Chapter 12: Total Station Surveys

Introduction

Modern surveying has undergone a technological transformation with the integration of electronic systems, and at the forefront of this evolution stands the **Total Station**. A **Total Station** is an electronic/optical instrument used in modern surveying and building construction that integrates an **electronic theodolite**, an **electronic distance meter (EDM)**, and a **microprocessor-based data collector and storage system**. It enables surveyors to measure both **horizontal and vertical angles**, **sloping distances**, and to compute **coordinates** with high precision and efficiency. Total Station surveys have revolutionized traditional methods, offering rapid data collection, high accuracy, and extensive functionality, thus playing a critical role in geospatial data acquisition for civil engineering projects.

12.1 Components of a Total Station

A Total Station is a highly integrated device composed of the following key components:

12.1.1 Electronic Theodolite

- Measures **horizontal and vertical angles** with high accuracy.
- Contains an **optical telescope**, **vertical circle**, and **horizontal circle**.
- Angular measurement resolution can go up to **1" or 0.1 mgon**.

12.1.2 Electronic Distance Meter (EDM)

- Measures **slant distance** between the instrument and a reflector (or prism).
- Operates using **infrared or laser waves**.
- Typical accuracy: **±(2 mm + 2 ppm)** for prism-based EDMs.

12.1.3 Microprocessor and Memory

- Controls instrument functions and stores survey data.
- Performs **on-board calculations** (e.g., coordinates, area).
- Allows **coding**, **note-taking**, and **automatic data logging**.

12.1.4 Display and Keyboard

- LCD screen displays readings and functions.
- Keyboard for user input, menu navigation, and operation commands.

12.1.5 Battery Pack

- Rechargeable batteries provide operational power.
- Battery life ranges from **6–10 hours**, depending on model and use.

12.2 Working Principle of Total Station

Total Stations operate by combining angle and distance measurements to compute the precise location of a point. The working principle involves the following steps:

1. **Distance Measurement** using EDM via a modulated infrared or laser beam.
2. **Angle Measurement** using the theodolite.
3. **Coordinate Calculation** using the trigonometric relationships:
   - $X = D \cdot \cos(\theta) \cdot \cos(\alpha)$
   - $Y = D \cdot \cos(\theta) \cdot \sin(\alpha)$
   - $Z = D \cdot \sin(\theta)$
4. **Data Storage** into internal/external memory for further processing.

12.3 Setting Up and Operating a Total Station

12.3.1 Instrument Setup

- Fix the **tripod** on firm ground.
- Mount the **Total Station** securely on the tripod.
- Use the **optical or laser plummet** to center over the survey station.
- Perform **leveling** using circular and electronic levels.

12.3.2 Initialization

- Power on the device.
- Select the **survey job or create a new file**.
- Input known **instrument and backsight coordinates**.

12.3.3 Orientation and Measurement

- Sight the **backsight point** and measure the angle.
- Turn to the **target/prism** to record observations.
- Use **single shot** or **continuous tracking** mode for data acquisition.

12.4 Data Acquisition and Storage

- **Raw data** collected includes angles, distances, and time stamps.
- Total Stations can store **thousands of points** internally.
- Some models support **external SD cards**, **USB**, or **Bluetooth** for transfer.
- Data can be **coded** with point names, descriptions, and feature types.

12.5 Coordinate Computation and Adjustment

- Internal processor calculates:
  - **Horizontal distance (HD)**
  - **Vertical height difference (VD)**
  - **Slope distance (SD)**
  - **Northing (Y), Easting (X), and Elevation (Z)**
- Coordinates are adjusted using:
  - **Least squares method** for control networks.
  - **Traverse closure correction**.
  - **Error propagation analysis**.

12.6 Applications of Total Station Surveys

Total Station surveys are applied across numerous domains in civil engineering and geospatial analysis:

12.6.1 Topographic Surveying

- Creation of **contour maps**, **DEM**, and **spot height plans**.

12.6.2 Construction Layout

- Marking exact locations for **pillars**, **buildings**, and **infrastructure**.

12.6.3 Monitoring Structures

- Repeated measurements to detect **displacement**, **subsidence**, or **deformation**.

12.6.4 Road and Railway Alignment

- Setting out curves, gradients, and slopes using stored alignment data.

12.6.5 Volume Computation

- Measuring **cut-and-fill volumes** in excavation and land development.

12.7 Advantages of Total Station Surveys

- **High accuracy** in angle and distance measurements.
- **Fast data collection** and **automatic calculations**.
- **Digital storage** eliminates manual note-taking.
- **Integrated graphical display** helps visualization in the field.
- **Efficient error checking and correction** capabilities.

12.8 Limitations and Errors in Total Station Surveying

12.8.1 Instrumental Errors

- Calibration errors in EDM or theodolite.
- Misalignment of optical axis.

12.8.2 Environmental Errors

- Atmospheric conditions (temperature, pressure, humidity).
- Heat shimmer and fog affecting laser path.

