BABU BANARASI DAS
INSTITUTE OF TECHNOLOGY & MANAGEMENT
Affiliated to Dr A P J Abdul Kalam Technical University (AKTU College Code- 054)
Approved by All India Council for Technical Education (AICTE)
Website: **www.bbditm.ac.in** / e-mail: **director@bbdnitm.ac.in**
Phone Number: +91 – (522) – 6196222 / 6196223 / 6196305 (VPN No. 723)

Vision of the Institute	Mission of the Institute
"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. ⇨ To develop technocrats with creative skills and leadership qualities, to solve local and global challenges. ⇨ To impart human values and ethics in students, to make them socially and Eco-friendly responsible.

LAB MANUAL
OF
INTEGRATED CIVIL ENGINEERING LAB

[BCE 751]

B. TECH, 4th Year, 7th Sem

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

2025-26

Department of Civil Engineering

Faculty Name: Mr. Mohd. Aquib
Assistant Professor

Dr. Supriya Phurailatpam
Head of Department

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MANUAL CONTENTS

This manual is intended for the 4th year students of Civil Engineering in the subject of Integrated Civil Engineering Lab (BCE 751) as prescribed by AKTU. The manual contains multidisciplinary practical sessions related to structural engineering, geotechnical engineering, environmental engineering, transportation engineering, surveying, FEM, GIS, BIM and machine learning applications in civil engineering.

Students are advised to thoroughly perform and understand all experiments for better conceptual visualization and practical exposure to modern civil engineering tools and techniques.

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

Mission-1. To provide a comprehensive platform for the academic expertise and proficiency.

Mission-2. To develop Civil Engineering professionals with creative skills and leadership qualities in order to face regional and global challenges.

Mission-3. 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

The following are PEOs of the department:

PEO 1: To enhance skill and expertise in field of Civil Engineering with aim of boosting employability and entrepreneurship.

PEO 2: To develop multidisciplinary approach of Civil Engineering system with lifelong learning solutions.

PEO 3: To develop the potential to pursue higher education and research in field of Civil Engineering.

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Program Outcomes:(PO)

Graduates will be able to achieve

PO 1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering Fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO 2. **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO 3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO 4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO 5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO 6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO 7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO 8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO 9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO 10. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear

PO 11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO 12. **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.

PSO 2: Graduates shall be able to inculcate the idea of sustainability in engineering solution to meet real world challenges.

Course Evaluation Scheme

Sr No	Subject Code	Subject Name	Periods			Evaluation Scheme				Total	Credit
						Sessional Assessment			PE		
			L	T	P	CT	TA	PS			
1.	**BCE751**	**Integrated Civil Engineering Lab**	0	0	2	-	-	50	50	100	1

Course Objectives:

i) To provide practical, hands-on exposure across key civil engineering domains.
ii) To apply IS codes, basic simulations, and digital tools in solving civil engineering problems.
iii) To develop multidisciplinary problem-solving skills using modern tools like ML, GIS, FEM, and BIM.

Pre- requisite*:*

1) Strength of Materials / Solid Mechanics
2) Structural Engineering & RCC Design
3) Geotechnical Engineering
4) Fluid Mechanics & Hydraulic Engineering
5) Environmental Engineering
6) Surveying & Geomatics / GIS
7) Civil Engineering Software Knowledge
8) Engineering Mathematics & Numerical Methods
9) IS Codes and Laboratory Practices

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Course Outcomes (COs)

	Course Outcomes:	Knowledge Level, KL
CO1	Conduct tests and interpret results from structural, geotechnical, and environmental experiments.	L3
CO2	Apply IS codes and numerical models to solve practical design problems.	L3
CO3	Use ML and GIS tools for civil engineering problem-solving.	L4
CO4	Analyze simulation outputs and derive engineering inferences.	L5
CO5	Create integrated engineering reports using software and technical tools.	L6

CO-PO-PSO Mapping

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

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
CO1	2	-	-	1	2	1	1	2	1	2	2	1	1
CO2	2	-	-	1	1	1	1	2	1	1	2	1	1
CO3	2	-	-	-	1	1	1	1	1	1	1	1	1
CO4	1	-	-	1	1	1	1	1	1	1	1	1	1
CO5	2	-	-	-	1	-	2	1	1	1	1	1	1
Average	1.8	-	-	1	1.2	1	1.2	1.4	1	1.2	1.4	1	1

List of Experiments

S. No.	Experiment
1	To determine the compressive strength of concrete by using the rebound hammer.
2	To determine the quality of concrete by ultrasonic pulse velocity method.
3	To classify soil samples based on their index properties (Atterberg limits, specific gravity, grain size, etc.) using traditional methods, Python programming, Excel spreadsheets, and machine learning (ML) tools.
4	Efficient Mix Design for M40 Grade Concrete as per IS 10262:2019 with Excel Optimizer
5	To test and estimate the Water Quality Index (WQI) of a given water sample using laboratory data of selected water quality parameters and applying the NSF WQI (Brown et al., 1970) method.
6	Water Quality Index (WQI) using the Weighted Arithmetic Method (Indian/Brown)
7	Flexible Road Pavement Design Calculation using IRC 37 Guidelines based on Traffic Data on the Basis of PCU
8	To determine the peak runoff rate (Q) for a given catchment area using the Rational Method.

Beyond the Syllabus

1	
2	

INDEX

S.No.	Name of the Experiment	CO	BTL	Lab Conduction Date	Remark/ Grade/ Marks	Faculty Signature with Date
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						

Do's (What You Should Do)

- Read the experiment manual and procedure before entering the lab.
- Follow the instructions of the lab instructor strictly.
- Wear proper lab uniform, apron, safety shoes, gloves, and goggles whenever required.
- Maintain discipline and silence inside the laboratory.
- Check instruments and equipment for damage before use.
- Handle testing machines, pumps, loading frames, GIS systems, and electrical equipment carefully.
- Keep the work area clean and dry to avoid slipping hazards.

