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| Vision of the Institute | Mission of the Institute |
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| "To become a leading institute of providing professionally competent and socially responsive technocrats with high moral values." | ⇨ To create an eco-system for the dissemination of technical knowledge, to achieve academic excellence.<br>⇨ To develop technocrats with creative skills and leadership qualities, to solve local and global challenges.<br>⇨ To impart human values and ethics in students, to make them socially and Eco-friendly responsible. |

# LAB MANUAL
# OF
# CAD LAB

# [BCE 551]

## B.TECH, 3rd Year, Semester -5th

Dr. A.P.J. Abdul Kalam Tech. University
Uttar Pradesh

## 2025-26
## Department of Civil Engineering

Faculty Name: Mr. Mohit Choubey

(Assistant Professor)

Approved by: (Head of the Department)

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# MANUAL CONTENTS

This manual is intended for the 3rd year students of Civil Engineering in the subject of CAD Lab. This manual typically contains practical/lab sessions related to the use of the latest versions of surveying and geotechnical engineering software, including both open-source and commercial applications, for enhanced understanding of modern civil engineering practices and analysis techniques.

Students are advised to thoroughly go through this manual rather than only focusing on topics mentioned in the syllabus, as practical exposure to engineering software is essential for understanding, visualizing, and applying theoretical concepts in real-world civil engineering projects.

The laboratory sessions are designed to help students gain hands-on experience in drafting, surveying data analysis, terrain modeling, and geotechnical problem-solving using advanced software tools. These practical exercises will also help students develop technical, analytical, and problem-solving skills required in professional engineering practice.

Good Luck for your Enjoyable Laboratory Sessions.

# *PREFACE*

This practical manual will be helpful for students of Civil Engineering for understanding the course from the point of view of applied aspects. Though all the efforts have been made to make this manual error free, yet some errors might have crept in inadvertently. Suggestions from the readers for the improvement of the manual are most welcomed.

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# VISION OF THE DEPARTMENT

To impart academic excellence in civil engineering field with emphasis on holistic development of the professional, while inculcating ethics, socially and professionally responsive technocrats.

# MISSION OF THE DEPARTMENT

- **M1** – To provide a comprehensive platform for academic expertise and proficiency.
- **M2** – To develop civil engineering professionals with creative skills and leadership qualities in order to face regional and global challenges.
- **M3** – To develop ethics in students in order to promote socially responsible environmental awareness with innovative thinking.

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## Program Educational Objectives(PEOs ) of Department

**PEO 1:** To develop capacities and proficiency in the field of Civil engineering field towards improving employability attitude.
**PEO 2:** To develop multidisciplinary approach through sophisticated tools/information system, construction projects and data bases to meet the social requirements.
**PEO 3:** To utilize basic knowledge in the actual working conditions as a contribution towards safe and sustainable society.

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# Program Outcomes:(PO)

Graduates will be able to achieve

- **PO1: Engineering Knowledge**

  Apply the knowledge of mathematics, science, engineering fundamentals, and engineering specialization to solve complex engineering problems.
- **PO2: Problem Analysis**

  Identify, formulate, review research literature, and analyze complex engineering problems using first principles of mathematics, natural sciences, and engineering sciences.
- **PO3: Design / Development of Solutions**

  Design solutions for complex engineering problems and design system components or processes that meet specified needs with appropriate consideration for public health, safety, cultural, societal, and environmental aspects.
- **PO4: Conduct Investigations of Complex Problems**

  Use research-based knowledge and methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.
- **PO5: Modern Tool Usage**

  Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modeling, with an understanding of their limitations.
- **PO6: The Engineer and Society**

  Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal, and cultural issues and responsibilities relevant to professional engineering practice.
- **PO7: Environment and Sustainability**

  Understand the impact of professional engineering solutions in societal and environmental contexts and demonstrate knowledge of sustainable development.
- **PO8: Ethics**

  Apply ethical principles and commit to professional ethics, responsibilities, and norms of engineering practice.
- **PO9: Individual and Team Work**

Function effectively as an individual and as a member or leader in diverse teams and multidisciplinary settings.

- **PO10: Communication**

  Communicate effectively on complex engineering activities with the engineering community and society through reports, presentations, and clear instructions.

- **PO11: Project Management and Finance**

  Demonstrate knowledge and understanding of engineering management principles and apply them to manage projects and multidisciplinary environments.

- **PO12: Life-long Learning**

  Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

## Program Specific Outcomes(PSOs) of the Department

- **PSO 1:** Graduates shall be able to apply critical thinking in research, design, analysis and implementation of Civil Engineering problems.
- **PSO2:** Graduate shall be able to inculcate the idea of sustainability in engineering solution to meet real world Challenges.

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# Course Evaluation Scheme

| Sr No | Subject Code | Subject Name | Periods | | | Evaluation Scheme | | | | Total | Credit |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Sessional Assessment | | | | | |
| | | | L | T | P | CT | TA | PS | PE | | |
| 1. | BCE551 | CAD Lab | 0 | 0 | 2 | - | 50 | - | 50 | 100 | 1 |

# Course Objectives:

*The teacher will explain:*

| | |
|---|---|
| 1. | To develop practical knowledge and hands-on experience in using the latest geotechnical, structural, and surveying software for civil engineering applications. |
| 2. | To understand the analysis, modeling, drafting, and interpretation of engineering data using open-source and commercial software tools. |
| 3. | To enhance technical, analytical, and problem-solving skills through the application of modern engineering software in real-life civil engineering projects. |

***Pre- requisite:*** Basic knowledge of Civil Engineering drawing, surveying concepts, geotechnical engineering principles, soil mechanics, computer operations, engineering data interpretation, and basic familiarity with QGIS and GEO5.

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# Course Outcomes (COs)

| **Course Outcomes:** The students should be able to: | | **Bloom's Level** |
|---|---|---|
| **CO1** | Students will be able to work on Geo 5 /PLAXIS/STAAD Pro /Etabs software. | L4 |
| **CO2** | Students will be able to work on QGIS software. | L4 |
| **CO3** | Students will be able to design and analyze Cantilever, Gravity wall retaining wall using geotechnical engineering software/design and analysis of multistory building using Structural analysis and design software. | L4 |
| **CO4** | Students will be able to Geo reference a given map using QGIS softwares. | L4 |
| **CO5** | Students will be able to Prepare maps using QGIS. | L4 |

# CO-PO-PSO Mapping

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 | PSO1 | PSO2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | **2** | **1** | **1** | – | **3** | **1** | – | – | **2** | **2** | - | **1** | **1** | **1** |
| CO2 | **2** | **1** | – | – | **3** | – | - | – | **2** | **2** | – | **1** | **1** | **1** |
| CO3 | **2** | **1** | **1** | - | **3** | **1** | **1** | – | **2** | **2** | – | **1** | **2** | **1** |
| CO4 | **1** | – | – | – | **3** | – | - | – | **2** | **2** | – | **1** | **1** | - |
| CO5 | **1** | **1** | – | **2** | **3** | **1** | **1** | – | **2** | **2** | – | **1** | **1** | **1** |
| Avg. | **1.6** | **1** | **1** | **2** | **3** | **1** | **1** | - | **2** | **2** | - | **1** | **1.2** | **1** |

The extent of mapping is as follows: 1 for low, 2 for moderate, 3 for high &"-" for No correlation between CO & PO.

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# List of Experiments

| S. No. | Experiment |
|---|---|
| **1.** | Working on latest version of geotechnical engineering software, structural engineering software (Open source/commercial software). |
| **2.** | Working on latest version of surveying software (Open source/commercial software). |

**Beyond Syllabus**:

NA

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# INDEX

| S. No. | Name of the Experiment | CO | BTL | Lab Conduction Date | Remark/ Grade/ Marks | Faculty Signature with Date |
|---|---|---|---|---|---|---|
| 1. | GEO5 Interface Study | CO1 | L2 | | | |
| 2. | Bearing Capacity Analysis | CO2 | L3 | | | |
| 3. | Slope Stability Analysis | CO2 | L4 | | | |
| 4. | Retaining Wall Design | CO3 | L3 | | | |
| 5. | ETABS Software Interface Study and Basic Structural Modeling | CO1 | L4 | | | |
| 6. | Foundation Analysis | CO2 | L4 | | | |
| 7. | QGIS Interface Study | CO4 | L2 | | | |
| 8. | Contour Map Preparation | CO5 | L3 | | | |
| 9. | Layer Management | CO5 | L3 | | | |
| 10. | Coordinate Plotting | CO5 | L3 | | | |
| 11. | Spatial Data Analysis | CO3 | L4 | | | |

**Software's required:**

GEO5, QGIS, STAAD.Pro, ETABS, Windows Operating System.

## Hardware's required:

Computer System with Intel i3/i5 Processor, minimum 4 GB RAM, minimum 20 GB free storage space, mouse, keyboard, internet connectivity, printer/plotter (if required).

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# Do's

1. Follow the laboratory instructions carefully.
2. Maintain proper handling of computer systems and software.
3. Save work regularly during practical sessions.
4. Use licensed/open-source software properly.
5. Keep the laboratory clean and disciplined.
6. Shut down the system properly after use.

# Don'ts

1. Do not install unauthorized software.
2. Do not change system settings without permission.
3. Do not delete laboratory files or data.
4. Do not use external storage devices without permission.
5. Do not mishandle computer hardware or accessories.
6. Do not leave the computer system running unattended.

# Detailed Lab Manual (Geotechnical Engineering & GIS Lab)

## Experiment 1: GEO5 Interface Study

### Objective

To study the GEO5 software interface, understand its tools, menus, and various geotechnical analysis modules used in civil engineering design.

### Theory

GEO5 is a professional geotechnical engineering software package widely used for the design and analysis of soil-structure interaction problems. It is developed to assist civil and geotechnical engineers in performing accurate and reliable calculations based on internationally accepted engineering standards and geotechnical theories.