12.8.3 Personal and Setup Errors

- Incorrect leveling or centering.
- Improper use of prism or target.

12.9 Recent Trends in Total Station Technology

12.9.1 Robotic Total Stations

- Operated by a single person via **remote control**.
- **Autotracking** and **auto-target recognition**.

12.9.2 Reflectorless Total Stations

- Measures distance without using a prism.
- Ideal for inaccessible or hazardous targets.

12.9.3 Integration with GNSS and GIS

- Combines **satellite positioning** with **high-precision EDM**.
- Field data can be exported to **GIS databases** directly.

12.10 Maintenance and Calibration

- **Routine cleaning** of lenses and display.
- Regular **firmware updates** for enhanced performance.
- Periodic **calibration checks** to ensure accuracy.
- **Battery care** and storage in dry, shockproof cases.

12.11 Total Station Survey Procedures – Step-by-Step Field Methodology

A standard **field procedure** for conducting a Total Station survey involves the following sequence:

12.11.1 Reconnaissance and Planning

- Visit the site to identify **control points**, **line-of-sight**, and **obstructions**.
- Establish a **survey control network** or use **existing geodetic control stations**.
- Plan **data collection route**, **number of stations**, and **data types**.

12.11.2 Establishing Control Points

- Fix **permanent control markers** (e.g., concrete pillars, pegs).
- Record initial **coordinates**, or set using GPS or previous survey data.

12.11.3 Instrument Station Setup

- Place and level the Total Station over a control point.
- Perform **instrument orientation** using known coordinates or resection.

12.11.4 Observation and Data Collection

- Use **standard coding** for topographic features (trees, walls, drains).
- Collect data in **auto-mode** or **manual prism mode** based on terrain.
- For detail points, record **offset distances**, **object types**, and **notes**.

12.11.5 Daily Field Checks

- Perform **repeat measurements** for verification.
- Check **prism constants**, **atmospheric settings**, and **zero errors**.

12.12 Post-Processing and Data Analysis

12.12.1 Data Transfer

- Transfer field data to a computer using **USB, SD card**, or **wireless transfer**.
- Use manufacturer software (e.g., Leica Geo Office, Trimble Business Center).

12.12.2 Processing Software

- Perform computations of:
  - **Traverse adjustment**
  - **Spot height interpolation**
  - **Contour generation**
- Commonly used software includes:
  - **AutoCAD Civil 3D**
  - **MicroSurvey STAR*NET**
  - **Surfer**, **QGIS** for GIS integration

12.12.3 Output Generation

- Create:
  - **Topographic maps**
  - **Alignment drawings**
  - **Digital Terrain Models (DTMs)**
  - **Cross-sections and longitudinal profiles**

12.13 Integration with Other Surveying Technologies

12.13.1 GNSS and Total Station

- Combine **GNSS for global coordinates** and **Total Station for precision**.
- Used in areas with **limited satellite visibility** (urban canyons, forests).

12.13.2 GIS and Total Station

- Export survey data into **GIS platforms** for thematic mapping.
- Attribute data like **land use**, **utilities**, or **ownership** can be linked to spatial data.

12.13.3 UAV/Drone-Based Surveys

- Use Total Station data to **geo-reference drone imagery**.
- Cross-verify **UAV point clouds** with ground survey data.

12.14 Safety and Best Practices in Total Station Surveying

12.14.1 Equipment Handling

- Avoid exposure to **dust, water**, or **extreme temperatures**.
- Transport equipment in **padded, waterproof cases**.
- Use **tripod stabilizers** on uneven or windy terrain.

12.14.2 Personal Safety

- Wear **reflective jackets**, especially near roads or construction sites.
- Avoid standing in **laser beam paths**.
- Follow site-specific **safety protocols** for confined spaces or elevated locations.

12.14.3 Data Integrity

- Maintain **backup copies** of raw and processed data.
- Use **field notes** as a backup to digital logging.
- Calibrate and test instruments before each new project.

12.15 Standard Specifications and Accuracy Standards

12.15.1 Instrument Accuracy

Parameter	Typical Value
Angle Measurement	±1” to ±5”
Distance (prism-based)	±(2 mm + 2 ppm)
Distance (reflectorless)	±(3 mm + 2 ppm)

12.15.2 Classification by ISO Standards

- **ISO 17123-3**: Field procedures for testing geodetic and surveying instruments (theodolites and Total Stations).
- **ISO 9849**: EDM instrument performance testing.

12.16 Common Field Problems and Troubleshooting

Problem	Likely Cause	Solution
No distance reading	Prism not aligned or wrong constant	Recheck prism position and settings
Angle errors	Instrument not leveled	Re-level and re-center the instrument
Inaccurate coordinates	Wrong backsight or station input	Re-input station and orientation data
Reflectorless mode fails	Surface too absorbent or angled	Use prism or re-orient target surface
Data not saving	Memory full or error in data card	Clear memory or replace storage media