- Record observations carefully and systematically during experiments.
- Switch OFF electrical supply after completing the experiment.
- Report any malfunction, accident, spill, or injury immediately to the instructor.
- Use equipment only after proper demonstration or training.
- Follow IS codes, laboratory standards, and safety procedures during testing.
- Return all tools, apparatus, and accessories to their designated places after use.
- Work cooperatively with team members during integrated experiments and simulations.
- Wash hands after handling soil, concrete, chemicals, wastewater samples, or lubricants.
- Maintain proper digital data backup while working on FEM/GIS/software-based experiments.
- Ensure specimens are properly aligned before applying loads in structural experiments.
- Apply loads gradually and within permissible limits.
- Keep emergency exits, fire extinguishers, and first-aid boxes accessible.
- Use computers, sensors, and data acquisition systems responsibly.

Dont's (What You Should Avoid)

- Do not enter the laboratory without permission of the instructor.
- Do not perform unauthorized experiments or modify procedures.
- Do not operate machines or software systems without proper guidance.
- Do not touch moving parts, rotating shafts, belts, or loaded specimens.
- Do not exceed the rated capacity of testing equipment.
- Do not run, push, or indulge in horseplay inside the laboratory.
- Do not wear loose clothing, sandals, dangling jewellery, or untied long hair.
- Do not eat, drink, smoke, or chew gum in the laboratory.
- Do not use mobile phones unnecessarily during experiments.
- Do not leave running equipment unattended.
- Do not handle chemicals, acids, wastewater, or concrete additives carelessly.
- Do not touch electrical panels, plugs, or switches with wet hands.
- Do not throw waste materials, broken glass, or specimens randomly.
- Do not disconnect sensors, cables, or instruments forcefully.
- Do not crowd around testing machines during loading operations.
- Do not attempt to repair damaged equipment yourself.
- Do not ignore abnormal sound, vibration, smoke, leakage, or overheating.
- Do not save software files carelessly or install unauthorized programs in computer labs.
- Do not remove laboratory equipment or accessories from the lab without permission.
- Do not leave the laboratory without cleaning the workspace and submitting observations.

EXPERIMENT NO. 1

1. Objective:

To determine the compressive strength of concrete by using the rebound hammer.

2. Theory:

Recent development in concrete is high strength concrete, which is mixture of cement, sand, aggregate, water and admixtures. The compressive strength of concrete is its one of the most valuable property. To determine compressive strength of concrete is a major task of engineers/researchers for existing concrete structures. There are two aspects of determination of compressive strength of concrete which are destructive tests (DT) and non- destructive tests (NDT). The DT of concrete is not always appropriate method to find compressive strength of concrete and concrete structures because it affects the durability and lifespan of concrete. Hence, the NDT method is only one predominant method to find the strength of existing concrete and concrete structures, and to judge the quality of concrete. The NDT method is direct and easy tool to find in situ compressive strength of concrete. The NDT test methods include rebound hammer, ultrasonic pulse velocity test, penetration test, radiography test, sonic integrity tests etc. There are two distinct areas in civil engineering works where it has to be relied on NDT for practical and theoretical purposes. The first ones are the old monumental structural systems like ancient temples and edifices. The second ones are the buildings which are coming up so fast in the urban areas as the result of burgeoning housing industry, which badly needs quality control for mass safety and security of the people.

3. Apparatus: Rebound hammer, ultrasonic pulse velocity equipment, cubes of 150mm size.

4. Procedure:

a) Take the concrete block which is to be tested and mark one side of the surface into 9 parts toobtain average strength of the block.

b) Do the same for minimum 4 sides of the concrete block.

c) Press the rebound hammer on to the surface of the concrete block so that the plunger is pushedinside the hammer.

d) When the plunger against the surface of the concrete, the mass rebound from the plunger.

e) The distance travelled by mass, is called the rebound number. It is indicated by the ridermoving along a graduated scale.

f) Hold it and lock the plunger with lock button provided on the top of the hammer.

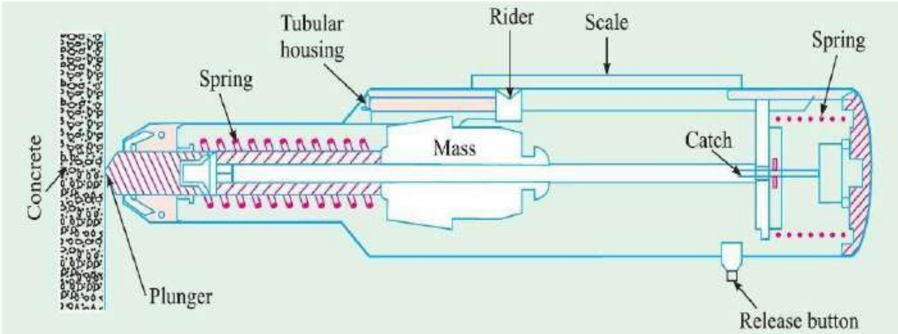
g) Note the reading on the graduated scale present on the rebound hammer which is known asrebound number.

h) Follow the same procedure for four sides of the block where each side is divided into 9 parts.

i) After taking reading press the hammer on to the surface and the plunger gets released due tothe spring action.

j) Take the corresponding strengths with respect to the rebound number which is present on thetable on the hammer.

k) Take the average of all the strengths and obtain average strength of the concrete block.



5. Observations and calculations:

	Side 1		Side 2	
S. No.	Rebound number	Strength (kg/cm^2)	Rebound number	Strength (kg/cm^2)
1				
2				
3				
4				
5				
6				
7				
8				
9				

	Side 3	Side 4

S. No.	Rebound number	Strength (kg/cm^2)	Rebound number	Strength (kg/cm^2)
1				
2				
3				
4				
5				
6				
7				
8				
9				

Average strength of the concrete=________________________kg/cm^2

5. Result: The average strength of the concrete is_________________N/mm^2

6. Precautions -

1. Ensure the concrete surface is clean, dry, and smooth before testing.
2. Avoid testing on honeycombed, cracked, or damaged surfaces.
3. The rebound hammer should be properly calibrated before use.
4. Maintain a minimum spacing of 25 mm between impact points.
5. Take multiple readings (at least 10) and use the average value.