The software consists of multiple specialized modules, each dedicated to solving specific engineering problems. Some commonly used modules include:

- **Spread Footing Design** – Used for designing shallow foundations and checking bearing capacity, settlement, and reinforcement requirements.
- **Pile Foundation Analysis** – Used for pile capacity, settlement, and pile group behavior analysis.
- **Retaining Wall Design** – Used for analyzing earth pressure, wall stability, sliding, overturning, and structural safety.
- **Slope Stability Analysis** – Used for evaluating natural and man-made slopes using methods such as Bishop, Fellenius, and Janbu.
- **Settlement Analysis** – Used to estimate immediate and consolidation settlement in soil layers.
- **Earthquake Analysis Modules** – Used for dynamic and seismic geotechnical design.

GEO5 applies several standard geotechnical engineering theories and methods, including:

- **Terzaghi's Bearing Capacity Theory** for foundation design.
- **Coulomb and Rankine Earth Pressure Theories** for retaining structures.
- **Bishop's Method of Slices** for slope stability calculations.
- **Elastic and Consolidation Settlement Theories** for deformation analysis.
- **Limit State Design Principles** for structural safety checks.

The software offers an interactive graphical interface that allows users to input soil properties, define structural dimensions, apply loading conditions, and generate analytical results with diagrams and reports. Understanding the GEO5 interface is essential before performing any advanced geotechnical design because it helps users navigate efficiently, reduce errors, and interpret engineering outputs accurately.

## Apparatus/Software Required

The following tools and resources are required to perform this experiment:

- Computer or Laptop with sufficient processing capability
- GEO5 software installed and licensed
- Operating system compatible with GEO5 (Windows recommended)
- Sample soil investigation data
- Internet connection (optional for updates and help documentation)
- Laboratory manual for reference

## Procedure

### Step 1: Launching GEO5 Software

Open the GEO5 software from the desktop shortcut or installed applications menu. Wait for the software to initialize and load the main dashboard.

### Step 2: Study of Main Interface

Observe the various components of the GEO5 interface, including:

- **Title Bar:** Displays project name and active module.
- **Menu Bar:** Contains options such as File, Edit, View, Settings, Help, and Analysis tools.
- **Toolbar:** Provides quick-access icons for common operations like save, open, calculate, and print.
- **Project Explorer:** Displays project files and module hierarchy.
- **Workspace Area:** Main area where data entry and graphical modeling are performed.
- **Status Bar:** Shows calculation status and software messages.

### Step 3: Exploring the File Menu

Open the **File** menu and study options such as:

- New Project
- Open Existing Project
- Save Project
- Import/Export Data
- Print Reports
- Close Project

Create a sample project and save it in the desired folder.

### Step 4: Opening Different GEO5 Modules

Access and open various modules to understand their purpose:

- Spread Footing
- Retaining Wall
- Slope Stability
- Pile Foundation
- Settlement Analysis

Observe how each module has a separate interface tailored for specific engineering calculations.

**Step 5: Inputting Soil Parameters**
Navigate to the input panels and study how to enter geotechnical properties such as:

- Soil type
- Unit weight
- Cohesion (c)
- Angle of internal friction (φ)
- Young's modulus
- Groundwater level

Learn how these parameters influence calculations.

**Step 6: Defining Loading Conditions**
Enter structural loading data including:

- Vertical load
- Horizontal load
- Moment
- Eccentricity

Observe how loading affects design outputs.

**Step 7: Running Analysis**
Click on the **Calculate** or **Analyze** button to run the geotechnical simulation.

**Step 8: Observing Results**
Review output sections such as:

- Safety factor values
- Bearing capacity results
- Settlement values
- Stability diagrams
- Failure surfaces

**Pressure distribution graphs**

**Step 9: Report Generation**

Use the report generation feature to create detailed engineering reports containing:

- Input data summary
- Calculation steps
- Graphical results
- Design conclusion

---

## Observation

During the experiment, the following observations were made:

- GEO5 provides an intuitive and user-friendly graphical interface.
- Navigation between modules is simple and efficient.
- Different geotechnical analysis modules are available for specialized tasks.
- Soil and load parameters can be entered systematically.
- Graphical visualization improves understanding of engineering behavior.
- Calculation results are generated quickly and accurately.
- Detailed professional reports can be exported in printable formats.
- Error-checking features help prevent incorrect data entry.

---

## Result

The GEO5 software interface was successfully studied and understood. The major menus, tools, modules, input panels, and result sections were explored in detail. Familiarity with the GEO5 environment was achieved, providing a strong foundation for performing advanced geotechnical engineering analysis and design in future experiments.

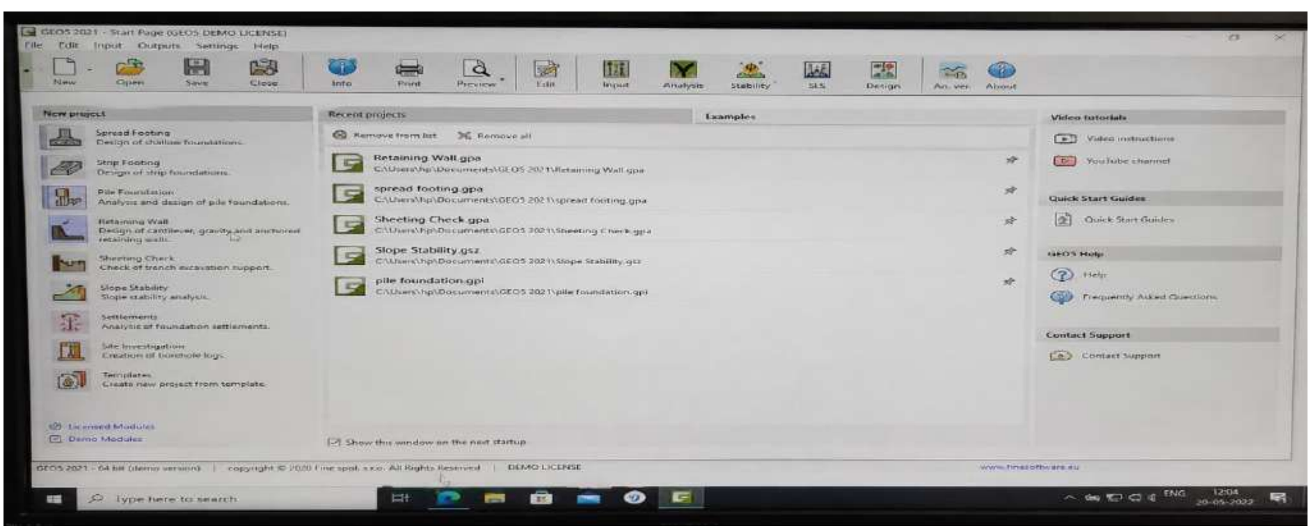


**Figure 1:** GEO5 Main Interface with Toolbar and Modules

# Experiment 2: Bearing Capacity Analysis

## Objective

To determine the safe bearing capacity of soil using GEO5 software.

## Theory

Bearing capacity refers to the ability of soil to support loads imposed by structures without undergoing shear failure or excessive settlement. It is one of the most important parameters in foundation design. The ultimate bearing capacity can be calculated using theories developed by Terzaghi, Meyerhof, and Hansen. GEO5 simplifies this process by allowing engineers to input soil properties such as cohesion (c), angle of internal friction (φ), and unit weight (γ), and then calculates ultimate and allowable bearing capacities.

### Apparatus/Software Required

- GEO5 software
- Soil test data
- Foundation dimensions

### Procedure

1. Open GEO5 and select the Bearing Capacity module.
2. Enter soil properties: cohesion, friction angle, and unit weight.
3. Input foundation dimensions and depth.
4. Apply structural load conditions.
5. Run the analysis.
6. Examine ultimate and allowable bearing capacity results.

### Observation

- Soil failure pattern can be visualized.
- Bearing capacity values are automatically computed.

### Result

The safe bearing capacity of the given soil was calculated successfully.

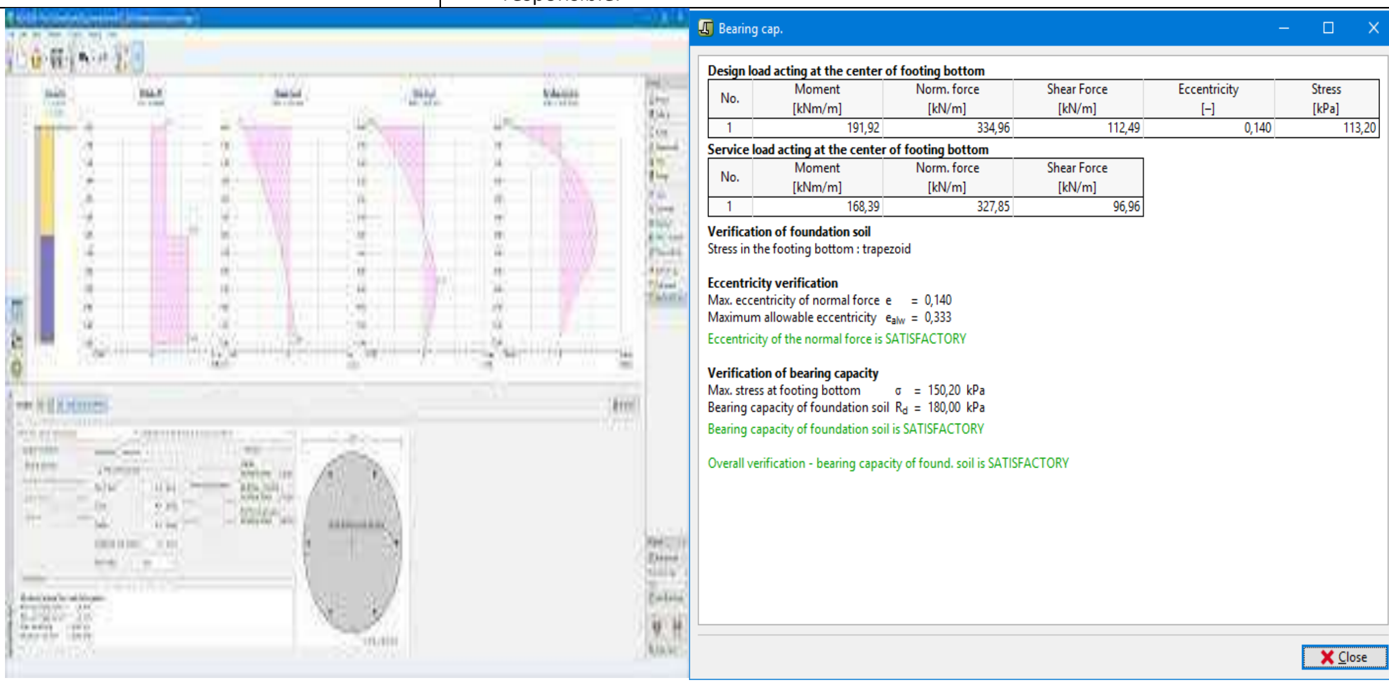



**Figure 2:** Bearing Capacity Analysis Result Screen

# Experiment 3: Slope Stability Analysis

**Objective**

To evaluate slope safety and determine the factor of safety against slope failure.

