability to store thousands of readings digitally.
- Interface with data collectors or USB for data transfer.
- Remote object tracking and reflectorless measurement in some models.

5.1.5 Field Procedure of Total Station Survey

1. **Setting up the Total Station** on a tripod and leveling it.
2. **Centering** the instrument using the optical plummet.
3. **Inputting station data** (coordinates, instrument height).
4. **Sighting the prism** and measuring angle and distance.
5. **Recording and storing** data.
6. **Transferring data** to computers for post-processing.

5.1.6 Applications of Total Station

- Topographic surveying.
- Road and highway alignment.
- Construction site layout.
- Monitoring deformations in structures.
- Tunnel and bridge surveying.
- GIS data collection.

5.2 GPS Surveying

5.2.1 Overview of GPS

The **Global Positioning System (GPS)** is a satellite-based navigation system that provides geolocation and time information anywhere on Earth. It is a vital tool for high-precision geospatial positioning in surveying.

5.2.2 Components of GPS

- **Space Segment**: Consists of at least 24 satellites orbiting the Earth.
- **Control Segment**: Ground-based stations that monitor, manage, and control satellite operations.
- **User Segment**: GPS receivers used to collect signals and compute position, velocity, and time.

5.2.3 Principles of GPS Operation

GPS works by calculating the distance between the receiver and multiple satellites. Using **trilateration**, the position is determined by knowing:

- The location of at least 4 satellites.
- The time it takes for the satellite signals to reach the receiver.

5.2.4 Types of GPS Surveying

1. **Static GPS Surveying**
   - Requires long observation times.
   - Used for control surveys and high-accuracy applications.
   - Involves two or more receivers at known and unknown points.
2. **Kinematic GPS Surveying**
   - Suitable for moving platforms.
   - Faster data collection but slightly less accurate than static.
3. **Real-Time Kinematic (RTK) Surveying**
   - Provides real-time correction via a base station.
   - Accuracy up to centimeter level.
   - Requires continuous communication (radio or cellular).
4. **Differential GPS (DGPS)**
   - Utilizes a fixed base station with known coordinates.
   - Base station transmits correction signals to the rover GPS unit.
   - Used in hydrographic and GIS applications.

5.2.5 Sources of GPS Error

- **Ionospheric and tropospheric delay**
- **Satellite clock errors**
- **Multipath effects**
- **Receiver noise**
- **Orbital errors (ephemeris)**

5.2.6 GPS Accuracy and Precision

GPS accuracy varies based on:

- Type of equipment (survey-grade vs. navigation-grade)
- Observation time
- Number and geometry of satellites (PDOP)
- Use of correction techniques (RTK/DGPS)

5.2.7 Advantages of GPS in Surveying

- Global coverage and availability.
- Operable in any weather condition.
- High accuracy with proper techniques.
- Faster data collection and processing.
- Reduces manpower and logistics.

5.2.8 Limitations of GPS Surveying

- Signal obstructions in urban canyons or forests.
- Vulnerable to multipath errors.
- Requires visibility of a minimum number of satellites.
- Dependence on battery and communication for RTK.

5.3 Integration of Total Station and GPS

5.3.1 Hybrid Surveying Methods

Surveyors often combine Total Station and GPS to optimize efficiency and accuracy. GPS provides global coordinates, while Total Stations offer localized, precise measurements in areas where GPS signals may be weak.

5.3.2 Applications of Integrated Surveying

- Large-scale topographic surveys.
- Construction projects involving georeferenced site layouts.
- Monitoring ground deformation and settlement.
- Highway and railway corridor mapping.

5.3.3 Data Transfer and Processing

- Data from both instruments are imported into GIS or CAD platforms.
- Coordinate transformations and adjustments are performed.
- Field-to-finish solutions are adopted using software like AutoCAD, Civil 3D, or ArcGIS.

5.4 Future Trends and Advancements

5.4.1 Robotic Total Stations

These allow one-person operation with motorized tracking of the prism, eliminating the need for multiple field personnel.