7. Signature of Faculty with Date & Remark:

EXPERIMENT NO. 2

1. Objective:

To determine the quality of concrete by ultrasonic pulse velocity method.

2. Apparatus:

Electrical pulse generator, transducer, amplifier, electronic-timing device and concrete specimen (150mmX150mmX150mm).

3. Theory

The Ultrasonic Pulse Velocity (UPV) method is a non-destructive testing (NDT) technique used to assess the quality, uniformity, and integrity of concrete. The method is based on measuring the time taken by an ultrasonic pulse to travel through a known length of concrete.

An ultrasonic pulse is generated by a transmitting transducer and received by a receiving transducer placed on the surface of the concrete. The pulse velocity is calculated using the relation:

Pulse Velocity (V)=Path Length (L)/Transit Time (T)

The velocity of the ultrasonic pulse depends on:

- Density and elasticity of concrete
- Presence of cracks, voids, and honeycombing
- Moisture condition and age of concrete

Higher pulse velocity indicates good quality and dense concrete, while lower velocity indicates poor quality, cracks, or internal defects.

As per IS 13311 (Part 1): 1992, concrete quality is graded based on pulse velocity values (Excellent, Good, Medium, or Poor). Thus, the UPV test is useful for evaluating concrete without causing any damage to the structure.

4. Procedure:

a) Take the specimen and mark the suitable number of locations on the specimen to be tested.

b) First take the distance between the two points on the surface for testing.

c) Before testing make sure that the surface of the concrete specimen is smooth. If the surface of the specimen is rough apply grease to it before testing.

d) Take the UPV tester and fix the wires to it which transducers are fixed at the end.

e) Calibrate the instrument by the reference bar. The pulse time for calibration is engraved on the reference bar.

f) After calibration place the transducers on the surface and press it hard onto the surface.A value of pulse time in microsecond is displayed on the screen and it is noted.

g) According to the placing of transducers the respective length is also measured.

h) This is followed for number of marked points to be tested. After obtaining the pulse time value and the distance, velocity is calculated.

i) Based on the value of velocity the quality of concrete is determined as per IS code 13311(part-1)-1992, table-2.

Ultrasonic Pulse velocity meter

5. Observations and calculations:

S.No.	Pulse velocity time(T)-μs	Distance (L)-mm	Velocity km/s

Formula:

Pulse velocity time (V) = length (L) / Pulse time (T)

As per IS code 13311 part-1Table-2: velocity criterion for concrete quality grading.

S. No.	Pulse velocity by cross probing (km/sec)	Concrete quality grading
1	Above 4.5	Excellent
2	3.5 to 4.5	Good
3	3.0 to 3.5	Medium
4	Below 3.0	Doubtful

6. Result: The average pulse velocity of the specimen is_____________(km/s).

Quality of the specimen is____________________________.

7. Precautions

1. Ensure proper surface contact between transducers and concrete using a coupling medium (grease or gel).
2. The concrete surface should be clean and free from loose particles.
3. Maintain correct alignment of transmitting and receiving transducers.
4. Measure the path length accurately.

5. Avoid testing near edges or corners unless specifically required.

8. **Signature of Faculty with Date & Remark:**

EXPERIMENT NO. 3

1. Objective

To classify soil samples based on their index properties (Atterberg limits, specific gravity, grain size, etc.) using traditional methods, Python programming, Excel spreadsheets, and machine learning (ML) tools.

2. Theory

2.1 Soil Classification

Soil classification helps in identifying soil behavior for engineering applications.

Two commonly used classification systems:

- **IS Soil Classification System (ISSCS)**
- **Unified Soil Classification System (USCS)**

2.2 Index Properties Used

1. **Liquid Limit (LL)**
2. **Plastic Limit (PL)**
3. **Plasticity Index (PI = LL – PL)**
4. **Shrinkage Limit (SL)**
5. **Specific Gravity (Gs)**
6. **Grain Size Distribution (Coarse vs. Fine fractions)**

2.3 Plasticity Chart (Casagrande's Chart)

- Used to classify fine-grained soils based on **LL** and **PI**.

3. Apparatus / Tools

- **Laboratory Tests**: Casagrande apparatus, Oven, Sieve set, Pycnometer.
- **Software Tools**:
  - **Excel** (for calculation, charting)
  - **Python (Pandas, Matplotlib, Scikit-learn)**
  - **ML tools (Weka, Orange, or Python ML models)**

4. Procedure

4.1 Traditional (Manual) Classification

1. Perform Atterberg limit tests → obtain LL, PL.
2. Compute PI = LL – PL.
3. Determine % passing 75µ sieve (clay fraction).
4. Plot (LL vs. PI) on Casagrande's plasticity chart.
5. Identify soil type (CL, CH, ML, MH, etc.).

4.2 Excel-Based Analysis

1. Enter test data (LL, PL, % passing, Gs, etc.) in Excel.
2. Use formulas to calculate PI.
3. Create a scatter chart for PI vs. LL (Plasticity chart).
4. Apply conditional formatting to highlight soil classification zones.

Excel provides an easy tool to classify soils when you have laboratory results.

Procedure:

1. **Input Data:**
   - Enter soil properties (LL, PL, PI, % passing 75 µm sieve, Gs, etc.) in Excel columns.
2. **Formulas:**
   - Calculate PI automatically using formula: =LL - PL.
   - Use logical formulas (IF, AND, OR) to assign soil groups. Example:
   - =IF(AND(LL>50,PI>7),"CH","CL")
3. **Charts:**
   - Create **Plasticity Chart** in Excel (LL on x-axis, PI on y-axis) and plot soil samples.
4. **Automated Classification:**
   - Use a **lookup table** (VLOOKUP / INDEX-MATCH) to map test results to soil classes (USCS or AASHTO).