**Theory**

Slope stability analysis is an essential part of geotechnical engineering used to assess whether a slope is stable or prone to failure. Slopes may be natural (such as hillsides and embankments) or man-made (such as highway cuttings, earth dams, and retaining embankments). Failure of a slope can occur due to several factors including:

- Excessive gravitational forces acting on the soil mass
- Weak soil strength or low cohesion
- Increase in pore water pressure due to groundwater or rainfall
- External loads such as buildings, vehicles, or surcharge loads
- Earthquakes or vibrations

The primary objective of slope stability analysis is to calculate the **Factor of Safety (FoS)**, which represents the ratio of resisting forces (shear strength of soil) to driving forces (forces causing movement).

Factor of Safety (FoS)=Resisting ForcesDriving ForcesFactor\ of\ Safety\ (FoS)=\frac{Resisting\ Forces}{Driving\ Forces}Factor of Safety (FoS)=Driving ForcesResisting Forces

- **FoS > 1.5** → Slope is considered stable and safe.
- **FoS = 1.0–1.5** → Slope is marginally stable and may require monitoring or reinforcement.
- **FoS < 1.0** → Slope is unstable and failure is likely to occur.

Modern geotechnical software such as **GEO5 Slope Stability** uses advanced limit equilibrium methods to evaluate slope safety. Common methods include:

1. **Bishop Method**
   A widely used method that assumes circular failure surfaces and provides accurate results for homogeneous soils.
2. **Fellenius (Swedish Circle) Method**
   A simpler method used for preliminary analysis, assuming circular slip surfaces.
3. **Janbu Method**
   Suitable for analyzing both circular and non-circular failure surfaces and layered soil conditions.

The software automatically generates multiple possible slip surfaces and determines the **critical slip surface**, which gives the minimum factor of safety and represents the most likely failure path.

---

**Procedure**

### Step 1: Open the Slope Stability Module

Launch the **GEO5 software** and select the **Slope Stability Analysis** module from the available geotechnical tools.

### Step 2: Define the Slope Geometry

Create the geometric profile of the slope by entering dimensions such as:

- Height of slope
- Inclination angle
- Length of slope
- Bench dimensions (if any)

The slope can be drawn manually or imported from CAD files.

### Step 3: Enter Soil Layer Properties

Define the engineering properties of each soil layer, including:

- Unit weight (γ)
- Cohesion (c)
- Angle of internal friction (φ)
- Elastic modulus (if required)

Multiple soil strata can be assigned different parameters depending on site conditions.

### Step 4: Add Groundwater Conditions

If groundwater is present, define:

- Water table level
- Pore water pressure
- Seepage conditions

Groundwater significantly affects slope stability because it reduces effective stress and shear strength.

### Step 5: Apply External Loads

Input surcharge loads such as:

- Buildings
- Traffic loads
- Retaining structures
- Equipment loads

These additional loads increase driving forces on the slope.

**Step 6: Select Analysis Method**

Choose the appropriate calculation method such as:

- Bishop Simplified Method
- Fellenius Method
- Janbu Method

Different methods may produce slightly different FoS values.

**Step 7: Generate Potential Slip Surfaces**

The software automatically generates several possible circular or non-circular failure surfaces and evaluates each one.

**Step 8: Run the Analysis**

Execute the slope stability calculation. GEO5 computes:

- Critical slip surface
- Minimum factor of safety
- Stability diagrams
- Graphical representation of failure zones

**Step 9: Interpret Results**

Analyze the graphical and numerical output to determine whether the slope is safe or requires stabilization measures such as retaining walls, soil nailing, drainage improvement, or slope flattening.

---

**Observation**

During the analysis, the following observations were recorded:

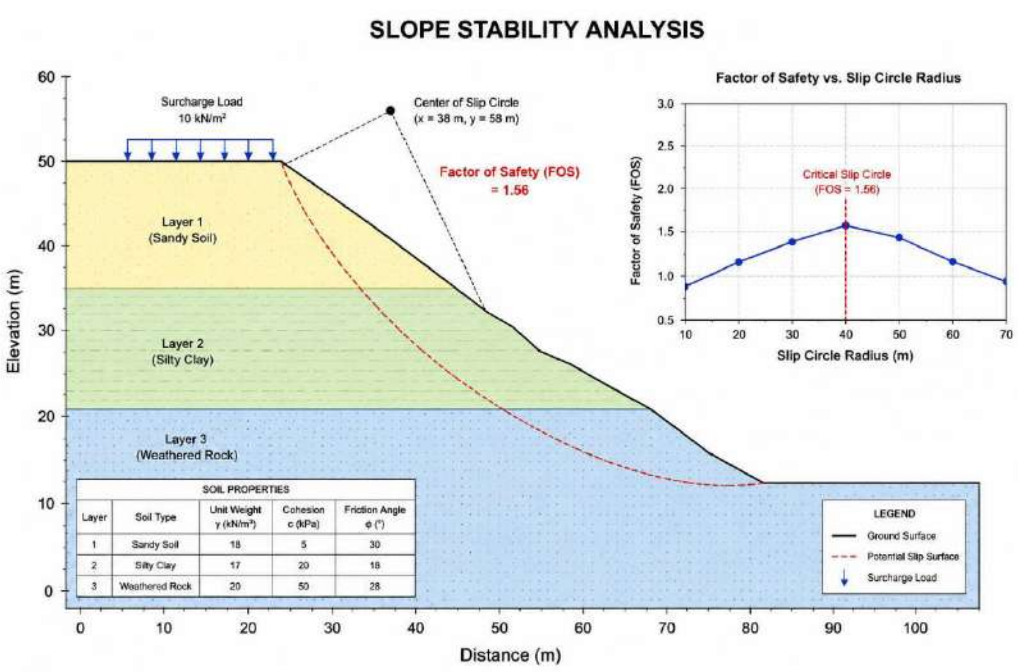
- The software successfully identified the **critical slip surface** representing the most probable failure path.
- Multiple trial slip circles were generated and compared.
- The **minimum Factor of Safety (FoS)** was displayed both numerically and graphically.
- Soil layers and groundwater effects influenced overall slope stability.
- Areas of potential failure were highlighted in the analysis graph.
- Graphical output clearly showed the relationship between slope geometry and stability conditions.
- Stability improved or reduced depending on soil parameters and loading conditions.

---

**Result**

The slope stability analysis was successfully performed using **GEO5 Slope Stability software**. The critical failure surface was identified, and the **minimum factor of safety** was calculated. Based on the obtained FoS value, the slope condition was evaluated as stable/unsafe. The analysis helps engineers design suitable remedial measures to ensure long-term slope safety and prevent landslides or structural failures.

**Slope Stability Analysis Graph**

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# Experiment 4: Retaining Wall Design

## Objective

To design a retaining wall and verify its safety against overturning, sliding, and bearing failure.

## Theory

A **retaining wall** is a structure constructed to retain or support soil at different ground elevations where the natural slope of the ground cannot be maintained. Retaining walls are commonly used in highways, basements, bridge abutments, embankments, and hill-cut constructions.

The primary purpose of a retaining wall is to resist the **lateral earth pressure** exerted by the backfill soil and any additional surcharge loads acting on the retained soil mass.

The design of a retaining wall must ensure safety against the following major failure modes:

### 1. Sliding Failure

Sliding occurs when the lateral earth pressure acting on the wall exceeds the frictional resistance between the base of the wall and the foundation soil, causing the wall to move horizontally.

The factor of safety against sliding is expressed as:

$FoS_{overturning=}$ Resisting Moment/Overturning Moment

A typical acceptable value is:

- **FoS > 1.5** for safe design

---

### 2. Overturning Failure

Overturning happens when the lateral earth pressure creates a moment that causes the wall to rotate about its toe.

The factor of safety against overturning is calculated as:

FoSoverturning=Resisting MomentOverturning MomentFoS_{overturning}=\frac{Resisting\ Moment}{Overturning\ Moment}FoSoverturning=Overturning MomentResisting Moment

Acceptable criteria:

- **FoS > 2.0** for stability

---

### 3. Bearing Capacity Failure

Bearing failure occurs when the pressure beneath the wall foundation exceeds the allowable bearing capacity of the soil, leading to excessive settlement or shear failure.

The design must ensure:

- Maximum base pressure ≤ Allowable soil bearing capacity
- Uniform or acceptable pressure distribution beneath the footing

---

### Earth Pressure Theories Used

To calculate the lateral earth pressure, GEO5 commonly applies the following theories:

### Rankine Earth Pressure Theory

This theory assumes:

- Smooth wall surface
- No wall friction
- Homogeneous backfill soil

It is commonly used for simple retaining wall designs.

---

### Coulomb Earth Pressure Theory

This method considers:

- Wall friction
- Inclined backfill surfaces
- Wall inclination

It provides more realistic results for practical retaining wall analysis.

---

### Components of a Retaining Wall

A typical retaining wall consists of:

- **Stem:** Vertical portion resisting earth pressure
- **Heel:** Base slab extending under retained soil
- **Toe:** Front projection of the base slab
- **Foundation/Base Slab:** Supports the entire structure
- **Drainage System:** Prevents water pressure buildup behind the wall

Proper drainage is essential because water pressure can significantly increase lateral loads.