5.4.2 GNSS instead of GPS

Modern systems now use **GNSS (Global Navigation Satellite Systems)** that integrate GPS, GLONASS, Galileo, and BeiDou for higher accuracy and reliability.

5.4.3 Cloud-Based Data Management

Surveying data can now be synced directly to cloud platforms, enabling real-time collaboration and remote access.

5.4.4 Integration with Drones and LiDAR

UAV-based systems are integrated with GPS and Total Station data for advanced 3D modeling and mapping.

5.5 Instrument Calibration and Error Management

5.5.1 Importance of Calibration

Surveying instruments like Total Stations and GPS receivers must be calibrated regularly to maintain precision. Calibration ensures that instrumental, systematic, and environmental errors are accounted for, especially in high-stakes engineering projects.

5.5.2 Calibration of Total Station

- **Collimation Error Check**: Verifying the alignment of optical axis with the mechanical axis.
- **Horizontal and Vertical Angle Calibration**: Comparing observed angles with known angular references.
- **EDM Calibration**: Checking distance measurement against a standard baseline.
- **Plummet Check**: Ensuring optical or laser plummet is correctly aligned with the vertical axis.

5.5.3 Calibration of GPS Equipment

- **Baseline Check**: Comparing measurements over known distances.
- **Antenna Height Verification**: Ensuring correct input of antenna height to avoid elevation errors.
- **Receiver Firmware Update**: Keeping the device updated to minimize computational and satellite decoding errors.
- **Environmental Conditions**: Adjusting for temperature, humidity, and satellite constellation status.

5.6 Data Processing and Coordinate Systems

5.6.1 Raw Data Processing

Both Total Station and GPS generate raw data (angles, distances, time stamps, satellite positions, etc.) which must be processed into meaningful geographic coordinates. This is done using surveying software like:

- Leica Geo Office
- Trimble Business Center

- AutoCAD Civil 3D
- ArcGIS/ArcMap

5.6.2 Coordinate Systems and Transformations

Survey data needs to be referenced to a coordinate system for geospatial consistency. Common systems used include:

- **UTM (Universal Transverse Mercator)**
- **WGS 84 (World Geodetic System 1984)**
- **Local State Plane or Arbitrary Coordinate Systems**

Transformation between coordinate systems is necessary when integrating data from GPS and Total Station.

5.6.3 Datum and Projection Considerations

- **Datum**: A reference point or surface from which measurements are made (e.g., WGS84, NAD83).
- **Map Projections**: Transforming the curved Earth surface to a flat map (e.g., UTM, Lambert Conformal Conic).

Proper understanding of datum shifts and projection parameters is essential when integrating datasets from multiple sources.

5.7 Legal, Ethical, and Safety Considerations

5.7.1 Surveying Regulations

Surveyors must follow national and regional surveying standards, especially when the data is used for land registration, construction, or legal boundaries.

- Adherence to **Survey of India** guidelines.
- Use of **approved geodetic benchmarks**.
- Following **municipal codes** and **land record standards**.

5.7.2 Data Privacy and Security

GPS data, especially when used for mapping sensitive infrastructure, must be securely stored and transmitted. Unauthorized sharing of coordinates, especially in defense or restricted zones, is illegal in many countries.

5.7.3 Occupational Safety

- **Total Station setup on roads or construction sites** must follow safety protocols (cones, vests, signage).
- **Lightning hazards** when using metal tripods or GPS poles in open fields.

- Ergonomic handling to avoid strain injuries due to prolonged instrument use.

5.8 Case Studies and Real-World Applications

5.8.1 Highway Alignment Survey Using Total Station and GPS

A national highway alignment was surveyed using DGPS for control points and Total Station for detailed cross-sections. The integration allowed high-accuracy corridor planning and minimized resurvey costs.

5.8.2 Dam Monitoring with Robotic Total Station

In a hydroelectric dam project, robotic Total Stations were used to monitor deformation in the structure due to seasonal water level changes. The system triggered alerts when readings crossed safety thresholds.

5.8.3 Urban Planning Using GPS-GIS Integration

In a metropolitan city, GPS data from handheld receivers was used to collect land use information. This was integrated with GIS to develop zoning maps and infrastructure planning.