Sheet Name: Lab Manual Instructions

Step	Instructions
1	Go to the **Soil Classification** sheet. Enter your experimental values:
	- **Soil_ID** (any serial/sample number)
	- Liquid Limit (LL)
	- Plastic Limit (PL)
	- **% Finer (passing 75µ sieve)**
2	The sheet will automatically calculate the **Plasticity Index (PI = LL – PL)**.
3	The sheet will automatically classify the soil using rules:
	- If % Finer > 50% (Fine-grained):
	• PI < 7 → **ML (Silt)**
	• PI ≥ 7 and LL < 50 → **CL (Clay, low plasticity)**
	• PI ≥ 7 and LL ≥ 50 → **CH (Clay, high plasticity)**
	- Else → **Coarse-grained soil**
4	Check the **Plasticity Chart (LL vs PI)** on the right side of the sheet. This graph is

	automatically updated when you enter values.
5	Compare Excel classification results with **Casagrande's Plasticity Chart** (manual method) to validate.
6	Use this sheet in your **lab experiments and project reports** for faster soil classification.

4.3 Python-Based Analysis

```
import pandas as pd
import matplotlib. pyplot as plt

# Sample soil data
data = {
    'Soil_ID': [1, 2, 3],
    'Liquid_Limit': [35, 55, 25],
    'Plastic_Limit': [20, 25, 18],
    'Percent_Finer_75micron': [60, 85, 40]
}
df = pd.DataFrame(data)
df['Plasticity_Index'] = df['Liquid_Limit'] - df['Plastic_Limit']

# Simple rule-based classification (USCS logic)
def classify_soil(row):
    if row['Percent_Finer_75micron'] > 50:  # Fine-grained
        if row['Plasticity_Index'] < 7:
            return "ML (Silt)"
        elif row['Plasticity_Index'] >= 7 and row['Liquid_Limit'] < 50:
            return "CL (Clay, low plasticity)"
        else:
            return "CH (Clay, high plasticity)"
    else:
        return "Coarse-grained soil"

df['Soil_Class'] = df.apply(classify_soil, axis=1)
```

```
print(df)

# Plasticity chart
plt.scatter(df['Liquid_Limit'], df['Plasticity_Index'], color='blue')
plt.axline((20, 0), slope=0.73, color='red', linestyle='--')  # A-line
plt.xlabel("Liquid Limit (LL)")
plt.ylabel("Plasticity Index (PI)")
plt.title("Plasticity Chart")
plt.show()
```

Procedure:

Import Libraries:

```
import pandas as pd
import matplotlib. pyplot as plt
Input Data:
data = pd.DataFrame({
    'Sample': ['S1','S2','S3'],
    'LL': [45, 60, 25],
    'PL': [20, 30, 15],
    'Percent_Fines': [40, 70, 10]
})
data['PI'] = data['LL'] - data['PL']
```

Classification Logic (USCS Example):

```
def classify_soil(ll, pi, fines):
    if fines > 50:
        if ll > 50 and pi > 7:
            return 'CH (High Plasticity Clay)'
        elif ll < 50 and pi > 7:
            return 'CL (Low Plasticity Clay)'
        else:
            return 'ML/MH (Silt)'
```

```
    else:
        return 'Coarse-Grained Soil'
data['Class'] = data.apply(lambda x: classify_soil(x.LL, x.PI, x.Percent_Fines), axis=1)
```

Plotting Plasticity Chart:

- Use matplotlib to plot LL vs PI with A-line boundary.

4.4 ML-Based Classification

1. Prepare dataset: Input (LL, PL, PI, % passing, Gs), Output (Soil Class).
2. Train ML models (Decision Tree, Random Forest, SVM) using Python or Weka.
3. Evaluate accuracy using test data.

Procedure:

1. **Data Preparation:**
   - Collect dataset with soil properties (LL, PL, PI, Gs, % fines, etc.) and their **classified soil type**.
   - Split into **training and testing sets**.
2. **Feature Selection:**
   - Input features: LL, PL, PI, % fines, Gs, moisture content.
   - Target variable: Soil classification label (e.g., CL, CH, ML, SW).
3. **Model Selection:**
   - Use classification algorithms like:
     - **Decision Trees / Random Forests**
     - **Support Vector Machines (SVM)**
     - **K-Nearest Neighbors (KNN)**

Example in Python (sklearn):

```
from sklearn.model_selection import train_test_split
from sklearn.tree import DecisionTreeClassifier
from sklearn.metrics import accuracy_score

X = df[['Liquid_Limit', 'Plasticity_Index', 'Percent_Finer_75micron']]
```

```
y = df['Soil_Class']

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3, random_state=42)

model = DecisionTreeClassifier()
model.fit(X_train, y_train)
y_pred = model.predict(X_test)

print ("Accuracy:", accuracy_score(y_test, y_pred))
```

5. Observations

Record all test data in tabular form:

Soil ID	LL	PL	PI	% Finer (75μ)	Soil Class
1	35	20	15	60	CL
2	55	25	30	85	CH
3	25	18	7	40	ML

6. Result

- Soil samples were classified as **CL, CH, ML** etc.
- Excel and Python methods matched manual classification.
- ML models showed potential for automated soil classification.

7. Signature of Faculty with Date & Remark:

EXPERIMENT NO. 4

1. Objective

- To design a concrete mix of M40 grade as per IS 10262:2019.
- To understand the role of material properties in concrete mix proportioning.
- To utilize MS Excel as an optimizer tool for efficient, accurate, and repeatable mix design calculations.
- To achieve desired strength, workability, and durability with economical use of materials.