---

## Procedure

### Step 1: Open Retaining Wall Module

Launch **GEO5 software** and select the **Retaining Wall Design** module from the available geotechnical analysis options.

---

### Step 2: Define Wall Geometry

Create the retaining wall model by entering its dimensions, including:

- Wall height
- Stem thickness
- Base width
- Heel length
- Toe length
- Foundation depth

The geometry can be customized according to project requirements.

---

### Step 3: Enter Backfill Soil Properties

Input the engineering properties of the retained soil, such as:

- Unit weight ($\gamma$)
- Cohesion (c)
- Angle of internal friction ($\varphi$)
- Soil type classification

These parameters are essential for calculating earth pressure accurately.

### Step 4: Define Foundation Soil Parameters

Enter the properties of soil beneath the wall foundation, including:

- Bearing capacity
- Density
- Shear strength parameters

These values are required for bearing capacity verification.

### Step 5: Apply Surcharge Loads

Additional loads acting on the retained soil are specified, such as:

- Traffic loads
- Building loads
- Equipment loads
- Uniform surcharge pressure

These loads increase lateral earth pressure on the wall.

### Step 6: Define Groundwater Conditions

If groundwater is present, enter:

- Water table level
- Hydrostatic pressure conditions

Water pressure behind the wall can greatly affect stability and must be included in design calculations.

### Step 7: Perform Stability Analysis

Run the analysis to check:

- Stability against sliding
- Stability against overturning
- Bearing pressure under foundation
- Resultant force location

The software automatically computes factors of safety for each condition.

---

### Step 8: Review Structural Reinforcement

If reinforced concrete retaining wall design is included, check:

- Required steel reinforcement
- Bending moments
- Shear forces
- Reinforcement detailing

GEO5 provides optimized reinforcement recommendations.

---

### Step 9: Interpret Results

Examine the graphical and numerical outputs, including:

- Earth pressure diagrams
- Moment diagrams
- Base pressure distribution
- Safety factor values
- Wall displacement indicators

If safety requirements are not met, modify wall dimensions and repeat analysis.

---

## Observation

During the retaining wall design and analysis, the following observations were recorded:

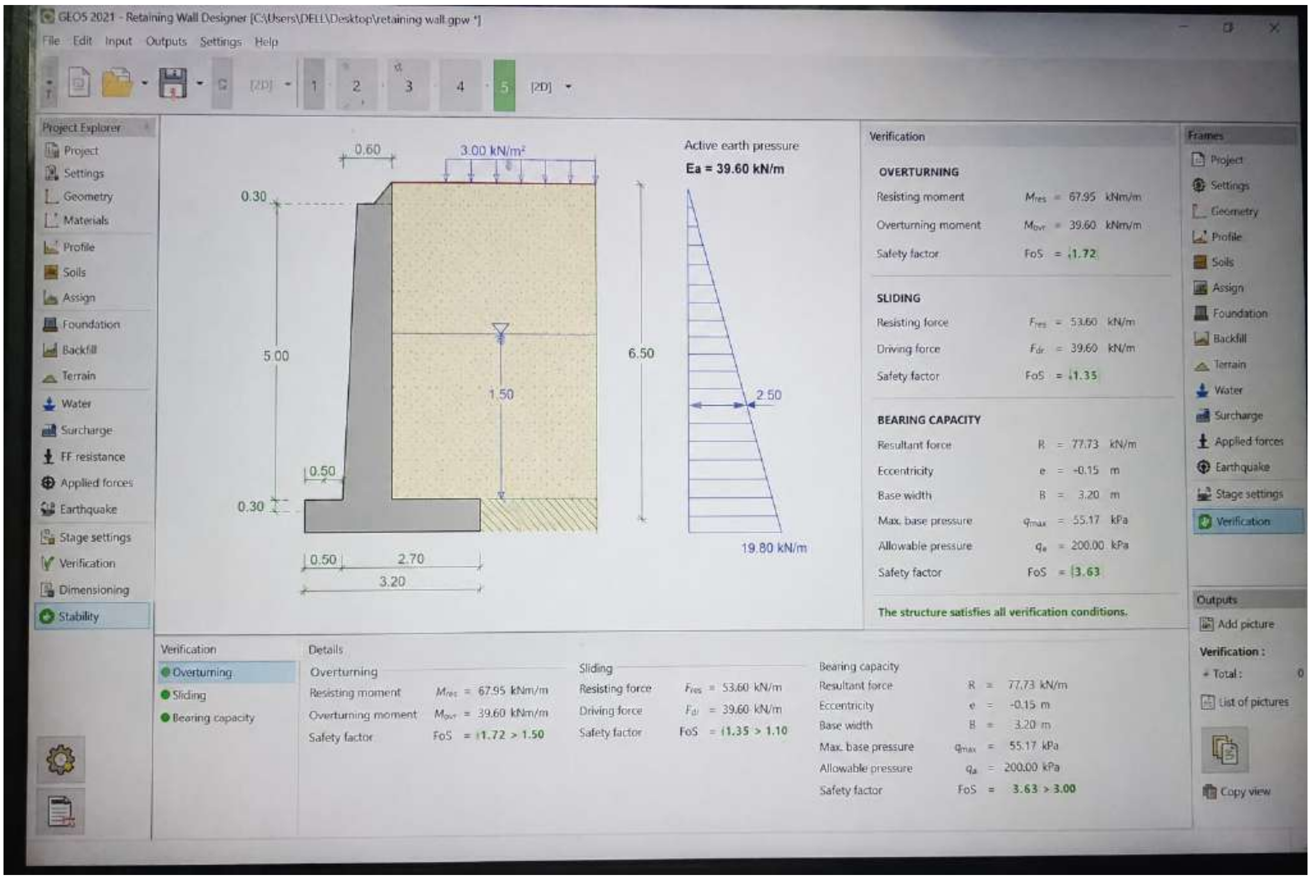
- The lateral earth pressure acting on the wall was calculated successfully.
- Stability against **sliding** was verified.
- Stability against **overturning** was checked and found satisfactory.
- Bearing pressure under the foundation was within allowable limits.
- The resultant force remained within the middle third of the base.
- Reinforcement requirements were generated automatically.
- Graphical outputs showed pressure distribution and structural behavior clearly.
- The designed wall dimensions were adequate for the given loading conditions.

---

## Result

The retaining wall was successfully designed using **GEO5 Retaining Wall software**. All stability checks including **sliding, overturning, and bearing capacity** were performed and found to satisfy the required safety criteria. The reinforcement design was also verified, confirming that the retaining wall is structurally safe and suitable for construction under the given soil and loading conditions.

**Figure 4:** Retaining Wall Design Output



| Vision of the Institute | Mission of the Institute |
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| "To become a leading institute of providing professionally competent and socially responsive technocrats with high moral values." | ⇨ To create an eco-system for the dissemination of technical knowledge, to achieve academic excellence.<br>⇨ To develop technocrats with creative skills and leadership qualities, to solve local and global challenges.<br>⇨ To impart human values and ethics in students, to make them socially and Eco-friendly responsible. |

# EXPERIMENT 05

## Study of ETABS Software Interface and Basic Structural Modeling

**Objective**

To study the latest version of **ETABS** software interface and understand its tools, menus, and applications in structural engineering analysis and design.

---

**Theory**

**ETABS (Extended Three-Dimensional Analysis of Building Systems)** is one of the most widely used commercial structural engineering software packages developed by **Computers and Structures, Inc. (CSI)**. It is specifically designed for modeling, analyzing, and designing building structures such as residential buildings, commercial complexes, towers, and industrial structures.

The latest version of ETABS provides an integrated environment for creating structural models, assigning material properties, applying loads, performing analysis, and designing structural elements according to various international design codes.

Key features of ETABS include:

- User-friendly graphical interface.
- 2D and 3D structural modeling.
- Automatic load calculations (dead load, live load, wind load, seismic load).
- Finite Element Analysis (FEA) for accurate structural behavior prediction.
- Design of beams, columns, slabs, and shear walls.
- Dynamic analysis including response spectrum and time history analysis.
- Detailed graphical and tabular output reports.
- BIM compatibility and import/export with other software like **AutoCAD** and **SAFE**.

ETABS is extensively used by civil and structural engineers to ensure safety, stability, and economic design of structures.

---

**Apparatus/Software Required**

- Computer/Laptop with Windows OS
- Installed latest version of **ETABS**
- Structural design data (building dimensions, material properties, load values)

---

**Procedure**

1. Launch **ETABS** software.
2. Study the main interface including toolbar, menu bar, model window, and status bar.
3. Create a new model using the built-in model wizard.
4. Define grid spacing and number of stories.
5. Assign material properties such as concrete and steel.
6. Define structural sections (beam, column, slab).
7. Draw structural elements in plan and elevation views.
8. Apply loads such as dead load and live load.
9. Run structural analysis.
10. Observe deformation, bending moment, shear force, and reaction diagrams.
11. Review design results and generate reports.
12. Save the project file.

---

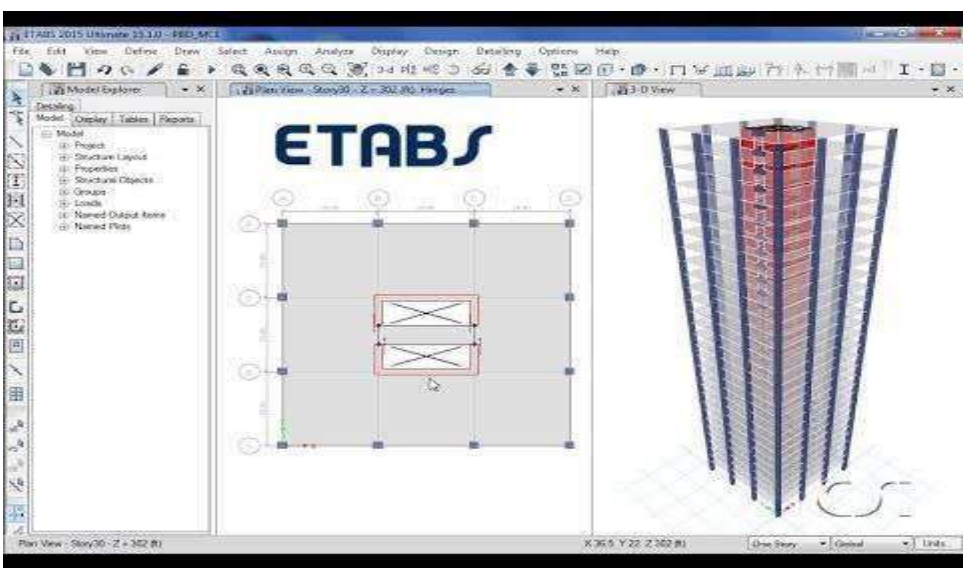
## Observation

- ETABS provides easy navigation between plan, elevation, and 3D views.
- Structural elements can be modeled efficiently using graphical tools.
- Analysis results are displayed in both graphical and numerical formats.
- Design checks can be performed according to selected design codes.

---

## Result

The ETABS software interface was studied successfully, and a basic structural model was created, analyzed, and interpreted using the latest version of the software.



# Experiment 6: Foundation Analysis

## Objective

To analyze foundation behavior under structural loading.

## Theory

Foundation analysis is one of the most important aspects of geotechnical engineering because it determines how the loads from a structure are safely transferred to the underlying soil or rock. A properly designed foundation ensures the long-term stability, safety, and durability of buildings, bridges, towers, and other engineering structures.

The primary function of a foundation is to:

- Transfer structural loads safely to the soil
- Prevent excessive settlement
- Maintain structural stability
- Avoid bearing capacity failure
- Distribute loads uniformly to the supporting ground

Foundation failure can occur due to:

- Excessive settlement
- Uneven or differential settlement
- Bearing capacity failure
- Soil shear failure
- Groundwater effects
- Weak or compressible soil layers

Foundation analysis helps engineers understand how the soil responds under applied loads and whether the foundation dimensions are adequate.

---

# Important Parameters in Foundation Analysis

### 1. Settlement Analysis

Settlement refers to the downward movement of a foundation caused by compression of soil under loading.

Settlement may be:

- **Immediate Settlement:** Elastic deformation occurring immediately after loading
- **Consolidation Settlement:** Time-dependent settlement due to expulsion of water from saturated soils
- **Differential Settlement:** Uneven settlement that may cause structural cracks or tilting

Allowable settlement limits must not be exceeded to ensure serviceability.

---

### 2. Stress Distribution

Structural loads create stresses in the soil beneath the foundation. These stresses must be analyzed to determine how pressure spreads through different soil layers.

Uniform stress distribution helps prevent localized failure and excessive deformation.

---

### 3. Soil Bearing Pressure

Bearing pressure is the pressure exerted by the foundation on the supporting soil.

It must satisfy:

qapplied≤qallowableq_{applied} \leq q_{allowable}qapplied≤qallowable

Where:

- **$q_{applie}$d** = Pressure exerted by foundation
- **$q_{allo}w_{a}b_{le}$** = Safe allowable bearing capacity of soil

If applied pressure exceeds allowable pressure, foundation failure may occur.

---

### 4. Bearing Capacity

Bearing capacity refers to the maximum load the soil can support without shear failure.

Typical bearing capacity theories include:

- **Terzaghi's Bearing Capacity Theory**
- **Meyerhof Method**
- **Hansen Method**

These methods are commonly integrated into GEO5 for accurate analysis.

---

### 5. Load Combination Analysis

Foundations must withstand different types of loads, such as:

- Dead loads (self-weight of structure)
- Live loads (occupancy loads)
- Wind loads
- Seismic loads
- Equipment loads

GEO5 allows multiple load combinations to evaluate foundation performance under various conditions.

---

## Procedure

### Step 1: Select Foundation Analysis Module

Open **GEO5 software** and choose the appropriate **Foundation Analysis** module depending on the type of foundation, such as:

- Spread Footing
- Strip Footing
- Raft Foundation
- Pile Foundation

---

### Step 2: Input Foundation Type and Dimensions

Define the geometry and dimensions of the foundation, including:

- Foundation length
- Width
- Depth below ground level
- Thickness of footing
- Shape (square, rectangular, circular)

Proper dimensions are necessary for accurate load transfer analysis.

---

### Step 3: Enter Loading Values

Input all structural loads acting on the foundation, such as:

- Vertical load

- Horizontal load
- Bending moments
- Eccentric loading

These loads may come from columns, walls, or structural frames.

---

**Step 4: Define Soil Properties**

Enter geotechnical parameters of the supporting soil, including:

- Unit weight (γ)
- Cohesion (c)
- Angle of internal friction (φ)
- Elastic modulus (E)
- Poisson's ratio (ν)
- Soil stratification details

These properties determine how the soil behaves under load.

---

**Step 5: Add Groundwater Conditions**

If groundwater exists near the foundation level, define:

- Water table depth
- Pore water pressure

Groundwater can significantly reduce effective stress and soil strength.

---

**Step 6: Run the Analysis**

Execute the foundation analysis to calculate:

- Settlement values
- Soil pressure distribution
- Bearing capacity utilization
- Stress contours beneath foundation
- Safety factors

The software automatically performs numerical calculations and generates graphical outputs.

### Step 7: Observe Pressure and Settlement Results

Review the generated results, including:

- Settlement graphs
- Pressure distribution diagrams
- Stress contour plots
- Load transfer patterns

Identify whether the foundation behaves within acceptable engineering limits.

### Step 8: Verify Safety Criteria

Check whether:

- Settlement is within allowable limits
- Soil pressure does not exceed allowable bearing capacity
- Factor of safety is satisfactory
- No differential settlement risks exist

If conditions are not satisfied, modify foundation dimensions and repeat analysis.

## Observation

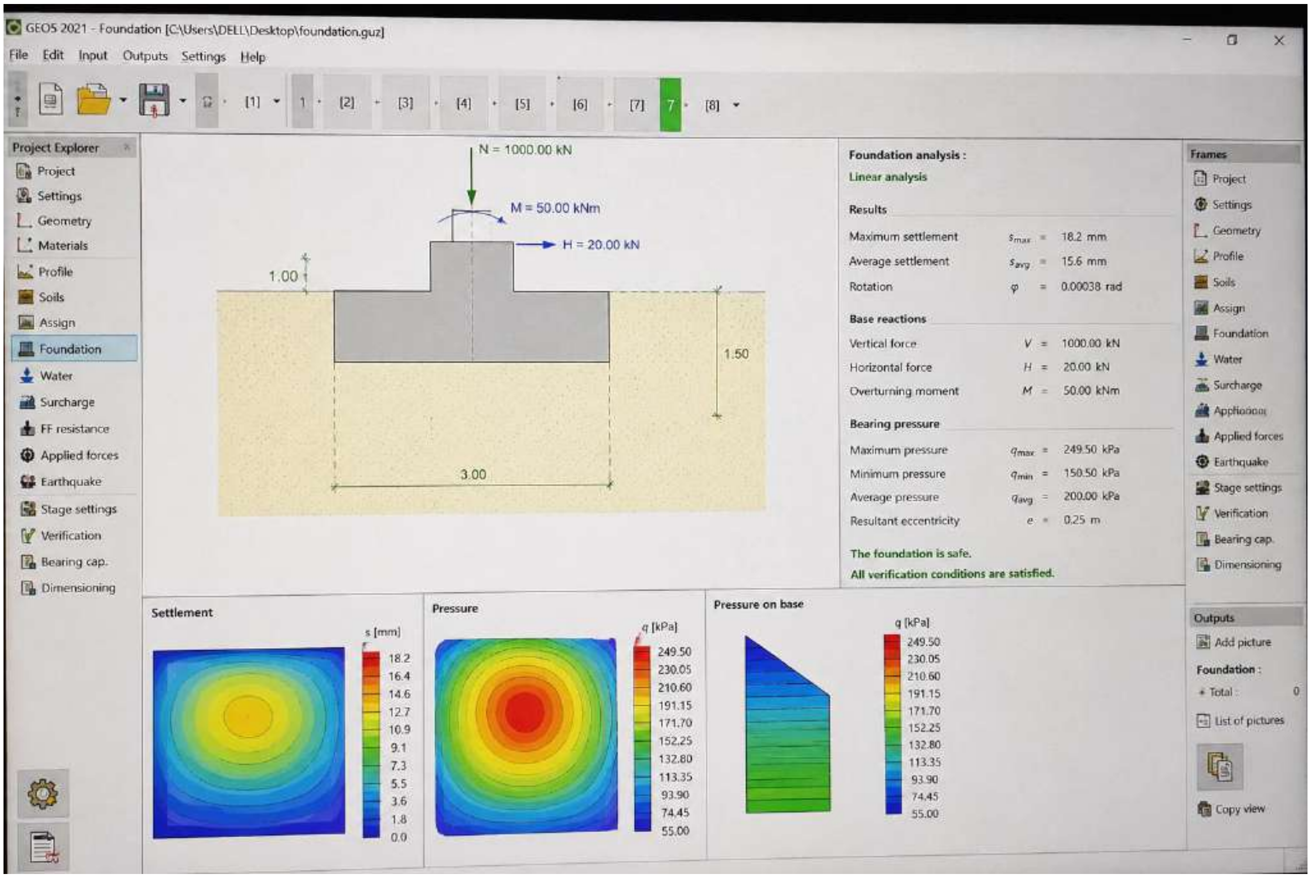
During the foundation analysis, the following observations were recorded:

- Structural loads were successfully transferred to the supporting soil.
- Soil pressure distribution beneath the foundation was displayed graphically.
- Settlement values were calculated numerically.
- Maximum settlement was within allowable design limits.
- Bearing pressure remained below allowable soil capacity.
- Stress distribution indicated uniform load transfer.
- No significant differential settlement was observed.
- Foundation stability was confirmed under the applied load combinations.

## Result

The foundation analysis was successfully performed using **GEO5 Foundation Analysis software**. The behavior of the foundation under structural loading was evaluated through settlement analysis, stress distribution, and soil pressure assessment. The obtained results confirmed that the foundation satisfies the required safety and serviceability conditions and is suitable for supporting the applied structural loads.