2. Principle

Concrete mix design is based on the principle of selecting suitable proportions of cement, fine aggregate, coarse aggregate, water, and admixtures to produce concrete with required strength, durability, and workability.

As per IS 10262:2019, the design is governed by: - Target mean strength - Water–cement ratio - Degree of workability - Exposure conditions

Excel optimizer helps in iterative calculations, minimizes manual errors, and allows quick modification of input parameters to obtain an efficient mix.

3. Apparatus Required

1. Digital weighing balance
2. Measuring cylinders
3. Concrete mixer or mixing tray
4. Slump cone with tamping rod
5. Cube moulds (150 mm × 150 mm × 150 mm)
6. Compression Testing Machine (CTM)
7. Trowel and scoop
8. Water container
9. Personal Protective Equipment (gloves, safety shoes)
10. Computer system with MS Excel

4. Theory

As per IS 10262:2019, mix design involves the following key steps: - Determination of target mean strength using standard deviation - Selection of water–cement ratio based on strength and durability requirements - Estimation of water content for required workability - Calculation of cement content - Proportioning of fine and coarse aggregates based on grading zone and nominal maximum size

For M40 grade concrete: - Characteristic compressive strength = 40 MPa - Target mean strength is higher to account for variations

Excel-based optimization allows automatic calculation of quantities and enables comparison of different trials to select the most economical and efficient mix.

5. Procedure

1. Select grade of concrete (M40) and exposure condition as per IS 456:2000.
2. Determine target mean strength using standard deviation.
3. Choose suitable water–cement ratio.
4. Estimate water content for desired workability.
5. Calculate cement content and check against minimum and maximum limits.
6. Determine proportions of fine and coarse aggregates.
7. Enter all input data into Excel mix design sheet.
8. Use Excel formulas to optimize mix proportions.
9. Prepare concrete using calculated proportions.
10. Conduct slump test to check workability.
11. Cast concrete cubes and cure them for 7 and 28 days.
12. Test cubes in CTM to determine compressive strength.

6. Observation Table

Material Properties

Parameter Value

Grade of Concrete M40

Maximum Aggregate Size ______ mm

Water–Cement Ratio ______

Cement Content ______ kg/m³

Fine Aggregate ______ kg/m³

Coarse Aggregate ______ kg/m³

Test Results

Cube No.	Age (Days)	Load (kN)	Compressive Strength (MPa)
1	7		
2	7		
3	28		

7. Result

- Mix proportions for M40 grade concrete were successfully designed as per IS 10262:2019.
- Desired workability was achieved.
- The 28-day compressive strength satisfied the requirements of M40 grade concrete.
- Excel optimizer proved effective in achieving accurate and economical mix design.

8. Precautions

1. Ensure all materials are clean and free from impurities.
2. Accurate measurement of materials is essential.
3. Maintain proper water–cement ratio.
4. Ensure proper mixing for uniformity.
5. Compaction should be adequate to avoid honeycombing.
6. Cure specimens properly to obtain accurate strength results.
7. Follow safety practices while handling equipment and machinery.

9. Signature of Faculty with Date & Remark:

EXPERIMENT NO. 5

1. Objective:

To test and estimate the **Water Quality Index (WQI)** of a given water sample using laboratory data of selected water quality parameters and applying the **NSF WQI (Brown et al., 1970) method**.

2. Principle:

The **National Sanitation Foundation Water Quality Index (NSF WQI)** is based on the evaluation of nine key water quality parameters. Each parameter is assigned a **weight (Wi)** according to its importance for overall water quality. The measured value of each parameter is converted into a **sub-index (Qi)** using rating curves or standard tables.

The final WQI is calculated as:

$$WQI = \frac{\sum_{i=1}^{n}(W_i \times Q_i)}{\sum_{i=1}^{n} W_i}$$

W_i = Weight of the ith parameter

Q_i = Quality rating (sub-index) of the ith parameter

The **NSF WQI** typically uses the following nine parameters:

a) Dissolved Oxygen (DO)

b) Fecal Coliform

c) pH

d) Biochemical Oxygen Demand (BOD)

e) Temperature change (ΔT)

f) Total Phosphate

g) Nitrate

h) Turbidity

i) Total Solids

3. Apparatus Required:

- DO meter / Winkler's titration set
- Incubator (for BOD test)
- COD digester & titration setup (if COD is measured additionally)
- pH meter
- Turbidity meter
- Spectrophotometer (for phosphate, nitrate determination)
- Filtration apparatus
- Measuring cylinders, beakers, conical flasks, burettes
- Distilled water
- Standard reagents (alkaline KI, $MnSO_4$, sulfuric acid, starch, sodium thiosulfate, Nessler's reagent, etc.)
- Sample bottles (sterile for microbiological parameters)

4. Theory:

Water Quality Index (WQI) provides a **single numerical value** that summarizes the overall quality of water based on multiple parameters. This makes it easier for policymakers, scientists, and the general public to interpret water quality.

The **NSF WQI (Brown et al., 1970)** is widely used as it incorporates multiple parameters with scientifically assigned weights. For instance, **DO has the highest weight (0.17)** since it is most critical for aquatic life, while **nitrates and phosphates** are indicators of eutrophication.

Interpretation of WQI (NSF scale):

- **90–100** → Excellent
- **70–90** → Good
- **50–70** → Medium
- **25–50** → Bad
- **0–25** → Very Bad

5. Procedure:

a) Collect the water sample from the designated site using sterilized bottles.

b) Analyze the following parameters using standard methods (APHA, IS, or BIS):

- **Dissolved Oxygen (DO):** Winkler's method / DO meter
- **Fecal Coliform:** Membrane filtration method (MPN count)
- **pH:** pH meter (standardized)
- **BOD:** 5-day incubation at 20°C followed by titration
- **Temperature Change (ΔT):** Difference between sample and reference (standard) water body temperature
- **Phosphate:** Spectrophotometric molybdenum blue method
- **Nitrate:** UV spectrophotometric method
- **Turbidity:** Nephelometric turbidity meter
- **Total Solids:** Gravimetric method (evaporation at 105°C)

c) Convert each measured parameter value into a **quality rating (Qi)** using NSF rating curves/standard charts.

d) Multiply each sub-index Qi with its respective weight Wi.

e) Sum up all weighted sub-indices and divide by the sum of weights.

f) Report the final WQI value and interpret the quality class.