**Figure 5:** Foundation Analysis Diagram



# Experiment 7: QGIS Interface Study

**Objective**

To study the QGIS interface and understand GIS tools.

## Theory

**QGIS** is a free and open-source **Geographic Information System (GIS)** software used for creating, editing, analyzing, and visualizing spatial data. It is widely used in engineering, environmental studies, urban planning, surveying, and resource management.

QGIS supports both major types of geographic data:

- **Vector Data** – Includes points, lines, and polygons (e.g., roads, buildings, boundaries).
- **Raster Data** – Includes satellite images, digital elevation models, and scanned maps.

The software provides powerful tools for:

- Map creation and layout design
- Spatial data editing and management
- Coordinate system handling
- Geoprocessing and spatial analysis
- Data visualization through layers and symbols
- Plugin integration for advanced GIS functions

QGIS has a user-friendly graphical interface consisting of several important sections such as the **Menu Bar**, **Toolbar**, **Browser Panel**, **Layers Panel**, **Map Canvas**, and **Processing Toolbox**. Understanding these components is essential for efficient GIS work.

---

## Procedure

**Step 1: Launch QGIS Software**

Open the **QGIS application** from the desktop or start menu and wait for the main interface to load.

**Step 2: Explore the Menu Bar and Toolbar**

Study the options available in the menu bar such as:

- Project
- Edit
- View
- Layer

- Settings
- Plugins
- Vector
- Raster
- Processing

Observe the toolbar icons used for quick access to common functions like zooming, selecting, and editing layers.

**Step 3: Study the Browser Panel and Layers Panel**

Examine the **Browser Panel**, which allows access to files, folders, databases, and GIS datasets.

Study the **Layers Panel**, where loaded spatial data layers are displayed and managed. Layer visibility, order, and symbology can be controlled from this panel.

**Step 4: Understand the Map Canvas**

Observe the **Map Canvas**, which is the main working area where maps and spatial data are displayed.

Practice basic navigation tools such as:

- Zoom in / Zoom out
- Pan map
- Identify features
- Measure distance and area

**Step 5: Explore Plugins and Processing Toolbox**

Open the **Plugins menu** to view additional tools that can extend QGIS functionality.

Study the **Processing Toolbox**, which provides advanced geoprocessing tools such as:

- Buffer
- Clip
- Merge
- Intersect
- Raster analysis

**Step 6: Load Sample GIS Data**

Import a sample shapefile or raster dataset and observe how layers are displayed and managed within the interface.

## Observation

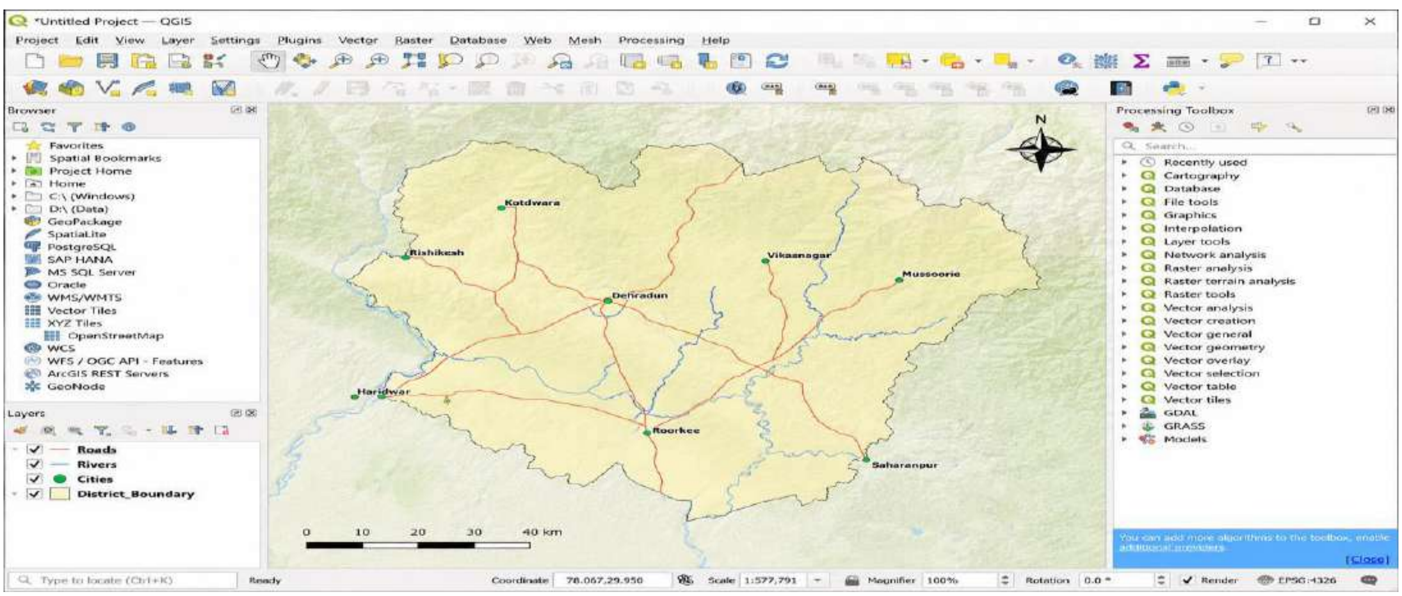
During the study of the QGIS interface, the following observations were made:

- The software interface is organized and user-friendly.
- Different GIS tools are easily accessible through menus and toolbars.
- The Layers Panel helps manage multiple spatial datasets efficiently.
- The Map Canvas provides interactive visualization of geographic data.
- Plugins and the Processing Toolbox offer advanced spatial analysis capabilities.
- QGIS supports a wide variety of vector and raster file formats.

## Result

The **QGIS interface** was studied successfully, and the main GIS tools and interface components were understood. The experiment provided basic knowledge of spatial data handling, map visualization, and geospatial analysis functions available in QGIS.

**Figure 6:** QGIS Interface Screenshot



# Experiment 8: Contour Map Preparation

## Objective

To generate contour maps using elevation data in QGIS.

## Theory

A **contour map** is a graphical representation of terrain where lines connect points of equal elevation above a reference level, usually mean sea level. These lines help visualize the shape, slope, and height variations of the land surface.

Contour maps are widely used in:

- **Terrain and slope analysis**
- **Drainage and watershed planning**
- **Road and railway alignment**
- **Site selection and land development**
- **Civil engineering design**

In QGIS, contour maps are commonly generated from **Digital Elevation Model (DEM)** or other raster elevation datasets. The software processes elevation values and creates contour lines at a specified **contour interval** (e.g., 5 m, 10 m, or 20 m).

Key terms:

- **DEM (Digital Elevation Model):** Raster data representing ground elevation.
- **Contour Interval:** Vertical difference between successive contour lines.
- **Index Contours:** Major contour lines shown more prominently for easy reading.

QGIS provides built-in tools for generating and styling contour maps efficiently.

---

## Procedure

### Step 1: Import DEM or Elevation Data

Open **QGIS** and load the DEM or raster elevation dataset into the project using the **Add Raster Layer** option.

### Step 2: Open Contour Generation Tool

Go to:

**Raster → Extraction → Contour**

or use the **Processing Toolbox** and search for the **Contour** tool.

**Step 3: Set Contour Parameters**

Enter the required settings such as:

- Input elevation raster
- Contour interval (e.g., 10 m)
- Output file location
- Attribute field for elevation values

**Step 4: Generate Contour Lines**

Run the tool to create contour lines automatically from the elevation data.

**Step 5: Style the Contour Map**

Apply suitable symbology such as:

- Different line colors
- Label contour values
- Highlight index contours

This improves readability and presentation.

---

## Observation

During the experiment, the following observations were made:

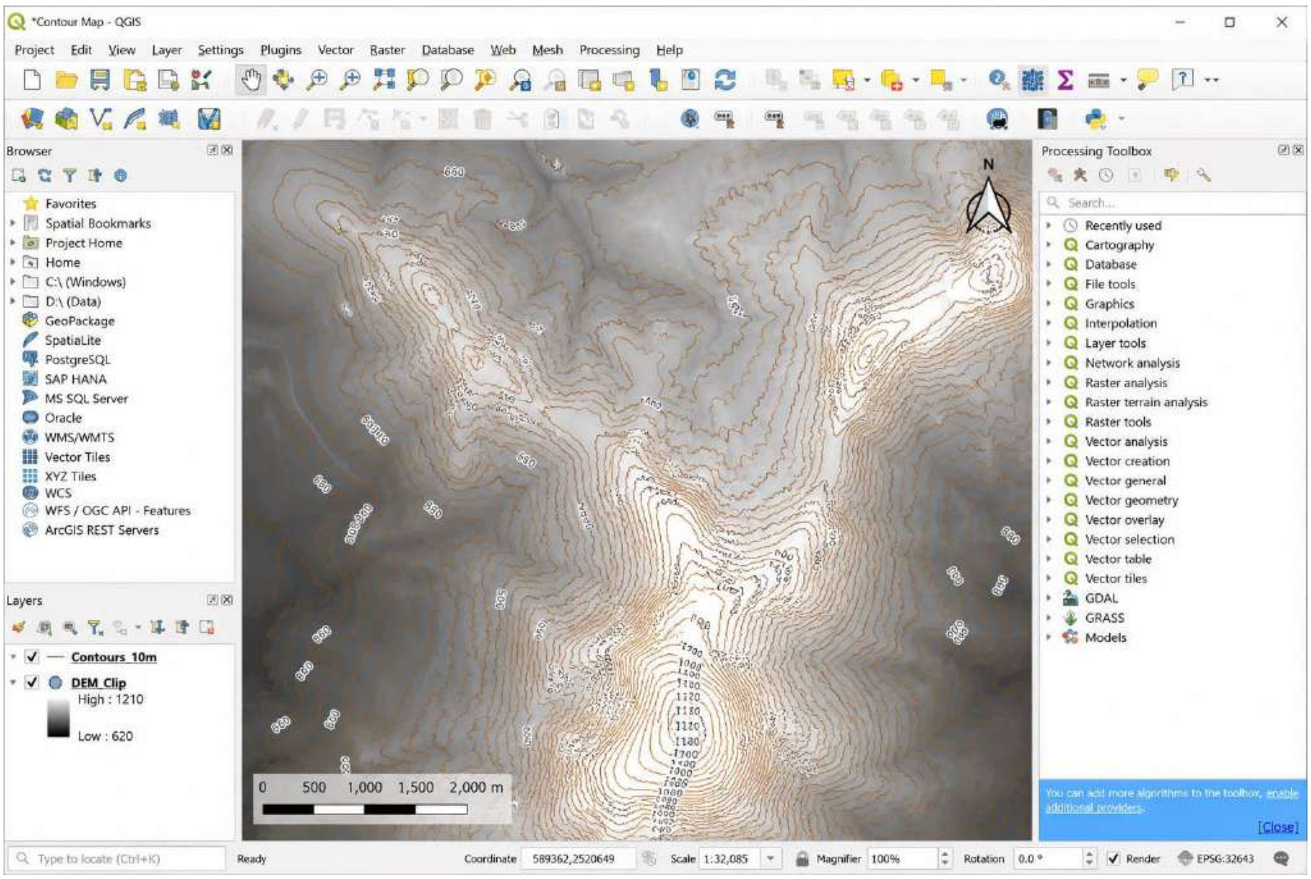
- DEM data was imported successfully into QGIS.
- Contour lines were generated based on selected elevation intervals.
- Terrain variation and slope patterns became clearly visible.
- Styled contour lines improved map interpretation.
- The generated map can be used for further spatial analysis and engineering planning.

---

## Result

The contour map was successfully generated using **QGIS** from elevation data. The experiment helped in understanding contour line creation, terrain representation, and the practical use of contour maps in geospatial and civil engineering applications.

**Figure 7:** Contour Map Generated in QGIS



# Experiment 9: Layer Management

## Objective

To manage and organize multiple GIS layers in QGIS.

## Theory

In Geographic Information Systems (GIS), a **layer** is a collection of spatial data representing specific geographic features such as roads, rivers, land use, buildings, or elevation. Efficient **layer management** is essential for organizing large amounts of geospatial data and improving workflow during map preparation and spatial analysis.

QGIS allows users to work with multiple types of layers, mainly:

- **Vector Layers** – Represent geographic features using:
  - Points (e.g., wells, landmarks)
  - Lines (e.g., roads, rivers)
  - Polygons (e.g., districts, land parcels)
- **Raster Layers** – Represent continuous data such as:
  - Satellite imagery
  - DEM (Digital Elevation Models)
  - Land cover maps

Layer management involves several important operations, such as:

### 1. Adding Layers

Users can import multiple spatial datasets into QGIS from various formats like:

- Shapefile (.shp)
- GeoJSON
- GeoTIFF
- CSV with coordinates
- Database connections

---

### 2. Renaming and Grouping Layers

Layers can be renamed for better identification and organized into groups or folders. Grouping helps manage complex projects containing many related datasets.

---

### 3. Symbology and Styling

Each layer can be customized using different:

- Colors
- Line styles
- Symbols
- Labels
- Transparency settings

Proper symbology improves map readability and interpretation.

---

### 4. Layer Visibility Control

Users can turn layers on or off depending on the analysis requirement. This helps focus only on relevant information without cluttering the map.

---

### 5. Layer Order Management

The display order of layers is important because upper layers may hide lower layers. Proper arrangement ensures all important features remain visible.

---

### 6. Attribute Table Access

Each layer contains an attribute table storing descriptive information. Managing layers also includes viewing and editing attribute data linked to spatial features.

Effective layer management makes GIS projects more organized, efficient, and easier to analyze.

---

## Procedure

### Step 1: Add Multiple Vector and Raster Layers

Open **QGIS** and import several datasets using:

**Layer → Add Layer**

Load both vector layers (roads, boundaries, rivers) and raster layers (satellite images or DEM).

### Step 2: Rename and Group Layers

Rename each layer with meaningful names for easy identification.

Create layer groups to organize similar datasets, such as:

- Base Maps
- Administrative Boundaries
- Transportation
- Hydrology

### Step 3: Apply Symbology

Customize the appearance of each layer by applying suitable symbology:

- Different colors for different features
- Line thickness adjustments
- Labels for important elements
- Transparency settings for overlapping layers

### Step 4: Adjust Layer Display Order

Drag and rearrange layers in the **Layers Panel** to control which layers appear above or below others.

Ensure important features remain clearly visible on the map canvas.

### Step 5: Control Layer Visibility

Use the visibility checkbox beside each layer to turn layers on or off and observe how the map changes.

### Step 6: Explore Attribute Information

Open the attribute tables of selected layers and review feature-related information such as names, IDs, and classifications.

## Observation

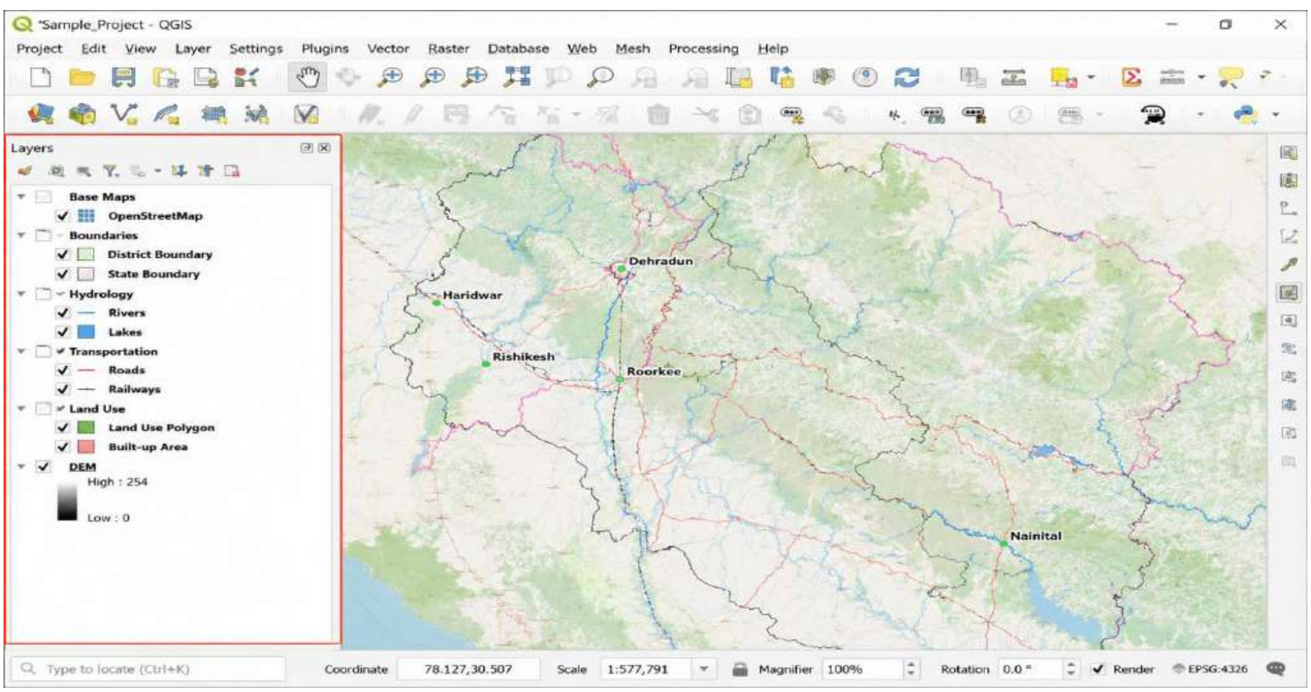
During the experiment, the following observations were made:

- Multiple vector and raster layers were successfully added into QGIS.
- Layers were renamed and grouped for better organization.
- Different symbology styles improved map clarity and visual appearance.
- Adjusting display order helped avoid overlapping issues.
- Layer visibility controls allowed selective viewing of map data.
- Attribute tables provided additional information linked to spatial features.
- Organized layer management made navigation and analysis easier.

## Result

GIS layer management was performed successfully in **QGIS**. The experiment helped in understanding how to organize, style, and control multiple spatial datasets effectively. Proper layer management improved map readability, project organization, and overall efficiency in GIS-based analysis.

**Figure 8:** Layer Panel in QGIS



# Experiment 10: Coordinate Plotting

**Objective**
To plot coordinate points on a map using QGIS.

## Theory

**Coordinate plotting** is the process of placing geographic locations on a map using numerical coordinate values. These coordinates define the exact position of a point on the Earth's surface and are essential in mapping, surveying, navigation, and spatial analysis.

The two commonly used coordinate systems are:

- **Geographic Coordinate System (GCS):** Uses **Latitude and Longitude** values (e.g., 28.6139° N, 77.2090° E).
- **Projected Coordinate System (PCS):** Uses planar coordinates such as **Easting and Northing** in meters (e.g., UTM coordinates).

In GIS, coordinate plotting is widely used for:

- Mapping survey locations
- Plotting GPS field data
- Identifying infrastructure locations
- Environmental monitoring
- Site analysis and planning

QGIS allows users to import coordinate data directly from files such as **CSV (Comma Separated Values)** and display them as spatial point layers on the map. To ensure accurate plotting, the correct **Coordinate Reference System (CRS)** must be defined.

Important concepts include:

- **CSV File:** A spreadsheet file containing coordinate values and related attributes.
- **CRS (Coordinate Reference System):** Defines how coordinates relate to real-world positions.
- **Point Layer:** A GIS layer showing plotted coordinate locations as points.
- **Shapefile:** A commonly used GIS file format for storing spatial data.

Proper coordinate plotting ensures accurate location representation and forms the basis for further GIS analysis.

---

## Procedure

**Step 1: Import CSV Containing Coordinates**

Open **QGIS** and select:

**Layer → Add Layer → Add Delimited Text Layer**

Browse and select the CSV file containing coordinate data.

---

**Step 2: Assign Coordinate Fields**
Choose the appropriate fields for:

- **X Field** → Longitude / Easting
- **Y Field** → Latitude / Northing

These fields determine where the points will be plotted on the map.