6. Observation Table:

The NSF-WQI combines **nine parameters** into a single score:

S.No.	Parameter	Typical Unit	Weight (W_i)	Mean Value	Q-Value (Q_i)	W_iQ_i
1	Dissolved oxygen (DO)	mg/L	0.17			
2	Fecal coliform	MPN/100 ml	0.15			
3	pH	Std Unit	0.12			
4	Biochemical oxygen demand (BOD) (5-day)	mg/L	0.1			
5	Nitrates	mg/L	0.1			
6	Phosphates	mg/L	0.1			
7	Water Temperature	°C	0.1			
8	Turbidity	NTU	0.08			
9	Total Dissolved Solids	mg/L	0.08			
		Tota weight =	**1**		**∑ WiQi**	

7. Result:

The **Water Quality Index (WQI)** of the given water sample (using NSF method) is:

$$WQI = \frac{\sum W_i Q_i}{\sum W_i}$$

$$WQI =$$

Interpretation: The water quality is **(Excellent / Good / Medium / Bad / Very Bad)**.

8. Precautions:

- Collect water samples in sterilized and contamination-free bottles.
- Calibrate instruments (pH meter, DO meter, turbidity meter, spectrophotometer) before use.
- Use freshly prepared reagents for accurate results.

- Maintain incubation temperature accurately during BOD test.
- Avoid spillage and handle acids/bases with care.
- Ensure no air bubbles remain in DO sample bottles before fixation.

9. Signature of Faculty with Date & Remark:

EXPERIMENT NO. 6

Water Quality Index (WQI) using the Weighted Arithmetic Method (Indian/Brown)

1. Objective:

To determine the **Water Quality Index (WQI)** of a water sample by measuring selected physico-chemical parameters (pH, DO, BOD_5, COD, TDS, turbidity, nitrate, etc.) in the laboratory and computing the WQI using the **Weighted Arithmetic Method (Brown)** commonly used in Indian practice.

2. Principle:

The Weighted Arithmetic WQI compresses multiple water-quality parameters into a single index by:

1. Converting each measured parameter into a quality rating (q_i) that expresses how close the observed concentration is to the ideal and permissible value.
2. Assigning each parameter a unit weight (w_i) (usually inversely proportional to its standard permissible value S_i).
3. Calculating the weighted average of the quality ratings to obtain the WQI.

Mathematical summary (when weights are normalized so $\Sigma w_i = 1$):

$$q_i = \frac{V_{actial,i} - V_{ideal,i}}{S_i - V_{ideal,i}} \times 100 \quad (for\ 'higher\ is\ worse'\ parameter)$$

$$WQI = \sum_{i=1}^{n} q_i w_i$$

Notes: For parameters where higher is better (e.g., DO) or where deviation in either direction matters (pH), use adapted forms so q_i represents deterioration (larger q_i → poorer quality). Use authoritative standards (BIS/WHO/local) for S_i values.

3. Apparatus & Reagents Required:

Field sampling

- Clean sampling bottles (amber/clear as required), cooler/ice, sample log, thermometer, GPS.

Laboratory

- pH meter & buffers
- DO meter or Winkler reagents & burettes
- BOD bottles & incubator (20 ± 1 °C)
- COD digestion apparatus & reagents (if COD included)
- Turbidity meter (nephelometer)
- Conductivity/TDS meter or gravimetric TDS apparatus
- Volumetric glassware, analytical balance, filtration unit
- Reagents: potassium dichromate, sulphuric acid, EDTA, standard buffers, nitrate/phosphate reagents, etc.
- PPE: gloves, goggles, lab coat; fume hood for strong reagents

4. Theory:

Key concepts

- **Ideal value (V_{ideal}):** the target/ideal value for the parameter (often 0 for pollutants; for DO use saturation or a biologically meaningful high value; for pH use 7.0).
- **Standard permissible value (S_i):** the regulatory guideline limit for the intended use (e.g., BIS 10500 for drinking, CPCB/state PCB for surface water). Always state the source and exact S_i used.

Unit weight determination

Preliminary unit weight:

$w_i' = \frac{1}{S_i}$

Normalized unit weight:

$$w_i = \frac{w_i'}{\sum w_i'} \text{ so that } \sum w_i = 1$$

Quality rating (q_i)

For pollutants (BOD, COD, TDS, turbidity, nitrate):

$$q_i = \frac{V_{actial,i} - V_{ideal,i}}{S_i - V_{ideal,i}} \times 100$$

For DO (where higher is better):

$$q_{DO} = \frac{V_{actial,DO} - V_{ideal,DO}}{V_{ideal,DO} - S_{DO}} \times 100$$

(V_ideal,DO = saturation or defined ideal; S_DO = minimum acceptable DO).

- For pH (deviation both sides):

$$q_{pH} = \frac{|V_{actial,pH} - V_{ideal,pH}|}{|S_{pH} - V_{ideal,pH}|} \times 100$$

(pick S_pH as the nearest permissible bound in the direction of deviation).

Final index

$$WQI = \sum (q_i w_i)$$

Interpret using chosen classification.

Classification example (common)

- 0–25: Excellent
- 26–50: Good
- 51–75: Poor
- 76–100: Very Poor
- 100: Unsuitable / Heavily polluted (Adjust classification to institution's convention and state it in the report.)

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5. Procedure:

A. Sampling

1. Select representative sampling points and collect grab samples following standard sampling practice. Label bottles with Sample ID, date, time, location, collector.
2. Preserve/transport samples on ice (4 °C) and analyze DO/BOD promptly.

B. Laboratory measurements (recommended sequence)

1. **pH & Temperature:** Calibrate pH meter; measure pH and temperature.
2. **Dissolved Oxygen (DO):** Measure immediately (Winkler fixation or calibrated DO meter).
3. **BOD_5:** Prepare dilution bottles, measure initial DO ($DO_{initial}$ incubate 5 days at 20 °C, measure final DO (DO_{final}).

Compute $BOD_5 = (DO_{initial} - DO_{final}) \times$ dilution factor (apply seed correction if necessary).

4. **COD (if used):** Perform standard digestion and titration / colorimetric determination; compute COD mg/L.
5. **Turbidity:** Measure with nephelometer.
6. **TDS / Conductivity:** Measure conductivity and convert or measure gravimetrically.
7. **Total Hardness / Nitrate / Phosphate:** Perform titrimetric or spectrophotometric methods as required.
8. **Quality controls:** Run blanks, duplicates, standards; record calibration details.

C. WQI calculation

1. Choose parameters to include (typical set: pH, DO, BOD, COD, TDS, Turbidity, Total Hardness, Nitrate, etc.).
2. Obtain S_i (permissible values) and V_ideal for each parameter; list the source (BIS/WHO).
3. Compute preliminary unit weights

$w_i' = \frac{1}{S_i}$ then normalize to obtain w_i.

4. Compute each quality rating q_i using the formulas above (handle DO and pH specially).
5. Compute WQI = $\Sigma(q_i \times w_i)$. Round sensibly (e.g., one decimal place).
6. Interpret the WQI and identify dominant contributors (parameters with large $q_i \times w_i$).

6. Observation Table:

Parameter	Unit	V_actual	V_ideal	S_i (Std Value) (BIS Standard Value)	q_i	w'_i = 1/S_i	w_i (Normalized)	q_i × w_i
pH	Std. Unit		7.00	8.50				
Dissolved Oxygen (DO)			14.60	5.00				
Biochemical Oxygen Demand (BOD_5)	mg/L		0.00	30.00				
Chemical Oxygen Demand (COD)	mg/L		0.00	250.00				
Total Dissolved Solids (TDS)	mg/L		0.00	500.00				
Turbidity	NTU		0.00	5.00				
Total Hardness	mg/L		0.00	300.00				
Nitrate	mg/L		0.00	45.00				
							WQI =	

Notes for table

- List the exact numeric S_i used and cite the regulatory source (e.g., BIS 10500:2012).
- Show intermediate values (w'_i and w_i) so students can reproduce calculations.
- If $q_i > 100$ for any parameter, note that it exceeds the permissible level.

7. **Result:**

The final computed **Weighted Arithmetic WQI = _______________** (dimensionless).

The water quality classification based on chosen scale is ___________________.

8. Precautions:

- Use approved standards for S_i and document their sources.
- Calibrate instruments before each use and record calibration logs.
- Preserve DO & BOD samples properly; run BOD incubations at constant 20 ± 1 °C.
- Handle strong reagents (acid/dichromate) in fume hood with PPE.
- Ensure no air bubbles in DO bottles before Winkler fixation.
- Use duplicates and blanks; flag any outliers and re-run if necessary.
- When converting conductivity to TDS use the correct conversion factor for your sample type and note it in the report.

9. Signature of Faculty with Date & Remark:

EXPERIMENT NO. 7

1. Objective

- To design a flexible road pavement as per IRC 37 guidelines.
- To convert mixed traffic volume into Passenger Car Units (PCU).
- To evaluate the effect of traffic volume and growth rate on pavement thickness.
- To determine pavement layer composition based on PCU-based traffic data.

2. Principle

Flexible pavement design is based on the principle that traffic loads are gradually distributed through successive pavement layers to the subgrade. As per IRC 37, traffic volume is first converted into PCU to account for mixed traffic conditions. The PCU-based traffic is then converted into design traffic (msa) considering growth rate, design life, and vehicle damage factor (VDF). Pavement thickness is selected so that stresses and strains in each layer remain within permissible limits. The flexible pavements has been modeled as a three-layer structure and stresses and strains at critical locations have been computed using the linear elastic model. To give proper consideration to the aspects of performance, the following three types of pavement distress resulting from repeated (cyclic) application of traffic loads are considered:

1. Vertical compressive strain at the top of the sub-grade which can cause sub-grade deformation resulting in permanent deformation at the pavement surface.
2. Horizontal tensile strain or stress at the bottom of the bituminous layer which can cause fracture of the bituminous layer.
3. Pavement deformation within the bituminous layer.

While the permanent deformation within the bituminous layer can be controlled by meeting the mix design requirements, thickness of granular and bituminous layers are selected using the analytical design approach so that strains at the critical points are within the allowable limits. For calculating tensile strains at the bottom of the bituminous layer, the stiffness of dense bituminous macadam (DBM) layer with 60/70 bitumen has been used in the analysis.

3. Apparatus Required

- Traffic volume count data
- PCU conversion factors (IRC recommendations)
- Calculator
- Design charts from IRC 37
- Computer system with MS Excel
- IRC 37 code book (latest edition)
- Stationery (pen, paper, ruler)

4. Theory

Based on the performance of existing designs and using analytical approach, simple design charts and a catalogue of pavement designs are added in the code. The pavement designs are given for subgrade CBR values ranging from 2% to 10% and design traffic ranging from 1 msa to 150 msa for an average annual pavement temperature of 35 C. The later thicknesses obtained from the analysis have been slightly modified to adapt the designs to stage construction. Using the following simple input parameters, appropriate designs could be chosen for the given traffic and soil strength:

- Design traffic in terms of cumulative number of standard axles; and
- CBR value of subgrade.

Design traffic

The method considers traffic in terms of the cumulative number of standard axles (8160 kg) to be carried by the pavement during the design life. This requires the following information:

- Initial traffic in terms of CVPD
- Traffic growth rate during the design life
- Design life in number of years
- Vehicle damage factor (VDF)
- Distribution of commercial traffic over the carriage way.