---

**Step 3: Define Coordinate Reference System (CRS)**
Select the correct CRS based on the coordinate format, such as:

- **EPSG:4326 (WGS 84)** for latitude and longitude
- **UTM projection** for projected coordinates

Correct CRS selection ensures accurate point placement.

---

**Step 4: Display Point Data on Map**
Click **Add** to load the data. The coordinate points will appear on the **Map Canvas** as plotted locations.

Zoom and inspect the points to verify correct placement.

---

**Step 5: Apply Symbology and Labels**
Customize the point appearance by changing:

- Marker size and color
- Point symbols
- Labels using location names or IDs

This improves map readability and presentation.

---

**Step 6: Save as Shapefile**
Right-click the plotted point layer and select:

**Export → Save Features As**

Save the layer as a **Shapefile** or other GIS-supported format for future use.

---

## Observation

During the experiment, the following observations were made:

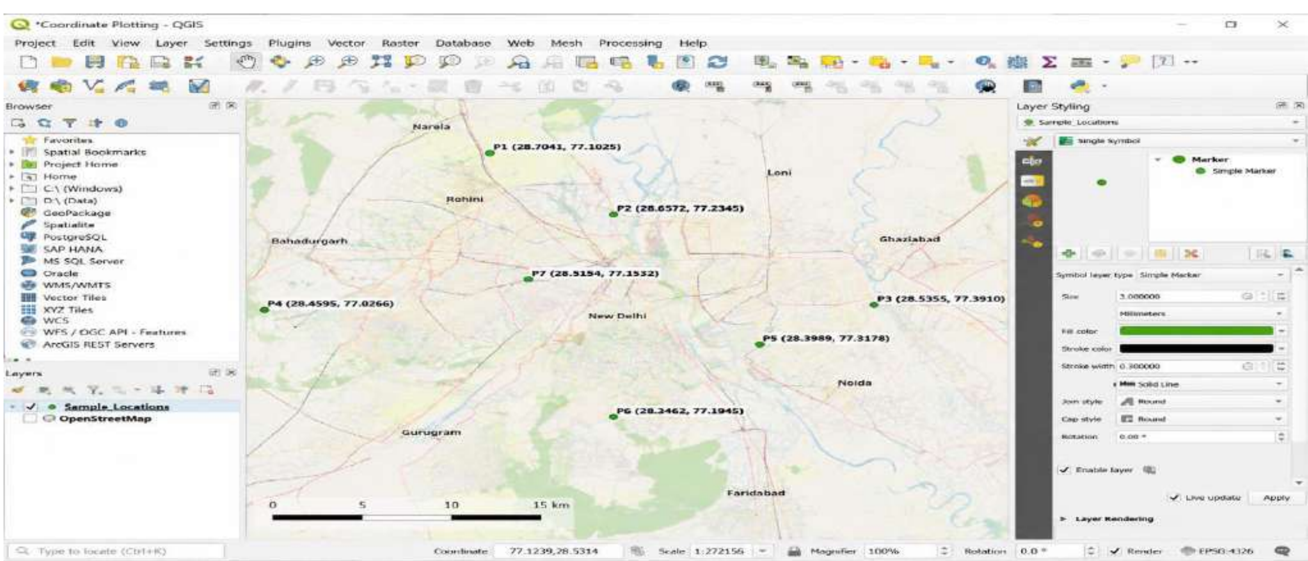
- The CSV file containing coordinate data was imported successfully.
- Coordinate fields were assigned correctly.
- The appropriate CRS ensured accurate point plotting.
- All locations appeared correctly on the map canvas.
- Symbology and labels improved visualization of the plotted points.
- The point data was successfully converted into a GIS layer (shapefile).
- The plotted coordinates can now be used for further spatial analysis and mapping.

---

## Result

The coordinate points were successfully plotted in **QGIS** using the provided coordinate data. The experiment helped in understanding coordinate systems, CRS selection, and the process of converting tabular coordinate data into spatial GIS layers for mapping and analysis.

**Figure 9:** Coordinate Plotting Output



# Experiment 11: Spatial Data Analysis

## Objective

To perform spatial analysis using GIS tools in QGIS.

## Theory

**Spatial data analysis** is the process of examining geographic data to identify patterns, relationships, and spatial interactions between different features. It is one of the most important functions of Geographic Information Systems (GIS), allowing users to solve real-world problems through location-based analysis.

Spatial analysis helps answer questions such as:

- Which areas fall within a certain distance from a road or river?
- Which regions overlap between different land-use zones?
- What features are present inside a selected boundary?
- How do different spatial layers interact with each other?

QGIS provides a wide range of built-in tools for performing such analyses efficiently.

### Common Spatial Analysis Tools

### 1. Buffer Analysis

The **Buffer** tool creates zones around selected features at a specified distance.

Examples:

- Creating a 500 m buffer around roads
- Identifying areas near rivers
- Defining service zones around schools or hospitals

---

### 2. Overlay Analysis

Overlay combines multiple spatial layers to study their relationships.

Common overlay operations include:

- Union
- Intersect
- Difference

This helps identify common or shared areas between datasets.

---

### 3. Clipping

The **Clip** tool extracts only the portion of a dataset that falls within a selected boundary.

Example:

- Extracting roads within a district boundary
- Cropping land-use data for a study area

---

### 4. Intersection

The **Intersection** tool identifies overlapping areas between two or more layers and creates a new layer containing only common features.

Example:

- Finding forest areas intersecting flood-prone zones
- Identifying buildings within buffer zones

Spatial analysis is widely used in:

- **Urban planning**
- **Environmental impact studies**
- **Transportation planning**
- **Infrastructure development**
- **Disaster management**
- **Resource management**

---

## Procedure

### Step 1: Load Required Spatial Datasets

Open **QGIS** and import the necessary vector or raster layers such as:

- Administrative boundaries
- Roads
- Rivers
- Land-use maps
- Infrastructure layers

Ensure all layers use the same **Coordinate Reference System (CRS)**.

---

### Step 2: Apply Buffer Tool

Open the **Buffer** tool from:

**Vector → Geoprocessing Tools → Buffer**

Select the desired layer and specify the buffer distance (e.g., 500 m or 1 km).

Generate the buffer zones around selected features.

---

### Step 3: Perform Overlay Analysis

Use overlay tools such as:

**Vector → Geoprocessing Tools → Union / Difference / Intersect**

Combine different layers to study spatial relationships and overlapping areas.

---

### Step 4: Perform Clipping

Open the **Clip** tool and select:

- Input layer
- Clipping boundary layer

Run the tool to extract only the required study area data.

---

### Step 5: Perform Intersection Analysis

Use the **Intersection** tool to identify common areas between two spatial datasets.

The output will show only overlapping geographic features.

---

### Step 6: Analyze Output Maps

Examine the generated output layers on the **Map Canvas**.

Apply suitable:

- Symbology
- Labels
- Layer styling

to improve interpretation and presentation.

---

## Observation

During the experiment, the following observations were made:

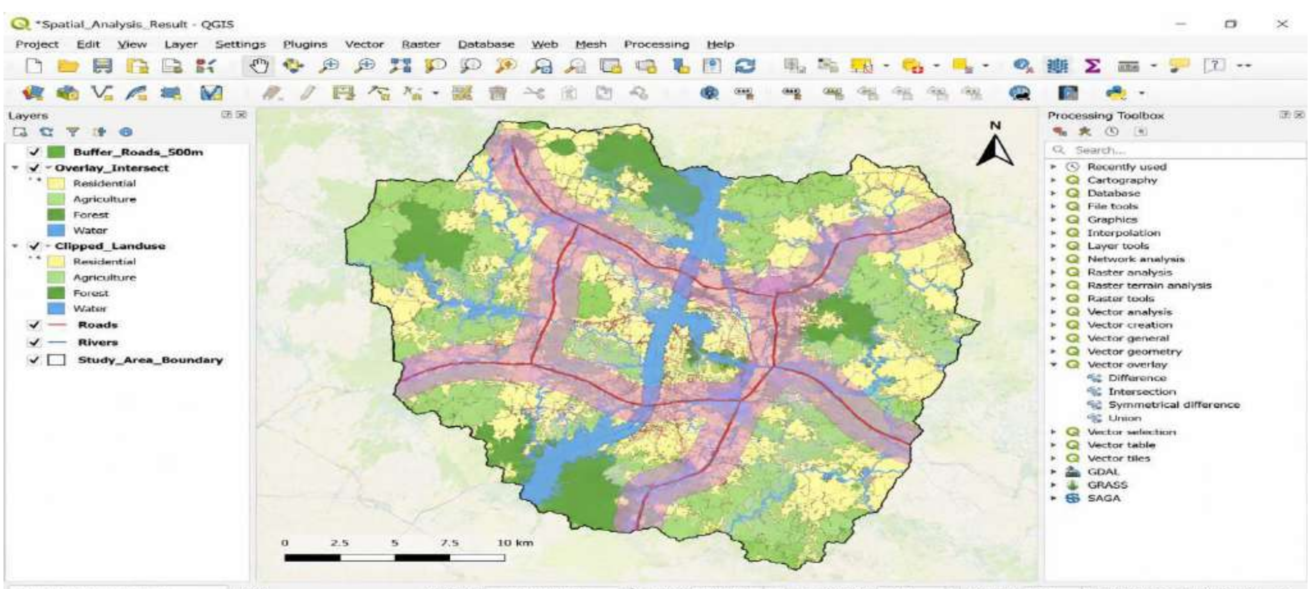
- Required datasets were loaded successfully into QGIS.
- Buffer zones were created accurately around selected features.
- Overlay analysis helped identify relationships between multiple layers.
- Clipping extracted only the required study area.
- Intersection analysis successfully identified overlapping features.
- Spatial patterns and geographic relationships became clearly visible.
- Output maps provided useful information for planning and analysis.

---

## Result

Spatial data analysis was successfully performed using **QGIS**. Various GIS tools such as **buffer, overlay, clipping, and intersection** were applied to analyze geographic relationships between spatial datasets. The experiment improved understanding of spatial problem-solving and demonstrated the practical importance of GIS analysis in engineering, planning, and environmental applications.

**Figure 10:** Spatial Analysis Result



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