Vehicle distribution

A realistic assessment of distribution of commercial traffic by direction and by lane is necessary as it directly affects the total equivalent standard axle load application used in the design. Until reliable data is available, the following distribution may be assumed.

- **Single lane roads**: Traffic tends to be more channelized on single roads than two lane roads and to allow for this concentration of wheel load repetitions, the design should be based on total number of commercial vehicles in both directions.
- **Two-lane single carriageway roads:** The design should be based on 75 % of the commercial vehicles in both directions.
- **Four-lane single carriageway roads:** The design should be based on 40 % of the total number of commercial vehicles in both directions.
- **Dual carriageway roads:** For the design of dual two-lane carriageway roads should be based on 75 % of the number of commercial vehicles in each direction. For dual three-lane carriageway and dual four-lane carriageway the distribution factor will be 60 % and 45 % respectively.

Design traffic

The design traffic is considered in terms of the cumulative number of standard axles in the lane carrying maximum traffic during the design life of the road. This can be computed using the following equation:

$$N = \frac{365 \times [(1+r)^n - 1]}{r} \times A \times D \times F \quad (3)$$

where N is the cumulative number of standard axles to be catered for the design in terms of million standards axle (msa), A is the initial traffic in the year of completion of construction in terms of the number of commercial vehicles per day, D is the lane distribution factors, F is the vehicle damage factor, n is the design life in years, and r is the annual growth rate of commercial vehicles (r =-0.075 if growth rate is 7.5 percent per annum). The traffic in the year of completion is estimated using the following formula:

$$A = P(1 + r)^x \quad (4)$$

where p is the number of commercial vehicles as per last count, and x is the number of ears between the last count and the year of completion between the last count and the year of completion of the project.

5. Procedure

- Conduct classified traffic volume survey.
- Convert each category of vehicle into PCU using standard PCU factors.
- Calculate total daily traffic in PCU.
- Determine commercial vehicles per day (CVPD).
- Select growth rate and design life as per IRC guidelines.
- Calculate design traffic in terms of msa.
- Determine subgrade CBR value from laboratory tests.
- Select pavement layer thicknesses from IRC 37 design charts.
- Check minimum thickness requirements.
- Finalize pavement composition.

6. Observation Table

Traffic Data (PCU Based)

Vehicle Type	**No. of Vehicles**	**PCU Factor**	**PCU/day**
Car/Jeep			
Bus			
Truck			
Two-Wheeler			
Total PCU/day			

Design Parameters for Two lane carriage way

Parameter	**Value**
Growth Rate (%)	
Initial traffic in the year of completion of construction (CVPD)	
Design Life (Years)	
Vehicle Damage Factor	
Design Traffic (msa)	
Subgrade CBR (%)	

7. Result

Flexible pavement design was successfully carried out using IRC 37 guidelines.

Pavement Thickness

Layer	**Thickness (mm)**
Bituminous surfacing	
Road-base	
Sub-base Course	

8. Precautions

- Use correct PCU conversion factors.
- Ensure traffic data is reliable and representative.
- Select appropriate growth rate and VDF.
- Determine CBR value accurately.
- Follow IRC 37 provisions strictly.
- Avoid calculation and unit conversion errors.

9. Signature of Faculty with Date & Remark:

EXPERIMENT NO. 8

1. Objectives

To understand the concept of peak runoff.

To learn and apply the Rational Method formula for runoff estimation.

To analyze the influence of rainfall intensity, catchment characteristics, and runoff coefficient.

To prepare observation tables and verify the calculation.

2. Theory

Peak runoff refers to the maximum rate of flow occurring at a particular point in a drainage system as a result of rainfall. It is critical in designing stormwater drains, culverts, and rainwater harvesting systems.

Rational Method Formula: $Q = 0.278 \times C \times I \times A$ Where:

Q = Peak runoff (m^3/s)

C = Runoff coefficient (dimensionless)

I = Rainfall intensity (mm/hr)

A = Catchment area (hectares)

0.278 = Unit conversion factor

3. Apparatus Required

Rainfall Intensity Data (from IDF curves or rainfall records)

Catchment Area details (maps/surveys)

Runoff Coefficient chart (based on land use/soil type)

Calculator / Computer software

4. Procedure

- Collect rainfall intensity (I) for the design return period and time of concentration.
- Measure the catchment area (A) in hectares.
- Select an appropriate runoff coefficient (C) based on surface type.
- Apply the Rational Method formula to calculate Q.
- Tabulate and analyze results.
- Compare results with design requirements.

5. Observation Tables

Table 1: Catchment Characteristics

Catchment Type	Area (ha)	Runoff Coefficient (C)
Residential	5.0	0.6
Commercial	3.0	0.8
Open Space	2.0	0.3
Total	10.0	—

Table 2: Rainfall Intensity

Return Period (Years)	Rainfall Intensity (mm/hr)
2	60
5	90
10	120
25	150

Table 3: Peak Runoff Calculation

Return Period (Years)	I (mm/hr)	Weighted C	A (ha)	Q (m^3/s)
2	60	0.58	10.0	96.7
5	90	0.58	10.0	145.1
10	120	0.58	10.0	193.4
25	150	0.58	10.0	241.8

6. Sample Calculation

For 10-year return period: $Q = 0.278 \times C \times I \times A$

$Q = 0.278 \times 0.58 \times 120 \times 10$

$Q = 193.4$ m^3/s

7. Result

The peak runoff for the given catchment is calculated for different return periods. For a 10- year return period, the peak runoff is 193.4 m^3/s.

8. Conclusion

The Rational Method provides a simple and effective way to estimate peak runoff for small to medium catchments. The value of Q depends on rainfall intensity, land use (C), and catchment area (A).

9. Signature of Faculty with Date & Remark: