7th Semester Syllabus

Design & Detailing of Steel Structural Elements			
Course Code	1BIF701	Scheme	2025
Type of course	Integrated Professional Core Courses (IPCC)	Semester	VII
Teaching Hours/Week (L:T:P)	70 (3:0:2)	CIE Marks	50
Total Hours of Pedagogy per Semester CI (L /T): LI(P):TW&SL	120 (42:0:28:50)	SEE Marks	50
Credits	4	Total Marks	100
Type of Examination (IPCC):	Theory- CIE +SEE, and Lab- CIE only.	Exam Hours	03

Course Outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. **CO1 (L2 -- Understand):** Explain the properties of structural steel, advantages and limitations of steel structures, and the principles of Limit State Design as per IS 800:2007.
2. **CO2 (L3 -- Apply):** Design bolted and welded connections subjected to tension, shear, and combined loading with efficiency calculations and consideration of prying action effects.
3. **CO3 (L3 -- Apply):** Design tension members including angles, double angles, channels, and lug angles; calculate effective net area and determine design strength as per code provisions.
4. **CO4 (L3 -- Apply):** Design compression members (struts, built-up columns, laced and battened systems) considering slenderness effects, buckling, and member splices.
5. **CO5 (L4 -- Analyze):** Analyse and design steel beams for flexure, shear, web buckling, lateral-torsional buckling; detail plate girders and composite beams.
6. **CO6 (L5 -- Evaluate):** Evaluate industrial building frames, roof trusses, column bases, and prepare detailed working drawings with practical detailing; integrate sustainability and resilience (SDG 9, SDG 11).

Module-1

Introduction, Material Properties and Connections

- **Introduction:** Advantages of steel structures (high strength-to-weight ratio, ductility, reusability, speed of construction) and limitations (fire exposure, fatigue, corrosion, aesthetics); comparison with RCC and timber structures.
- **Structural Steel Types:** Mild steel, high-strength low-alloy (HSLA) steel, stainless steel; grades per IS 1161; stress-strain characteristics; yield point phenomenon; hardness and brittleness at low temperatures.
- **Properties & Specifications:** Yield strength, ultimate tensile strength, elongation, modulus of elasticity; effect of thickness on properties; notch brittleness; impact resistance.
- **Limit State Design Philosophy:** Concept of limit states (ultimate and serviceability); factored loads; material safety factors (γ_m); load factors; design approaches (elastic, plastic); partial safety factors per IS 800:2007.
- **Connections - Introduction:** Need for connections; types (riveted, bolted, welded); advantages/disadvantages of each; evolution from rivets to HSFG bolts to welding.
- **Bolted Connections:** Black bolts, high-strength friction grip (HSFG) bolts; specifications per IS 1367; types of bolt holes (standard, oversize, slotted); connection efficiency; lap joints, butt joints with cover plates.
- **Design of Bolted Connections:** Load transfer mechanisms; shear failure, tension failure, bearing failure, prying action; design strength of bolts in shear and tension; combined shear and tension; friction-type connections (HSFG); design procedures per IS 800:2007.
- **Welded Connections:** Types of welds (fillet, butt, intermittent); weld symbols and AWS notation; strength of fillet welds; throat thickness and effective length; weld size determination; stress distribution in fillet welds.
- **Design of Welded Connections:** Calculation of design strength; shear/tension in parent metal and weld; eccentrically loaded welds; stress concentration; practical detailing considerations; inspection and quality control.

Linked COs: CO1, CO2, CO6 | **Number of Hours: 10 hours**

Module-2

Tension Members and Design

- **Tension Member Fundamentals:** Classification; net section concept; effective net area; influence of bolt holes on strength; staggered holes; chain of holes.
- **Single Angles:** Design strength calculation; angle orientation; effect of eccentricity in connection; shear lag reduction factor; design procedure per IS 800:2007.
- **Double Angles and Channels:** Back-to-back angles with/without spacing; laced and battened double angles; determination of critical section; design strength; connection eccentricity effects.
- **Lug Angles:** Eccentric loading at connection; design for unsymmetrical section through lug angle connection; effective width concept; block shear failure check.
- **Effective Net Area Calculation:** Effect of stagger and pitch; formation of potential failure planes; calculation for single and multiple rows of bolts; shear lag concept; Whitmore effective area method.
- **Connection Design for Tension Members:** End connection detailing; minimum edge distance and spacing; hole diameter selection; fillet radii effects.
- **Design Procedure:** Step-by-step design from loads through selection of member section, verification of design strength, connection design, and detailing sketches.
- **Practical Examples:** Design of tension members in roof trusses, bridge members, bracing systems; member selection and verification; drawing preparation.

Linked COs: CO1, CO3, CO6 **Number of Hours : 10 hours**

Module-3

Compression Members and Struts

- **Column Fundamentals:** Classification of columns (short, intermediate, long slender); importance of slenderness ratio; effective length concept; end conditions (fixed, pinned, free).
- **Buckling and Slenderness Effects:** Euler formula and its limitations; Indian code approach for determination of design strength; Perry-Robertson formula; buckling curves per IS 800:2007.
- **Effective Length:** Determination based on end conditions per IS 800 Table 4; effective length factors for different support arrangements; practical considerations; wind bracing requirements.
- **Built-up Columns:** Single laced columns; double laced columns; battened columns; design of lacings and battens; spacing and proportioning requirements; slenderness of intermediate members.
- **Column Splices:** Lap splices, butt joints with cover plates, butt welds; transfer of load and moment at splices; design considerations; detailing requirements.
- **Design of Compression Members:** Calculation of design strength from slenderness ratio; interaction curve approach; design procedure; member selection; verification of local buckling (slenderness of flanges/webs).
- **Column Connections:** Connection to foundations; base plates; gusseted base plates; bearing plates; anchor bolts; transfer of axial load and moment.
- **Special Cases:** Hollow section columns; Circular Hollow Sections (CHS); Square Hollow Sections (SHS); advantages; design procedures for hollow sections per IS 800.
- **Practical Examples:** Design of single columns, built-up columns with lacings; design of splices; column base details; practical detailing sketches; fabrication considerations.

Linked COs: CO1, CO4, CO6 **Number of Hours (CI): 10 hours**

Module-4

Beams, Plate Girders and Flexural Members

- **Beam Theory and Analysis:** Bending stress distribution; neutral axis position; moment capacity; assumption of plane sections remain plane; limit state method for flexure.
- **Flexural Design:** Determination of section modulus required; selection of standard steel sections (I-sections, channels, double channels); plastic moment capacity vs elastic moment capacity.
- **Lateral-Torsional Buckling (LTB):** Concept and importance; slenderness of compression flange; reduction factor; lateral support provided by floor systems; design procedure per IS 800.
- **Laterally Supported Beams:** Design strength determination when lateral support prevents LTB; practical examples of laterally supported beams in buildings.
- **Laterally Unsupported Beams:** Design strength reduction due to LTB; effective length of compression flange; calculation of design strength; design procedure.
- **Shear Design:** Shear stress calculation; importance in plate girders and deep beams; minimum web thickness for shear; design of stiffeners.
- **Web Buckling and Crippling:** Local buckling of web due to concentrated loads; bearing stiffeners; connection stiffeners; design requirements per IS 800.
- **Deflection Control:** Deflection limits for different serviceability conditions (residential, commercial, industrial); calculation of deflection; effective moment of inertia concept; practical limits on span-to-depth ratio.
- **Plate Girders:** Built-up girders with cover plates or rolled sections; design of web; flange design; connection of flanges; intermediate and bearing stiffeners; welded vs riveted construction.
- **Composite Beams:** Concept of composite action; shear connectors; effective width of concrete slab; partial vs full composite action; design procedure.
- **Connection of Beams:** Beam-to-column connections (simple shear connections, moment-resisting connections); design of end plates, cleats, and welds; prying effects.

Linked COs: CO1, CO5, CO6 **Number of Hours (CI): 10 hours**

Module-5

Industrial Frames, Trusses and Detailing

- **Industrial Building Frames:** Single-storey frames; two-storey frames; portal frame action; load paths; bracing systems (vertical bracing, horizontal bracing); wind load distribution.
- **Roof Trusses:** Types of trusses (Truss, Warren, Pratt, etc.); joint loads determination; force distribution in members; design of individual members; connection design; practical proportioning.**Column Bases:** Functions; simple bases (bearing plates with anchor bolts); gusseted bases; transfer of axial load and moment; base plate design; bearing on concrete; anchor bolt design.
- **Bolted Connections in Frames:** End-plate connections; cleat angles; moment connections; eccentric connections; practical design procedures; detailing for fabrication and erection.
- **Bolted Column-Beam Connections:** Shear connections; moment connections; semi-rigid connections; design for combined shear and moment; slip factor consideration (HSFG bolts).
- **Welded Connections in Frames:** Field welded connections; shop welded connections; continuity plates; stiffening requirements; quality control and inspection.
- **Bracing Design:** Diagonal bracing members; X-bracing; V-bracing; design for tension and compression; buckling of bracing members; connection design.
- **Detailing Principles:** Detailing for constructability; clearances for bolts and welds; avoiding stress concentrations; ease of assembly and erection; economical design; working drawings preparation.
- **Sustainability and Reuse:** Sustainable steel design practices; material efficiency; design for disassembly; reuse and recycling of steel; life-cycle assessment; linkage to SDG 9, SDG 11, SDG 12.

Linked COs: CO3, CO4, CO5, CO6 **Number of Hours (CI): 10 hours**

PRACTICAL COMPONENTS OF IPCC

PART – A: FIXED SET OF EXPERIMENTS **LI : 20**

hours

1. Tensile Testing of Steel Specimen

2. Bolted Connection Testing

PART – B: OPEN ENDED EXPERIMENTS LI : 10 hours

Open-ended experiments are a type of laboratory activity where the outcome is not predetermined and students are given the freedom to explore, design, and conduct the experiment based on the problem statements as per the concepts defined by the course coordinator. It encourages creativity, critical thinking, and inquiry-based learning.

1. **Column Buckling Test**
2. **Lap Joint Welded Testing**

Suggested Learning Resources

Text Books:

1. Subramanian, N. (2014). *Design of Steel Structures* (2nd ed.). Oxford University Press India.
2. Duggal, S. K. (2010). *Design of Steel Structures* (3rd Ed.). Tata McGraw-Hill Publishing.
3. Bhavikatti, S. S. (2015). *Design of Steel Structures* (4th ed.). Vikas Publishing House.
4. Indian Standard 800:2007. *Code of Practice for General Construction in Steel* (3rd Revision). Bureau of Indian Standards, New Delhi.
5. SP-6 (Parts 1-5). *Handbook of Structural Steel Sections*. Bureau of Indian Standards.

Reference Books:

1. Galambos, T. V., Lin, F. J., & Johnston, B. G. (1998). *Basic Steel Design*. Prentice Hall.
2. Salmon, C. G., Johnson, J. E., & Malhas, F. A. (2009). *Steel Structures: Design and Behavior* (5th ed.). Prentice Hall.
3. Chen, W. F., & Lui, E. M. (2005). *Structural Stability - Theory and Implementation*. Elsevier.
4. Horne, M. R. (1975). *Plastic Theory of Structures* (2nd ed.). Nelson Publishers.
5. IS 875:2015. *Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures*. Bureau of Indian Standards.
6. IS 1367. *Specification for High-Strength Bolts and Associated Rivets for Structural Steelwork*. Bureau of Indian Standards.

Web Links and e-Resources:

1. NPTEL Courses on Steel Structures and Design of Steel Structural Elements
2. Bureau of Indian Standards (BIS) website for Indian Standards codes
3. Steel Authority of India Limited (SAIL) - Design aids and material specifications
4. Online design tools and calculators for connection design
5. Video tutorials on steel fabrication and detailing
6. Case studies of modern steel structures in India

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Assessment Structure:

The assessment for each course is equally divided between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each component carrying **50% weightage** (i.e., 50 marks each).
The CIE Theory component will be **25 marks** and CIE Practical component will be **25 marks**.

The CIE Theory component consists of IA tests for 25 marks. The CIE Practical component for continuous assessments will be for 15 marks through rubrics and for lab tests will be for 10 marks.

- To qualify and become eligible to appear for SEE, in the **CIE theory component**, a student must score at least **40% of 25 marks**, i.e., **10 marks**.
- To qualify and become eligible to appear for SEE, in the **CIE Practical component**, a student must secure **a minimum of 40% of 25 marks**, i.e., **10 marks**.
- To pass the **SEE**, a student must secure **a minimum of 35% of 50 marks**, i.e., **18 marks**.

A student is deemed to have **successfully completed the course** if the **combined total of CIE (and SEE is at least 40 out of 100 marks**.

Students' activities for TW/SL under NCrF: Samples only:

As per National credit framework (NCrF) students must spend 120 hours of study for 4 credit courses, which include Course instructions (CI-70 hour) and Teamwork/ Self learning (TW/Sl-50 hours). Hence, students must complete minimum of two actives as part of NCrF. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester

Team work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1.	**Activity 1 (CO2, CO3, CO6):** Steel-Truss Design–Build Project (Teamwork) Develops teamwork, problem-solving, and application of codel provisions for steel elements and connections.	25
2.	**Activity 2 (CO3, CO4):** Connection Detailing and Site-Visit / Case Study (Self-Learning) Strengthens self-learning, observation, and reconciliation of classroom theory with practical solutions.	25

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1.	NPTEL/SWAYAM, MOOCs, software/coding tutorials, self-initiated projects, digital platform learning.	25
2.	Self-initiated projects, digital platform learning.	25

Rubric – Integrated Design Mini-Project - (sample)

Criterion	**Exemplary (3)**	**Proficient (2)**	**Basic (1)**	**Weight**
Content & Technical Depth (CO1, CO5, CO6)	Comprehensive understanding; technically accurate; provides detailed analysis of design, failures, or detailing; clear connections to IS 800 provisions and practice	Good understanding; mostly accurate; reasonable technical depth; generally clear connections to course concepts	Limited technical knowledge; surface-level analysis; weak connection to steel design concepts	25%

Critical Analysis & Insights (CO5, CO6)	Thorough analysis of design decisions, failure mechanisms, or detailing implications; identifies key learning points; discusses practical implications for design	Some substantive analysis; identifies main lessons; discusses implications to practice to some extent	Minimal analysis; lessons not clearly identified; limited practical applications discussed	25%
Presentation Skills	Clear, engaging, well-paced presentation (10 min); effective visuals (photographs, drawings, data); answers confidently; professional language and appearance	Reasonably clear presentation; mostly well-paced; adequate visuals; answers most questions appropriately; professional presentation	Presentation unclear or rushed; pacing issues; limited visual support; difficulty answering questions; language sometimes unclear	20%
Written Report	Well-structured (4-5 pages); clear introduction, analysis, conclusions; proper citations; professional formatting; figures well-captioned; references properly formatted	Generally organized; analysis present; adequate citations; good language clarity; minor formatting issues; adequate references	Poor organization; weak analysis; inconsistent citations; significant language/formatting problems; incomplete references	20%
Visuals & Evidence	High-quality, relevant visuals (photographs, drawings, data); directly support narrative; all properly labeled and captioned	Visuals generally relevant and well-labeled; most support narrative effectively	Few visuals; poorly labeled; minimal support to narrative; missing captions	10%

Suggested rubrics for Practical continuous assessment:

Performance Indicators	**Excellent**	**Very Good**	**Good**	**Satisfactory**
Fundamental Knowledge (4) (PO1)	Demonstrates deep understanding of underlying connect experiment to theory and field applications (4).	Good understanding; minor gaps in linking to theory/field (3).	Basic understanding; limited theoretical connection (2).	Weak conceptual grasp; significant gaps (1).
Experimental planning & setup (5) (PO2 & PO3)	Can independently describe procedure, identify key parameters and set up apparatus correctly with safety and sustainability considerations (5).	Sets up with minor guidance; understands main steps (4).	Follows instructions; needs moderate guidance (3).	Requires significant guidance; procedural confusion (1–2).
Implementation & data quality (8) (PO3 & PO8)	Executes experiment systematically; obtains consistent, reliable data; records neatly and completely (7–8).	Executes well with minor lapses in data or recording (5–6).	Executes but with noticeable procedural/data issues (3–4).	Manages basic execution only; data/record poor (1–2).
Result analysis & inference (5) (PO4)	Correct calculations, graphs and interpretation; compares with theory and discusses possible errors (5).	Mostly correct; minor interpretation issues (4).	Partly correct; limited discussion (3).	Minimal analysis; little understanding of results (1–2).

Demonstration, reporting & teamwork (8) (PO9 & PO10)	Clear oral/written explanation; well-organised record; strong teamwork and role clarity (7–8).	Good explanation and record; teamwork evident (5–6).	Understandable but unstructured; uneven teamwork (3–4).	Poor explanation/record; weak teamwork (1–2).

Note: Can add Engineering & IT tool usage based on the nature of the course

Table – ICs/IPCCs 1 Distribution of marks		
Component	**Description**	**Marks**
Allotment of marks for regular class work		
Ability in Conducting Experiments	Initiative, skill, safety practices, teamwork, and independent handling of equipment during regular lab sessions.	5 marks
Laboratory Record / Journal	Regular and neat maintenance of lab record, accuracy of results, and timely submission.	10 marks
	Subtotal	**15**
Allotment of marks for CIE practical test		
Laboratory Test / Experiment Performance	Ability to set up apparatus follows procedure, take observations, and obtain correct results in the test experiment.	5 marks
Viva-Voce	Understanding of theory, concepts, and experimental procedure; ability to explain results and answer related questions.	5 marks
	Subtotal	**10**
	Total	**25**

Continuous Internal Evaluation (CIE):

(i) Theory component

The CIE marks of 25 shall be earmarked for two tests.

The first test shall be conducted after completing two modules of the syllabus and the second one after completing the rest three modules.

Each test shall be conducted for 25 marks. The average of the two tests scaled down to 25 marks shall constitute the test marks for a maximum of 25 marks.

(ii) Laboratory component

Out of 25 marks, 15 marks shall be assigned for assessment as per the rubrics listed in the course syllabus. The remaining 10 marks shall be based on the practical test conducted by two internal examiners appointed by the HoD. The allotment of marks shall be as per the rubrics defined for regular class work and practical test as indicated in the Table – ICs/IPCCs

i) To qualify and become eligible to appear for the SEE of the IC/IPCC, a student shall secure at least 40 % of 25 marks, i.e., 10 marks, in the CIE theory component, and at least 40 % of 25 marks, i.e., 10 marks in the CIE Practical component.

Passing requirement in SEE:

i. For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

ii. For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

iii. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

Professional Elective Course-III Syllabus

Advanced Concrete Technology for Infrastructure Applications			
Course Code	1BIF702A	Scheme	2025
Type of Course	Profession Elective Course(PEC)	Semester	VII
Teaching Hours/Week(L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per semester CI (L /T) :LI(P):SL&TW:	90(42:0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Examination type(SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. **CO1 (L2 -- Understand):** Explain the chemistry of cement hydration, properties of aggregates, admixtures, and their effects on concrete properties to understand the properties of ingredients of concrete.
2. **CO2 (L4 – Analyze):** Assess the fresh and hardened properties of concrete and interpret test results for quality assurance in infrastructure projects to study the behavior of concrete at its fresh and hardened state.
3. **CO3 (L4 – Analyze):** Identify appropriate special concrete types for specific infrastructural applications and evaluate their suitability.
4. **CO4 (L3 – Apply, L4 – Analyze):** Apply mix design principles for designing concrete mixes suitable for various infrastructure applications using IS: 10262-2019 and international methods.

Module-1

Concrete Making Materials & Microstructure:

- Advanced cement chemistry (OPC, PPC, GBFSC, types of cement),
- Aggregates: Characteristics, grading, blending, and recycled aggregates,
- Chemical admixtures (plasticizers, accelerators, retarders) and Mineral admixtures (fly ash, silica fume, GGBS, met kaolin).
- Microstructure of concrete, hydration process, and early-age properties

Linked COs: CO1, partial CO3, CO4 **Number of Hours Required (CI): 8hrs**

Module-2

Properties of Fresh and Hardened Concrete:

- Rheology of concrete: workability, viscosity, stability, Elasticity, creep, and shrinkage properties.
- Durability: Corrosion, chemical attack (sulphates, chloride), freeze-thaw resistance, and alkali-aggregate reaction

Linked COs: CO2, partial CO3, CO4 **Number of Hours Required (CI): 8hrs**

Module-3

Special Concrete Types for Infrastructure:

- Self-Compacting Concrete (SCC),
- High-Strength Concrete (HSC), and High-Performance Concrete (HPC),
- Fiber Reinforced Concrete (FRC) and Engineered Cementitious Composites (ECC),
- Lightweight, heavy-density, mass concrete, and roller-compacted concrete, Smart concrete (self-healing, conductive concrete),
- Ferro cement: Definition, different materials used, casting techniques, properties of Ferro cement, applications.

Linked COs: CO3, partial CO4,CO5 **Number of Hours Required (CI): 8hrs**

Module-4

Mix Design and Construction Techniques:

- Mix design methods (IS code, ACI) for special concretes,
- Design of pumpable and mass concrete,
- Special concreting techniques: Vacuum dewatering, tremie method.
- Shotcrete, slip-form construction.

Linked COs: CO4 CO3 **Number of Hours Required (CI): 9 hrs**

Module-5

Quality Control, Testing, and Sustainability:

- Advanced Non-Destructive Testing (NDT) techniques: Ultrasonic pulse velocity, rebound hammer, probe penetration, break-off methods.
- Structural Health Monitoring (SHM) of infrastructure.

Sustainability: Low-carbon concrete, waste material utilization in concrete.

Linked COs: CO3, CO4, CO5 **Number of Hours Required (CI): 9 hrs**

Suggested Learning Resources

Textbooks:

- Neville A.M. "Properties of Concrete"-4th Ed., Longman.
- M.S. Shetty, Concrete Technology - Theory and Practice Published by S. Chand and Company, New Delhi.
- Kumar Mehta. P and Paulo J.M. Monteiro "Concrete-Microstructure, Property and Materials", 4th Edition, McGraw Hill Education, 2014
- A.R. Santha Kumar, "Concrete Technology", Oxford University Press, New Delhi (New Edition).

Reference Books:

- M L Gambir, "Concrete Technology", McGraw Hill Education, 2014.
- N. V. Nayak, A. K. Jain Handbook on Advanced Concrete Technology, ISBN: 978-81-8487-186-9
- Job Thomas, "Concrete Technology", CENGAGE Learning, 2015.
- IS 4926 (2003): Code of Practice Ready-Mixed Concrete [CED 2: Cement and Concrete] Criteria for RMC Production Control, Basic Level Certification for Production Control of Ready Mixed Concrete- BMTPC.
- Specification and Guidelines for Self-Compacting Concrete, EFNARC, Association House

Web links and e-Resources:

- https://nptel.ac.in/courses/105106176
- https://onlinecourses.nptel.ac.in/noc25_ce93

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

Suggested Innovative Delivery Methods may include(but are not limited to):

- Flipped Classroom
- Problem-Based Learning(PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/industrial visits
- ICT-Enabled Teaching
- Role Play

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks.**
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks.**
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**..

Continuous Comprehensive Assessments (CCA)+Internal Assessment Test (IA)= Continuous Internal Evaluation CIE [25+25=50 marks]

- A minimum of **two Internal Assessment Tests (IA)** shall be conducted, carrying a total of **25 marks.**
- In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks.**
- It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development.**

Students' Learning activities: These activities shall be:

- Course Project
- Case Study Presentation
- Literature Review
- Seminars/Quizz (To assist in GATE Preparations)
- Demonstrations in Lab
- Virtual Lab Experiments
- Self-Study on simple topics
- Simple problems solving using Excel
- Assignment(at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Term Work (TW) Activity	Number of Hours/Semester
Material Testing Portfolio: Test 5 cement samples (fineness, consistency, setting time) + 3 aggregate samples (sieve analysis, specific gravity). Compare with IS 4031 specs.	24
Case Study Analysis: Analyze failure of Padma Bridge concrete deck (cracking issues). Propose 3 repair strategies using FRP/ geo polymer overlays.	24
Literature Review: Review 5 recent papers on UHPC for high-speed rail viaducts from Science Direct. Summarize mix design trends.	24
Self-Learning (SL) Activity	**Number of Hours/Semester**
MOOC + GATE/Data- Driven Track: Complete mapped NPTEL/MOOC modules, solve GATE-style and open-ended analysis problems involving probability and statistics in civil Engineering, culminating in an integrated open-book test.	24
Literature review on emerging tools; reflective learning journal	24

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):
1.Sample Rubrics-Integrated Design Mini-Project

Criterion	Exemplary(3)	Proficient(2)	Basic(1)	Weight
Problem Identification	Clear infrastructure problem with 3+ case studies & literature support	Defined problem with 2 case studies	Basic problem statement	15%
Methodology & Innovation	Novel mix design/NDT method with lab validation	Standard method with minor innovation	Basic testing procedures	35%
Results & Analysis	Statistical analysis + sustainability metrics	Basic graphs + observations	Raw data only	35%
Report & Presentation	Professional format, error-free, 15-min demo	Good format, minor errors	Basic report	15%

Continuous Internal Evaluation (CIE):

(i) The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii) Out of 50marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE:

(i) For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

(ii) For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

(iii) If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade 'F' (Fail).

Prestressed Concrete Structures			
Course Code:	1BIF702B	Scheme	2025
Type of Course	Profession Elective Core (PEC)	Semester	VII
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per semester CI (L /T) :LI(P):SL&TW:	90 (42:0:0:48)	SEE Marks	50
Credits	03	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

1. CO1 (L2–Understand): Explain the basic principles, materials, and systems of prestressed concrete.
2. CO2 (L3–Apply): Analyze prestressed members for flexure, shear, and torsion using stress and load balancing concepts.
3. CO3 (L3–Apply): Calculate losses in pre-stress and deflections in prestressed concrete members.
4. CO4 (L4–Analyze): Design prestressed concrete beams for serviceability and ultimate limit states.
5. CO5 (L3–Apply): Design end blocks, anchorages, and composite sections in prestressed structures
6. CO6 (L5–Evaluate): Evaluate applications of prestressed concrete in sustainable structures like bridges, promoting material efficiency and durability.

Module-1

Introduction and Materials:

- Scope of prestressed concrete in civil engineering structures like beams, slabs, bridges, and tanks.
- Basic principles: Pre-tensioning and post-tensioning systems, advantages and limitations over reinforced concrete.
- Materials: High strength concrete properties (stress-strain curve), high strength steel (wires, strands, tendons).
- Mechanical properties, mix design considerations for prestressed members.

Linked Cos; CO1. **Number of Hours Required (CI): 8 hours.**

Module-2

Prestressing Systems and Losses:

- Prestressing systems: Tensioning methods, end anchorages, cable profiles (straight, draped, parabolic).
- Load balancing concept, kern points, pressure line, centre of thrust.
- Losses: Elastic deformation, friction, anchorage slip, creep, shrinkage, relaxation; estimation of total losses.
- Analysis at transfer and service stages.

Linked Cos; CO1, CO3. **Number of Hours Required (CI): 8 hours.**

Module-3

Flexure and Deflection:

- Stress concept in prestressed members under axial, eccentric prestress and loads.
- Allowable stresses, design of prestress force and eccentricity.
- Deflections: Short-term and long-term due to prestress, creep effects, load-deflection curves.
- Limits as per IS 1343: Control of deflections, cracking, span-to-depth ratios.

Linked Cos; CO2, CO3 **Number of Hours Required (CI): 8 hours.**

Module-4

Shear and Torsion

- Shear in prestressed beams: Components of shear resistance, modes of failure.
- Design for shear: Transverse reinforcement, IS code provisions for limit state.
- Torsion in prestressed members, combined shear and torsion.
- Serviceability: Crack width limits.

Linked Cos; CO2, CO4. **Number of Hours Required (CI): 8 hours.**

Module-5

Design of Members and Applications

- Transmission length in pre-tensioned members, anchorage zone stresses in post-tensioned.
- End block design: Bursting forces, reinforcement as per IS code.
- Design examples: Symmetrical/asymmetrical sections, simply supported/post-tensioned beams.
- Applications: Bridges, sleepers, piles; composite construction.

Linked Cos; CO4, CO5, CO6. **Number of Hours Required (CI): 10 hours.**

Suggested Learning Resources

Textbooks:

1. N. Krishna Raju, Prestressed Concrete, Tata McGraw Hill.
2. P. Dayaratnam, Prestressed Concrete Structures, Oxford & IBH.

References:

1. IS 1343: Prestressed Concrete Code of Practice.
2. Lin, T.Y., Design of Prestressed Concrete Structures.

Web links and e-Resources:

1. NPTEL courses on Prestressed Concrete Design.

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching- learning process and facilitate the achievement of course outcomes.

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Assessment Structure: The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

- A minimum of **two Internal Assessment Tests (IA)** shall be conducted, carrying a total of **25 marks**.
- In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.
- It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development.**

Students' Learning activities: These activities shall be:

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)

- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Students' activities for TW/SL under NCrF: Samples only

As per National credit framework (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48hours). Hence, students must complete minimum of two actives as part of NCrF. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	**Prestressed Concrete Structural Assessment Mini-Project:** Conduct analytical/field-based study of prestressed members (beams/bridges), identify prestressing system, tendon profiles, losses and serviceability behaviour; document observations with reference to IS 1343.	24
2	**Design Case Study on Prestressed Members:** Prepare case studies on PSC applications (bridges, sleepers, girders); analyse design aspects such as flexure, shear, deflection, and losses; justify design choices using code provisions.	24
3	**Tools / Materials & Design Workbook:** Develop a technical workbook covering prestress losses calculation, stress analysis, deflection computations, and simple design problems using Excel/Python or standard ARE code procedures.	24

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1	**MOOC / NPTEL + GATE / Data-Driven Track:** Complete modules on prestressed concrete design; solve application-based numerical problems on losses, stresses, deflection and design.	24
2	**Literature Review & Reflective Learning Journal:** Review recent PSC applications (bridges, sustainable structures, infrastructure projects from IIT/NIT/industry); document insights on design efficiency, durability, and sustainability.	24

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

1. **Sample Rubrics - Mini-Project**

Criterion	Exemplary (3)	Proficient (2)	Basic (1)	Weight
Field/Design data collection (systems, losses, loads)	Visits multiple sites/reviews cases; records tendon profiles, materials, losses systematically with locations/dates; safety considered.	Reviews at least two cases; records main systems/losses; minor gaps.	Limited cases/desk-based; observations incomplete.	20%
PSC description accuracy (CO1, CO3)	Correct identification of systems, profiles, losses; clear descriptions using IS terms.	Mostly correct; minor errors in terminology.	Frequent misidentification ; limited terms.	25%
Engineering interpretation (flexure, shear, deflections; CO2, CO4)	Relates to design limits, serviceability; realistic comments per IS 1343.	Some links; partly justified.	Little interpretation; descriptive only.	25%
Code/SDG linkage reflection (CO5, CO6)	Connects to sustainable design (durability, economy, applications);	Brief mention of codes/sustainability.	No mention.	15%

	thoughtful reflection on SDG 9/11.			
Portfolio organization/presentation	Well-structured; labeled figures, calcs, references; clear language.	Generally organized; minor issues.	Disorganized; poor labels.	15%

Continuous Internal Evaluation (CIE):

(i) The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii) Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE:

i. For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

ii. For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

iii. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

Bridge Infrastructure: Analysis, Design and Innovation			
Course Code	1BIF702C	Scheme	2025
Type of Course	Profession Elective Course (PEC)	Semester	VII
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per semester CI (L /T) :LI(P):SL&TW:	90(42:0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course Outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. **CO1 (L2 -- Understand):** Explain fundamentals of bridge engineering including classification, load distribution mechanisms, design philosophies, and IRC standards for bridge loading and design per IRC 6:2014.
2. **CO2 (L3 -- Apply):** Analyse and design deck slabs and simple bridge superstructures under IRC standard live loads with proper reinforcement detailing per IS 456:2000.
3. **CO3 (L3 -- Apply):** Design and detail T-beam girder bridges including main girders, cross-girders, deck slab, and bearing details per IRC 19:2013 and IS codes.
4. **CO4 (L3 -- Apply):** Design and check stability of substructures (abutments, piers) under combined loading including lateral and seismic forces per IRC and IS 1893:2016.
5. **CO5 (L4 -- Analyze):** Analyse bridge performance under multiple loading scenarios; evaluate robustness and progressive collapse potential; understand inspection methodologies per IS 1175:1987.
6. **CO6 (L5 -- Evaluate):** Evaluate bridge sustainability using life-cycle assessment; design resilient and innovative bridge solutions integrating smart materials and climate resilience (SDG 9, SDG 11, SDG 13).

Module-1

Bridge Fundamentals, Classification and Loading

- **Introduction to Bridge Engineering:** Need for bridges in infrastructure; historical evolution; role in economic development; types of bridge failures and lessons learned.
- **Bridge Classification:** By function (highway, railway, pedestrian); by material (timber, masonry, steel, RCC, composite); by structural system (beam, truss, arch, suspension, cable-stayed, tied-arch).
- **Bridge Components:** Superstructure (deck slab, main girders, cross-girders, railings); substructure (abutments, piers, foundation); bearings and expansion joints; durability considerations.
- **Load Distribution in Bridges:** Load paths; analysis of vehicle loads; impact of live load position; longitudinal and transverse load distribution; concept of influence lines; distribution factors.
- **IRC Standards for Loading:** IRC 6:2014 (General Features); IRC 19:2013 (Concrete Road Bridges); IRC 83:2015 (Wooden Bridges); live load patterns (Class A, Class AA, Class B); environmental loads (temperature, wind, earthquake per IRC 92:2014).
- **Limit State Design Approach:** Ultimate and serviceability limit states; partial safety factors per IRC codes; design philosophy; comparison with working stress design; durability considerations.
- **Bearings and Joints:** Functions of bearings; types (elastomeric, pot, rocker, spherical); expansion joints; movement accommodation; design considerations.
- **Material Properties for Bridges:** Concrete grades and durability; water-cement ratio; steel reinforcement grades per IS 1786; stress-strain characteristics; durability in aggressive environments.

Linked COs: CO1, CO2, CO6 | **Number of Hours Required (CI): 08 hours**

Module-2

Deck Slab and Simple Bridges

- **Deck Slab Design:** Simply supported deck slabs; continuous deck slabs; analysis under IRC loads; distribution of vehicle loads across slab width; grillage method; influence surface method.
- **Reinforcement Design:** Longitudinal reinforcement for main bending moments; transverse reinforcement for load distribution; link reinforcement; shear reinforcement per IS 456; detailing requirements.
- **Simple Beam Bridges:** Single span RCC/prestressed concrete beam bridges; analysis under dead load and live load; deflection control; design of main girders and connecting elements.
- **Culverts and Box Structures:** Box culverts under live loads; earth pressure calculations; design considerations; waterproofing and drainage; detailing for durability.
- **Load Distribution Methods:** Lever rule; method of characteristics; Grillage analogy; Pigeaud's method; distribution factors; eccentric loading analysis; transverse distribution of wheel loads.
- **Practical Design Examples:** Complete design of deck slab bridge; step-by-step calculations; detailing drawings; bar

bending schedules; verification of design per IRC standards.

- **Serviceability Checks:** Deflection calculation per IS 456; crack width control; durability requirements; design for different exposure conditions (coastal, industrial, normal).

Linked COs: CO1, CO2 | **Number of Hours Required (CI): 08 hours**

Module-3

T-Beam Girder Bridges - Design and Detailing

- **T-Beam Bridge Configuration:** Typical cross-section; main girders (T or I-shaped); cross-girders; deck slab; spacing of girders; proportioning guidelines per IRC.
- **T-Beam Girder Analysis:** Analysis of main girders under dead and live loads; moment and shear force determination; critical loading positions; impact factor consideration; distribution among girders (lever rule, grillage method).
- **Design of Main Girders:** Effective width of flange; bending moment capacity; shear capacity; design for flexure and shear; deflection control; lateral-torsional buckling (LTB) considerations; design procedure per IRC 19.
- **Cross-Girder Design:** Analysis of secondary beams; design for bending and shear; connection details with main girders; optimization of section.
- **Deck Slab on T-Beam:** Design of continuous slab over main girders; impact of live load; longitudinal and transverse reinforcement; composite action considerations.
- **Reinforcement Detailing:** Main reinforcement in girders; shear reinforcement; detailing at supports and spans; lap lengths and anchorage per IS 456; bar bending schedules; practical detailing considerations.
- **Connection Details:** Connection between main and cross-girders; bearing arrangements; efficient and practical detailing; transfer of loads; bearing stud design.

Linked COs: CO2, CO3, CO6 | **Number of Hours Required (CI): 08 hours**

Module-4

Bridge Substructures - Abutments and Piers

- **Abutment Fundamentals:** Functions; types (gravity, cantilever, spill-through); failure modes; design considerations; stability requirements (overturning, sliding, bearing capacity).
- **Forces on Abutments:** Vertical loads (superstructure reaction, live load); horizontal loads (earth pressure, temperature, braking); seismic forces per IS 1893; water pressure effects.
- **Earth Pressure Calculations:** Active earth pressure; passive earth pressure; coefficient determination; surcharge effects; water table effects; dynamic earth pressure during earthquakes.
- **Design of Cantilever Abutments:** Stability analysis; design of stem and base; reinforcement detailing; construction joints; waterproofing; bearing capacity verification.
- **Pier Functions and Types:** Support intermediate spans; resist lateral loads (wind, seismic); architectural clearance; navigational requirements; configuration (solid wall, column, multi-column).
- **Forces on Piers:** Vertical loads; lateral loads (wind, seismic, braking, centrifugal); combination of loads; critical load cases; analysis under asymmetric loading.
- **Pier Design:** Structural analysis under combined loading; bending and shear force; design of pier shaft and base; bearing capacity check; sliding resistance verification; reinforcement detailing for ductility.
- **Bearing Design:** Support functions; types (elastomeric, pot, spherical); design approach; sizing; rotational and translational capacity; maintenance considerations.

- **Foundation Design:** Spread foundations (shallow); deep foundations (piles); bearing capacity determination; settlement analysis; design calculations; scour protection; pile cap design.
- **Seismic Design of Substructure:** Equivalent static approach; response spectrum method; design for ductility; detailing for earthquake resistance per IS 1893; confinement requirements.
- **Construction Aspects:** Cofferdam design; dewatering; compaction control; quality assurance; inspection procedures; construction sequencing.

Linked COs: CO1, CO4, CO6 | **Number of Hours Required (CI): 09 hours**

Module-5:

Advanced Topics - Sustainability, Innovation and Resilience

- **Bridge Inspection and Maintenance:** Visual inspection procedures; non-destructive testing (ultrasonic, half-cell potential, thermography); condition assessment; defect identification per IS 1175; maintenance scheduling.
- **Rehabilitation and Retrofitting:** Common bridge defects (corrosion, spalling, fatigue, settlement); repair methodologies; strengthening techniques (external prestressing, FRP, epoxy injection); cost-benefit analysis.
- **Progressive Collapse and Robustness:** Failure propagation mechanisms; redundancy in bridge systems; robustness assessment; design for robustness; monitoring systems for early warning.
- **Sustainability in Bridge Design:** Life-cycle assessment (LCA) - cradle to grave; environmental impact quantification; carbon footprint of materials; design for minimal impact; sustainable material choices (recycled aggregate, self-consolidating concrete).
- **Life-Cycle Cost Analysis (LCCA):** Initial cost; maintenance cost; repair and replacement; user costs; residual value; optimization for minimum total cost; discount rate considerations.
- **Smart Bridges and Monitoring:** Structural health monitoring (SHM) systems; sensor placement; real-time data acquisition; data analysis; artificial intelligence applications; predictive maintenance.
- **Innovative Bridge Materials:** High-performance concrete (HPC); self-consolidating concrete (SCC); recycled aggregate concrete (RAC); fiber-reinforced concrete; composite materials; shape memory alloys; sustainability benefits.
- **Innovation in Bridge Design:** Prefabrication and modular construction; 3D printing of elements; accelerated bridge construction (ABC); robotics in construction; BIM for bridge projects.

Linked COs: CO5, CO6 | **Number of Hours Required (CI): 09 hours**

Suggested Learning Resources

Text Books:

1. Ponnuswamy, S. (2011). *Bridge Engineering* (3rd ed.). Tata McGraw-Hill Publishing.
2. Vazirani, V. N., & Ratwani, M. M. (2008). *Design of Bridge Structures* (10th ed.). Khanna Publishers.
3. Subramanian, N. (2013). *Design of Concrete Bridges* (2nd ed.). Oxford University Press India.
4. Venkatramaiah, C. (2010). *Highway Engineering* - Vol. 2 (Bridges and Tunnels). Universities Press.
5. IRC 6:2014. *Standard Specifications and Code of Practice for Road Bridges - General Features*. Indian Roads Congress.
6. IRC 19:2013. *Design of Non-Urban Concrete Road Bridges*. Indian Roads Congress.

Reference Books:

1. Victor Johnson, J. (2002). *Bridge Engineering: Design, Rehabilitation and Maintenance*. McGraw-Hill.
2. Raina, V. K. (2009). *Concrete Bridges* (4th ed.). Oxford University Press.
3. Mandal, T. R. (2010). *Highway Engineering and Road Pavements* (5th ed.). Chand Publications.
4. IS 456:2000. *Code of Practice for Plain and Reinforced Concrete*. Bureau of Indian Standards.
5. IS 1893:2016. *Code of Practice for Earthquake Resistant Design and Construction*. Bureau of Indian Standards.
6. IS 1175:1987. *Code of Practice for the Inspection, Maintenance and Repair of In-Service Concrete Structures*. Bureau of Indian Standards.

Web Links and e-Resources:

1. NPTEL Courses on Bridge Engineering and Structural Analysis
2. Indian Roads Congress (IRC) website (www.ircindia.org)
3. Bureau of Indian Standards (BIS) website for Indian Standards codes
4. National Highway Authority of India (NHAI) technical guidelines
5. Video tutorials on bridge design and construction techniques
6. Case studies of modern bridges in India
7. Structural health monitoring systems research
8. BIM software tutorials for bridge projects

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching- learning process and facilitate the achievement of course outcomes.
Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Assessment Structure

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage. To qualify and become eligible to appear for

- SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks.**
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks.**
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE is at least 40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

- A minimum of **two Internal Assessment Tests (IA)** shall be conducted, carrying a total of **25 marks**.
- In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.

- It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development.**

Students' Learning activities: These activities shall be:

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity

Students' activities for TW/SL under NCrF: Samples only

As per National credit framework (NCrF) students must spend 120 hours of study for 4 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete two actives as part of NCrF as part of CCA, which carries 25 marks. The evaluations of these activities will be done using set of rubrics developed for each activity. The following sample activities are listed below.

Term Work (TW) and Self Learning (SL) components in

Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours/ Semester
1.	**Integrated RC Design Mini-Project -**Design and detail a complete reinforced concrete structure (beam-column frame / multi-story building) with calculations, sketches, and sustainability report (CO2, CO3, CO4, CO5, CO6)	**24**
2.	**Case Study & Seminar Presentation -**Research and present a case study on (a) a notable RC structure failure and lessons learned, (b) earthquake-resistant RC design in Indian context, or (c) sustainable RC construction practices. Includes written report and 10-min presentation	**24**

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1.	**MOOC + GATE/Data- Driven Track: Complete mapped NPTEL/MOOC modules, solve GATE-style and open-ended analysis problems involving probability and statistics in civil engineering, culminating in an integrated open-book test.**	**24**
2.	**Literature review on emerging tools; reflective learning journal**	**24**

Integrated Bridge Design Mini-Project Rubric

Criterion	Exemplary (3)	Proficient (2)	Basic (1)	Weight
Design Approach (CO1-CO4)	Correctly applies IRC 6:2014, IRC 19:2013; selects appropriate bridge type; all assumptions justified; load analysis comprehensive	Mostly correct design approach; minor gaps in IRC application; most assumptions justified	Approach partially correct; IRC provisions incomplete; some unjustified assumptions	20%
Calculations & Accuracy (CO2, CO3)	All calculations correct; IRC live load properly applied; distribution factors accurate; verification checks complete; code compliance verified	Mostly correct calculations; minor errors not affecting design; IRC mostly applied correctly; most checks performed	Frequent calculation errors; IRC provisions incomplete; design checks incomplete	25%
Connection & Detailing (CO2-CO4)	Reinforcement design accurate per IS 456; sketches clear, dimensioned, to-scale; connection details shown; bar bending schedules comprehensive; fabrication-ready	Reinforcement mostly correct; sketches legible with most dimensions; detailing mostly compliant; some gaps	Incomplete reinforcement design; sketches with flaws; non-standard detailing; interpretation difficult	20%
Working Drawings & CAD (CO2-CO4)	Professional drawings (plans, elevations, sections); all dimensions shown; reinforcement schedule complete; bill of materials provided; neat CAD work	Drawings generally complete; most dimensions shown; reinforcement mostly indicated; some CAD quality issues	Incomplete drawings; poor CAD quality; missing dimensions; fabrication unclear	15%
Sustainability & Quality (CO6)	Explicitly addresses material efficiency, fabrication feasibility; discusses sustainable practices; SDG linkage (9, 11, 13) clear; quality checklist included	Addresses sustainability aspects; material efficiency mentioned; some reflection on durability; limited innovation discussion	Minimal sustainability considerations; no fabrication discussion; no quality awareness	10%
Report Quality & Organization	Well-structured with clear sections; executive summary; calculations annexed; professional presentation; language clear; references cited	Generally organized; most sections clear; calculations mostly complete; adequate presentation	Disorganized presentation; incomplete sections; hard to follow; many formatting issues	10%

Total Mini-Project: 12.5 marks (100% rubric score scaled to 12.5)

Seminar/Case Study Rubric (12.5 marks)

Criterion	Exemplary (3)	Proficient (2)	Basic (1)	Weight
Content & Technical Depth (CO1, CO5, CO6)	Comprehensive understanding; technically accurate; detailed analysis of design decisions or failure mechanisms; clear connections to IRC and IS provisions	Good understanding; mostly accurate; reasonable technical depth; generally clear connections to course concepts	Limited technical knowledge; surface-level analysis; weak connection to bridge design concepts	25%
Critical Analysis & Insights (CO5, CO6)	Thorough analysis of design effectiveness, challenges, or failures; identifies key learning points; discusses practical implications; sustainability considerations	Some substantive analysis; identifies main lessons; discusses implications to practice; some sustainability focus	Minimal analysis; mostly descriptive; lessons not clearly identified; limited practical applications	25%

Presentation Skills	Clear, engaging, well-paced (10-12 min); effective visuals (photographs, drawings, data); answers questions confidently; professional appearance	Reasonably clear presentation; mostly well-paced; adequate visuals; answers most questions appropriately	Presentation unclear or rushed; pacing issues; limited visuals; difficulty answering questions	20%
Written Report	Well-structured (5-6 pages); clear introduction, analysis, conclusions; proper citations; professional formatting; figures well-captioned; references formatted	Generally organized; analysis present; adequate citations; good language clarity; minor formatting issues	Poor organization; weak analysis; inconsistent citations; significant language/formatting problems	20%
Visuals & Evidence	High-quality, relevant visuals; directly support narrative; all properly labeled and captioned	Visuals generally relevant and well-labeled; most support narrative effectively	Few visuals; poorly labeled; minimal support to narrative	10%

Total Seminar: 12.5 marks (100% rubric score scaled to 12.5)

Continuous Internal Evaluation (CIE):

(i) The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.
(ii) Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.
(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.
(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE:

i. For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
ii. For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.
iii. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

Cyber Security and Urban Infrastructure Management			
Course Code:	1BIF702D	Scheme	2025
Type of Course	Profession Elective Course (PEC)	Semester	VII
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per semester CI(L/T): LI (P): SL&TW:	90(42:0:0:48)	SEE Marks	50
Credits	03	Total Marks	100
Examination type (SEE)	**Theory**	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. CO1 (L2 – Understand): Explain cyber threats, vulnerabilities, and security fundamentals relevant to urban infrastructure systems (SCADA, IoT, smart grids, traffic).
2. CO2 (L3 – Apply): Interpret security requirements and risk assessments for civil infrastructure networks and control systems.
3. CO3 (L3 – Apply): Identify and describe cyber security measures (firewalls, encryption, IDS) for protecting smart city components.
4. CO4 (L4 – Analyze): Analyse cyber risks, attack vectors, and incident response strategies for urban infrastructure resilience.
5. CO5 (L3 – Apply): Apply access control, cryptography, and secure protocols in design of infrastructure management systems.
6. CO6 (L4 – Analyze/Evaluate): Assess governance, regulations, and sustainable cyber practices relating to resilient urban infrastructure in line with SDG 9, SDG 11, and SDG 16

Module-1

Introduction to Cyber Security in Infrastructure

- Cyber security basics: CIA triad, threats (malware, DDoS, phishing), attack surfaces in urban infra (IoT sensors, SCADA).
- Infrastructure overview: smart cities (sensors, CCTV, traffic lights), utilities (water, power grids), transportation (metro, signals).
- Cyber-physical systems (CPS): integration of IT/OT, vulnerabilities in legacy systems.
- Indian context: Smart Cities Mission, cyber-attacks on infra (e.g., power grid hacks).

Linked COs: CO1, CO6 **Number of Hours Required (CI):8 hours**

Module-2

Urban Infrastructure Systems and Vulnerabilities

- Key systems: SCADA/PLC in water treatment, smart grids, BMS in buildings, ITS (traffic management).
- Vulnerabilities: unsecured IoT, weak authentication, supply chain risks, insider threats.
- Threat modeling: STRIDE model for infra; common attacks (ransom ware, man-in-middle).
- Site assessment: network mapping, vulnerability scanning for civil infra projects.

Linked COs: CO1, CO2 **Number of Hours Required (CI):8 hours**

Module-3

Cyber Security Technologies and Controls

- Network security: firewalls, IDS/IPS, VPN, segmentation (OT/IT).
- Access control: RBAC, MFA, zero trust for infra operators.
- Encryption: symmetric/asymmetric, PKI for SCADA comms.
- Endpoint protection: antivirus, patch management for field devices.

Linked COs: CO3, CO4 **Number of Hours Required (CI):8 hours**

Module-4

Risk Management and Incident Response

- Risk assessment: NIST framework, likelihood/impact matrix for urban infra.
- Incident response: detection, containment, recovery (e.g., grid outage playbook).
- Forensics basics: log analysis, chain of custody for infra breaches.
- Resilience strategies: redundancy, backups, cyber insurance for cities.

Linked COs: CO4, CO5 **Number of Hours Required (CI):8 hours**

Module-5

Governance, Regulations and Smart City Security

- Standards: ISO 27001, NIST CSF, CERT-In guidelines for critical infra.
- Governance: CISO role in municipalities, policy frameworks, audits.
- Emerging tech: AI/ML for threat detection, block chain for supply chain.
- Case studies: global (Stuxnet, Colonial Pipeline), India (metro hacks); SDG linkages.

Linked COs: CO4, CO6 **Number of Hours Required (CI):10 hours**

Suggested Learning Resources

Text books:

1. Stallings, W., "Cryptography and Network Security." Pearson.
2. KUROSE & ROSS, "Computer Networking: Top-Down Approach." Pearson.
3. NIST SP 800-82, "Guide to ICS Security."

Reference Books:

1. CERT-In guidelines, "Cyber Security for Critical Infrastructure."
2. ISO 27001:2022, "Information Security Management".

Web links and Video Lectures (e-Resources):

1. NPTEL – Introduction to Cyber Security (IIT Kanpur).
2. NPTEL – Cyber Security for Physical Infrastructure (IIT Madras)

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

- **Flipped Classroom** – Pre-class videos/notes; in-class problem solving.
- **PBL** – Group work on real project scenarios using equipment planning.
- **Case-Based Teaching** – Analyze Indian and global project case studies.
- **Simulation / Virtual Labs** – Simple tools for equipment cycles and scheduling.
- **Industry Expert / Visits** – Expert talks and site/yard/plant visits or virtual tours.
- **ICT-Enabled Teaching** – LMS, NPTEL videos, spreadsheets, online quizzes.
- **Role Play** – Simulated contractor–client–supplier negotiation on equipment and costs.

Assessment Structure: The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks.**
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks.**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

- A minimum of **two Internal Assessment Tests (IA)** shall be conducted, carrying a total of **25 marks.**
- In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks.**
- It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development.**

Students' Learning activities: These activities shall be:

Course Project – Mini smart-city intervention plan for a selected area (problem, data, smart solution, basic feasibility).

- **Course Project** – Cyber risk assessment and basic security architecture for one urban infra system.
- **Case Study Presentation** – Group presentation on a real infra cyber incident and its lessons.
- **Programming / Configuration Assignment** – Simple log, firewall or IDS configuration tasks.
- **Tool / Software Exploration** – Use of Wireshark / scanners / topology tools on a mock city network.
- **Literature Review** – Study of emerging cyber–smart-city themes with SDG links.
- **Open Book Test** – Scenario-based questions using diagrams, standards and incident briefs.
- **GATE-style / Aptitude Test** – Numericals/logic on risk, crypto and networking for infra.
- **Assignment** – Reflective write-up on IT vs OT security or a city cyber-security policy.
- **Innovative Activity** – Red-team/blue-team tabletop, phishing analysis, or cyber drill design.
- **MOOCs / Online Platforms** – Cyber/cyber-physical NPTEL/SWAYAM courses with reflection.

Students' activities for TW/SL under NCrF: Samples only

As per National credit framework (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI- 42 hour) and Teamwork/ Selfe learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. The evaluation activities will be done using set of rubrics developed for each activity. The following sample

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	**Cyber Infra Portfolio Document:** Document 2–3 local smart-city / utility systems (traffic lights, water SCADA, CCTV network, smart meters) with diagrams, identified digital assets, visible vulnerabilities and existing controls.	24
2	**Cyber Case Study:** Short case on an urban infra cyber incident (real or realistic simulation) including threat analysis, attack path, response taken and improved control recommendations.	24
3	**Cyber Reflection Note**: Literature-based note on a major infra cyber-attack (e.g., Mumbai outage, Colonial Pipeline) focusing on causes, societal/urban impacts, governance lessons and resilient practices.	24

activities are listed below.SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1	**MOOC + Cyber / Infra Track:** Complete mapped NPTEL/SWAYAM modules on cyber security or cyber-physical security for infrastructure; solve associated quizzes and a short open-book task applying them to an urban system.	24
2	**Literature Review on Cyber-Infra Security + Reflective Journal**: Review CERT-In advisories, standards (NIST SP 800-82, ISO 27001), and city-level policies; maintain a journal linking them to course modules and SDG 9, 11, 16.	24

A. Rubrics for Students learning activities -TW/SL - (Samples)
1.Integrated Design Mini-Project – Rubric

Criterion	Exemplary (3)	Proficient (2)	Basic (1)	Weight
Field/Literature Data Collection & Coverage (CO1, CO2)	Reviews multiple real offshore projects/sites; systematically records met ocean data, structure types, load cases with references/locations/dates; marine safety/regulations considered.	Reviews 2–3 projects; main data/structure details present; minor gaps in sources/met ocean.	Limited projects or desk-based only; observations/sources incomplete or unsystematic.	10%
Technical Description & Accuracy (CO1, CO3)	Correct identification of structure types/components; clear descriptions of loads, materials, design parameters using appropriate terms (e.g., Morison eq., SCF).	Mostly correct; minor misclassification or weak terminology, but intent clear.	Frequent misidentification; very limited or incorrect terminology.	25%
Engineering Interpretation (Structure Selection, Loads,	Clearly relates site conditions to platform choice, load calculations, stability; realistic	Provides some links to selection/design; comments partly	Little/no engineering interpretation; mostly descriptive.	30%

Design) (CO2, CO3)	quantitative/qualitative comments with basic analysis.	relevant but not fully justified.		
Sustainability/SDG Linkage & Reflection (CO5, CO6; SDG 9, 11, 14)	Explicitly connects to resilient/sustainable marine infra (e.g., corrosion protection, decommissioning, ecosystem impact) with thoughtful analysis/reflection.	Mentions sustainability/SDG briefly; links somewhat general.	No or very superficial mention of sustainability/resilienc e.	20%
Portfolio Organization & Presentation	Well-structured document/digital portfolio; clear sections, labelled figures/charts (e.g., wave spectra, jacket layout), maps, references; language clear/concise.	Generally organised; some missing labels or minor clarity issues.	Disorganised; hard to follow; figures poorly labelled or missing.	15%

Continuous Internal Evaluation (CIE):
(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course. (ii) Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules. (iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus. (iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.
Passing requirement in SEE:
i. For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
ii. For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks
iii. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

Urban Climate Adaptation and Infrastructure Disaster Management			
Course Code	1BIF702E	Scheme	2025
Type of Course	Professional Elective Course	Semester	VII
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	90(42:0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. **CO1 (L2 – Understand)** Explain concepts of hazard, exposure, vulnerability, risk and resilience, and describe how climate change alters urban hazard profiles and disaster patterns.
2. **CO2 (L3 – Apply)** Apply basic methods of hazard, vulnerability and risk assessment for urban infrastructure systems (transport, water, power, housing).
3. **CO3 (L4 – Analyze)** Analyze impacts of key climate hazards (floods, heat waves, cyclones, landslides, sea level rise) on planning, design and performance of infrastructure.
4. **CO4 (L4 – Analyze)** Examine institutional, policy and governance frameworks for urban disaster management and climate resilience in India (DM Act 2005, NDMA/SDMA/ULBs, national missions).
5. **CO5 (L3 – Apply)** Propose structural and non-structural adaptation and disaster-risk-reduction (DRR) measures for critical infrastructure and urban systems, integrating nature-based solutions and SDG 11/13.
6. **CO6 (L4 – Analyze)** Assess and communicate urban climate and disaster risks using scenario analysis, resilience metrics and city disaster/climate action plans.

Module-1

Urban Climate, Disasters and Risk Concepts

- Climate system basics and climate change: components of climate system, radiative forcing, feedbacks, climate variability vs change, extreme events and slow-onset impacts relevant to cities.
- Urban climate: urban heat island, urban flooding, air quality interaction; how urbanization modifies exposure and vulnerability of people and infrastructure.
- Concepts and definitions: hazard, exposure, vulnerability, capacity, risk, disaster, resilience; classification of hazards (hydro-meteorological, geophysical, technological, biological) with urban examples.
- Global and national frameworks: Sendai Framework for DRR 2015–2030, Paris Agreement, SDG 11 and 13; overview of "Making Cities Resilient 2030" and global city networks

Linked COs: CO1, partial CO4, CO6 **Number of Hours: 08 hrs**

Module-2

Hazard, Vulnerability and Risk Assessment for Infrastructure

- Hazard assessment: frequency–magnitude concepts, return period, intensity–duration–frequency (IDF) curves; overview of flood, cyclone, heat, drought, landslide, seismic hazard mapping for cities.
- Exposure and vulnerability: physical, social, economic and environmental vulnerability; critical infrastructure and lifeline systems (transport, power, water, ICT, health) as risk multipliers.
- Risk assessment methods: qualitative (checklists, matrices) and semi-quantitative approaches; introduction to probabilistic risk, loss estimation, and risk prioritization for infrastructure projects.
- Tools and data: hazard and exposure mapping using GIS/remote sensing; use of open data (census, climate projections, city hazard maps) and risk indices; introduction to city disaster resilience scorecards

Linked COs: CO2, partial CO3, CO6 **Number of Hours: 08 hrs**

Module-3

Climate Hazards and Impacts on Urban Infrastructure

- Hydro-meteorological hazards: urban and riverine flooding, extreme rainfall, cyclones, storm surge, sea level rise; mechanisms and typical damage patterns in roads, bridges, drainage, water supply and power networks.
- Geophysical and secondary hazards: earthquakes, landslides, ground failures; cascading effects such as dam failures, slope instability, infrastructure collapse in hills/coastal zones.
- Heat waves and drought: impacts on urban services (water, energy, transport), pavement and rail performance, building performance and public health; interaction with air quality.
- Case examples: recent urban disasters and climate extremes in Indian and global cities (floods, cyclones, heat waves), highlighting infrastructure failures, lessons and good practices.

Linked COs: CO1, CO3, partial CO5 **Number of Hours: 08 hrs**

Module-4

Institutions, Policy and Planning for Resilient Cities

- Disaster management framework in India: DM Act 2005, National Policy on Disaster Management, NDMA/SDMA/DDMA structure; roles of ULBs, line departments and specialized agencies (IMD, CWC, INCOIS etc.).
- Urban climate and disaster policies: National Action Plan on Climate Change (NAPCC), State Action Plans on Climate Change (SAPCC), National Mission on Sustainable Habitat, AMRUT, Smart Cities Mission, National Urban Flooding guidelines.
- City-level planning instruments: City Disaster Management Plan (CDMP), Heat Action Plans, Local Climate Resilience Strategies, Master Plan/Development Plan integration of DRR and climate adaptation.
- Governance, financing and inclusion: institutional coordination, mainstreaming DRR/CCA in infrastructure projects, risk-sensitive land-use planning, climate-resilient budgeting, role of communities and vulnerable groups

Linked COs: CO4, CO6 **Number of Hours: 08 hrs**

Module-5

Adaptation, DRR Strategies and Resilient Infrastructure Design

- DRR and climate adaptation approaches: prevention, mitigation, preparedness, response, recovery; nature-based solutions (NBS) and ecosystem-based adaptation in cities (urban wetlands, green roofs, permeable surfaces, green corridors).
- Infrastructure-specific adaptation:
  – Urban drainage and flood-resilient design (SUDS, detention/retention, pumped systems).

  – Road and bridge adaptation (elevations, scour protection, redundancy, materials for extremes).

  – Water supply, wastewater and solid waste systems under climate stress (drought, flooding).

  – Energy and ICT networks: redundancy, backup, micro-grids, improved siting.
- Early warning systems and emergency preparedness: multi-hazard early warning, emergency operations centres, contingency planning for critical infrastructure, business continuity concepts.
- Resilience assessment and planning tools: Disaster Resilience Scorecard for Cities, risk-informed project appraisal, monitoring indicators; preparation of outline City Resilience/Action Plan linked to SDG 11/13 and Sendai targets

Linked COs: CO2, CO5, CO6 **Number of Hours: 10hrs**

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Urban Climate Adaptation and Mitigation – A. Sharifi & A. F. Rumsey, Elsevier (2022)
2. Hazard-Resilient Infrastructure: Analysis and Design (MOP 144) – ASCE (2021).
3. Adapting to Climate Change in Urban Areas – D. Dodman et al., IIED (2013)

Reference Books:

1. Resilient Cities: Cities and Adaptation to Climate Change – K. Otto-Zimmermann (ed.), Springer (2011)
2. Resilient Infrastructure – S. Bhattacharya et al., Springer
3. National Disaster Management Plan (NDMP) – NDMA, Government of India (2019).

4. Routledge Handbook of Resilient Urban Planning for Small and Medium-Sized Cities – Asare-Okyere et al., Routledge (2025)

Web links and Video Lectures (e-Resources):

1. Climate Hazards and Disaster Mitigation (NPTEL 2026, IIT Roorkee)/ onlinecourses.nptel.ac.in/noc26_ce10
2. Climate Risk, Adaptation and Sustainable Development (NPTEL 2026)/ onlinecourses.nptel.ac.in/noc26_ge06
3. NIDM e-Learning Portal (https://elearning.nidm.gov.in)
4. NDMA Guidelines & Videos (https://ndma.gov.in)

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks.**
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks.**
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks.**

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

- A minimum of **two Internal Assessment Tests (IA)** shall be conducted, carrying a total of **25 marks.**
- In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks.**
- It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students.** These activities shall be:

Students' Learning activities: These activities shall be:

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platform

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester		
Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1.	City Climate & Hazard Profile Portfolio, Compile a portfolio on a selected city (or region) summarizing key hazards, climate projections, past disasters, vulnerable infrastructure and populations, supported by maps and brief commentary.	24
2.	Policy and Plan Review with Reflection Note, Review a City Disaster Management Plan, Heat Action Plan or Climate Action Plan; summarize strengths and gaps from an infrastructure perspective, relate to Sendai/SDGs, and write a reflection on improving climate resilience.	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1.	Self-learning modules on NPTEL/SWAYAM; completion of online certification courses.	24
2.	Literature review on emerging technologies; reflective learning journal	24

Rubrics for Students learning activities -TW/SL - (Samples)

1. Integrated Design Mini-Project – Rubric

Criterion	Exemplary (3)	Proficient (2)	Basic (1)	Weight
Data collection and risk profiling (CO1, CO2)	Comprehensive hazard/exposure data (historical events, climate projections, infra inventories), vulnerability mapping, multi-hazard risk matrix; city/infrastructure corridor specific.	Adequate data from secondary sources; basic risk matrix; some gaps in coverage or analysis.	Limited/generic hazards listed; weak vulnerability assessment.	20%
Hazard/vulnerability assessment (CO2, CO3)	Detailed risk analysis (frequency-magnitude, cascading effects), exposure quantification, vulnerability scoring; GIS/spreadsheet models applied with site-specific scenarios.	Basic assessment methods applied; limited quantification or scenario analysis.	Incomplete assessment; missing key risk elements.	25%
Adaptation/DRR strategy selection (CO4, CO5)	Multiple adaptation options (NBS, structural, policy) compared across technical, economic, social criteria; NDMA/Sendai standards justified; prioritized portfolio developed.	Reasonable strategies selected with basic comparison; some standards referenced.	Strategies unjustified; limited comparison or technical basis.	25%
Resilience planning/reporting (CO4, CO6)	Full city/infrastructure resilience scorecard, regulatory gaps addressed (DM Act, NAPCC), professional plan with diagrams/timelines/stakeholder roles.	Basic plan elements; regulations mentioned but incomplete.	Superficial plan; regulations overlooked.	15%
Sustainability/reflection (CO6)	SDG 11/13 linkages, multi-sector integration, economic analysis (CBA), stakeholder engagement plan; innovative resilience measures proposed.	Basic sustainability noted; limited analysis.	No sustainability or reflection.	15%

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

i. For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
ii. For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.
iii. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

Smart Structural Health Monitoring Systems for Infrastructure			
Course Code	1BIF702G	Scheme	2025
Type of Course	Profession Elective Course(PEC)	Semester	VII
Teaching Hours/Week(L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per semester CI (L /T) :LI(P):SL&TW:	90(42:0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Examination type(SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. **CO1 (L2 – Understand):** Explain the fundamentals of structural dynamics, necessity of structural health monitoring, and various SHM techniques applicable to civil infrastructure.
2. **CO2 (L4 – Analyze):** Evaluate various sensor technologies and wireless communication protocols for designing integrated SHM systems.
3. **CO3 (L4 – Analyze):** Analyze the sensor systems and Apply SHM techniques to specific infrastructure problems such as building health monitoring, bridge integrity assessment, and long-term structural performance evaluation.
4. **CO4 (L4 – Analyze):** Design and implement a sensor-based monitoring system for a civil engineering structure.
5. **CO5 (L5 – Evaluate):** Synthesize IoT-based smart monitoring solutions integrating sensors and decision support systems for sustainable infrastructure management.

Module-1

Fundamentals of structural dynamics and SHM:

- Introduction to Structural Health Monitoring, Definition and importance of SHM in civil engineering,
- History and evolution of SHM
- SHM system components and their functions.
- Advantages and Challenges of SHM
- Fundamentals of Structural Dynamics
- Structural Degradation and Damage
- SHM Applications in Civil Engineering
- Comparison with Traditional Monitoring Methods

Linked COs: CO1,C02 **Number of Hours Required (CI): 8 hrs**

Module-2

Types of Sensors for Smart Structural Health Monitoring:

- Overview of different types of sensors in SHM
- Principles of operation and selection of sensors for different structures
- Advantages and disadvantages of different sensors
- Smart Material-Based Sensors
- Sensor Selection Criteria
- Wireless Sensor Networks (WSN)
- Sensor Calibration and Testing
- Sensor Layout and Installation
- SHM using Optical Fibres and other sensors

Linked COs: CO2,CO5 **Number of Hours Required (CI): 9 hrs**

Module-3

Structural Health Monitoring and Smart Materials:

- Structural Health Monitoring versus Non Destructive Evaluation,
- Health Monitoring and Demolition Techniques
- Long term health monitoring techniques
- Understanding Piezoelectric materials

Linked COs: CO3,CO5 **Number of Hours Required (CI): 8hrs**

Module-4	
Design of Sensor-based Monitoring System: • System design considerations • Sensor placement and installation • System calibration and validation	
Linked COs: CO4, CO5	**Number of Hours Required (CI): 8 hrs**

Module-5	
IOT-based smart SHM systems and applications: • IoT Architecture for SHM • Real-Time Monitoring and Alert Systems • Monitoring of buildings, bridges, and dams, • Case studies of SHM applications in civil engineering, • Future trends and challenges in SHM.	
Linked COs: CO4, CO5	**Number of Hours Required (CI): 9hrs**

Suggested Learning Resources

Textbooks:

1. Daniel Balageas, Claus-Peter Fritzen, Alfredo Güemes, "Structural Health Monitoring", John Wiley and Sons, 2006
2. Douglas E Adams, "Health Monitoring of Structural Materials and Components", John Wiley and Sons, 2000
3. Sohn, H., Farrar, C. R., Hemez, F. M., Czarnecki, J. J., Shunk, D. D., Stinemates, D. W., & Nadler, B. R. (2004). "A Review of Structural Health Monitoring Literature: 1996-2001." Los Alamos National Laboratory Report, LA-13976-MS.
4. Aktan, A. E., Dalal, V., Helmicki, A. J., & Hunt, V. J. (1994). "Issues in Health Monitoring for Intelligent Infrastructure." Smart Structures and Materials, Proceedings of SPIE, Vol. 2191.
5. E-resources 1. E-learning content on L&T EduTech Platform

Reference Books:

1. Doebling, S. W., Farrar, C. R., Prime, M. B., & Shevitz, D. W. (1996). "Damage Identification and Health Monitoring of Structural and Mechanical Systems from Changes in Their Vibration Characteristics." Los Alamos Report, LA-13070-MS.
2. Swann, C., Sohn, H., Farrar, C. R., & Hemez, F. M. (2003). "Structural Damage Assessment using a Statistical Time-Series Intervention Analysis Model." Journal of Structural Engineering, 129(11), 1429-1446.

Web links and e-Resources:

1. NPTEL: "Structural Health Monitoring" - Online video lectures by Indian Institute of Technology, URL: https://nptel.ac.in/courses/105106115
2. National Center for Supercomputing Applications (NCSA) - Structural Health Monitoring Repository
3. American Society of Civil Engineers (ASCE) - SHM resources and technical papers URL: https://www.asce.org/

Teaching-Learning Process (Innovative Delivery Methods):
The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.
Suggested Innovative Delivery Methods may include(but are not limited to):

- Flipped Classroom
- Problem-Based Learning(PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/industrial visits
- ICT-Enabled Teaching
- Role Play

Assessment Structure:
The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks.**
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks.**
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+Internal Assessment Test (IA)= Continuous Internal Evaluation CIE [25+25=50 marks]

- A minimum of **two Internal Assessment Tests (IA)** shall be conducted, carrying a total of **25 marks.**
- In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks.**
- It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development.**

Students' Learning activities: These activities shall be:

- Group design projects: Design SHM system for specific structures (residential building, bridge, dam)
- Case study analysis presentations (successful and failed SHM implementations)
- Field data collection exercises (ambient vibration testing on campus/nearby structures)
- IoT system architecture design and documentation.
- Case Study Presentation
- Seminars/Quizz (To assist in GATE Preparations)
- Assignment(at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Students' activities for TW/SL under NCrF: Samples only

As per National credit farm work (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Selfe learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below.

Term Work (TW)and Self Learning (SL)components in Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours/Semester
1.	**SHM System Design Mini-Project:** Design a comprehensive SHM system for a 5-story RC building or bridge: (a) Identify critical monitoring points; (b) Select appropriate sensors; (c) Propose DAQ system and wireless communication protocol.	24
2.	**Damage Detection Algorithm Development:** Develop a machine learning model for damage detection: (a) Collect or use provided synthetic SHM data; (b) Perform exploratory data analysis and feature extraction; (c) Train and validate classification/regression models.	24
3.	**Case Study Analysis: Real-World SHM Implementation:** Analyze a real infrastructure project with SHM system: (a) Select a case study (e.g., cable-stayed bridge, high-rise building, heritage structure); (b) Document sensor placement, data collected, and monitoring outcomes.	24

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours/Semester
1.	**MOOC + GATE/Data- Driven Track**: Complete mapped NPTEL/MOOC modules, solve GATE-style and open-ended analysis problems involving probability and statistics in civil Engineering, culminating in an integrated open-book test.	24
2.	Literature review on emerging tools; reflective learning journal	24

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

1. Sample Rubrics-Integrated SHM System Design Mini-Project Rubric:

Criterion	Exemplary (3)	Proficient (2)	Basic (1)	Weight
Problem Analysis & Sensor Selection	Comprehensive site assessment; optimal sensor selection with clear justification; complete understanding of structural requirements; cost-effective solutions	Adequate site assessment; appropriate sensor selection with partial justification; mostly correct understanding	Limited assessment; generic sensor selection; incomplete understanding of requirements	20%
System Design & Architecture	Complete system design with DAQ, communication protocol, power management; well-organized architecture diagram; professional documentation	Mostly complete design; adequate architecture; generally organized documentation	Incomplete design; basic architecture; poorly organized	25%

Technical Calculations & Specifications	Accurate calculations (sampling rate, sensor placement optimization); proper specifications; adherence to Indian standards	Mostly accurate calculations; minor errors; generally appropriate specifications	Several errors; incomplete specifications; limited standards adherence	20%
Alert System & Damage Classification	Clear threshold definition with scientific justification; multiple damage levels; realistic alert mechanisms	Reasonable thresholds; simple damage classification; basic alert mechanisms	Weak thresholds; insufficient damage levels; inadequate alert design	15%
Sustainability & Cost Analysis	Explicit SDG connections (9, 11, 12, 13); comprehensive cost-benefit analysis; lifecycle cost assessment; environmental impact consideration	General sustainability awareness; basic cost analysis; partial economic evaluation	Minimal sustainability consideration; limited cost analysis; no environmental assessment	15%
Presentation & Documentation	Well-organized report; clear diagrams/schematics; professional formatting; complete references; effective presentation	Generally organized; adequate diagrams; minor clarity issues; mostly complete documentation	Disorganized; incomplete diagrams; poor presentation; insufficient documentation	5%

Continuous Internal Evaluation (CIE):

i) The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

ii) Out of 50marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE:

(i) For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

(ii) For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

(iii) If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade 'F' (Fail).

Quantum Computing for Civil and Infrastructure Engineering			
Course Code	1BIF702H	Scheme	2025
Type of Course	Profession Elective Course (PEC)	Semester	VII
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	90(42:0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. **CO1 (L2 – Understand):** Explain the fundamental concepts of quantum computing (qubits, superposition, entanglement, gates) and contrast them with classical computing.
2. **CO2 (L3 – Apply):** Apply basic quantum circuits and algorithms (Deutsch-Jozsa, Grover, simple optimization setups) to idealized civil-engineering problems such as design optimization and network analysis.
3. **CO3 (L3 – Apply):** Map infrastructure-related problems (structural optimization, traffic-network routing, sensor-network design) onto quantum-inspired or quantum-hybrid formulations
4. **CO4 (L4 – Analyse):** Analyse the potential and limitations of quantum and quantum-inspired computing for large-scale civil-engineering simulations, risk assessment, and resilience planning.
5. **CO5 (L3 – Apply):** Implement simple quantum algorithms or quantum-inspired optimizers using Python-based frameworks (e.g., Qiskit, hybrid solvers) on toy-scale infrastructure-related problems.
6. **CO6 (L4 – Analyze/Evaluate):** Evaluate the role of emerging quantum technologies in sustainable and resilient infrastructure (SDG 6, 9, 11, 13) and describe ethical, environmental, and cyber security implications.

Module-1

Introduction to quantum computing and civil-engineering motivation

- Motivation from civil engineering: complexity of optimization, large-scale simulations, network reliability, and resilience-based design.
- Classical vs. quantum computing: bits vs. qubits, deterministic vs. probabilistic outcomes, limitations of classical supercomputers in large-scale infrastructure problems.
- Key concepts: superposition, entanglement, measurement, no-cloning and uncertainty; Dirac notation (bra- ket) at an intuitive level.
- Overview of quantum hardware platforms (superconducting qubits, trapped ions, photonic systems) and their current limitations (noise, coherence, scalability)

Linked COs: CO1, CO6 **Number of Hours: 08**

Module-2

Qubits, gates, circuits and basic algorithms

- Representation of qubits as vectors in Hilbert space; Bloch - sphere visualization (conceptual).
- Single-qubit and two-q gates (X, Y, Z, H, CNOT, Toffoli, etc.); reversible computation and unitary transformations.
- Quantum circuits and simple circuits for state preparation and entanglement; measurement statistics and probabilistic outputs.
- Basic algorithms: Deutsch and Deutsch Jozsa algorithms (concept + oracle interpretation), Grover's search type idea applied to finding a "best" configuration in a small design space (e.g., optimal node in a small network).

LinkedCOs:CO1,CO2,CO5 **Number of Hours: 09**

Module-3

Quantum-inspired optimization for infrastructure

- Classical combinatorial and optimization problems in civil engineering: layout planning, construction scheduling, traffic-network routing, structural topology optimization.
- Quantum-inspired optimization on classical hardware: simulated annealing, QUBO formulations, Ising models and

mapping to infrastructure-related objective functions

- Introduction to quantum annealing and gate-model quantum optimization (VQE, QAOA) for small-scale problems such as: Optimal placement of sensors in a bridge or building, Minimizing cost or carbon in network level operations (roads, water distribution).
- Hands-on case: formulating a small traffic-network routing or structural layout as a binary optimization problem using QUBO-like formulation

LinkedCOs:CO3, CO5 **Number of Hours:08**

Module-4

Quantum-enhanced sensing, data analytics and resilience

- Quantum and quantum-inspired sensing: basic principles of quantum sensors for deformation, strain, magnetic fields, and what they imply for long-term infrastructure monitoring
- Quantum-enhanced data analytics: sampling, quantum-machine-learning motifs (encoding data into quantum states, similarity-based classification) applied to structural health monitoring (SHM) or traffic-pattern-based prediction.
- Risk and resilience applications: Using quantum-enhanced solvers to explore failure scenarios in power-grid–infrastructure networks, Probabilistic failure-path analysis in multi-hazard scenarios (seismic + flooding + traffic collapse) via quantum-inspired sampling.
- Overview of cyber security and quantum resistant cryptography as part of infrastructure level digital trust.

Linked COs: CO3, CO4, CO6 **Number of Hours:08**

Module-5

Applications to civil infrastructure and future perspectives

- Case-oriented module linking quantum concepts to real-world infrastructure: Smart-city energy-and-traffic management using quantum-inspired, Lifespan and maintenance-scheduling optimization for bridges, tunnels, and water networks, Resilience planning for climate-related shocks (floods, heat waves) using quantum-enhanced scenario exploration
- Ethical, environmental, and sustainability considerations: energy footprint of quantum hardware, material-use implications, and inclusiveness of quantum-enabled smart-infrastructure
- Future outlook: hybrid quantum-classical workflows, cloud-based quantum platforms, and how civil engineers can interact with quantum specialists (third-party solvers, APIs)

Linked COs: CO2, CO3, CO4, CO5, CO6 **Number of Hours:10**

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. K. Smarsly et al., Quantum-inspired and quantum computing in civil engineering (selected chapters on formulations and applications).
2. Nielsen & Chuang, Quantum Computation and Quantum Information – selected introductory chapters on qubits, gates, basic algorithms.
3. A recent "Quantum Computing" elective syllabus (e.g., IIT-style or Amrita-style) for algorithm-level content and gate-based examples

<u>Reference books / Manuals:</u>

1. Quantum-inspired computing and infrastructure-optimization review papers (e.g. Smarsly2024- and Smarsly2025-kn-type surveys

Web links and Video Lectures (e-Resources):

1. NPTEL / Swayam course on Quantum Algorithms and Qiskit with hands-on circuits and small-scale examples.
2. Online course on Quantum Algorithms and Cryptography (conceptual parts only)

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Interactive lectures.
2. Problem-based learning.
3. Case studies of green buildings.
4. Flipped classroom.
5. Guest lectures from industry professionals (green building consultants, LEED APs).
6. Tutorials on rating systems and calculations.

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks.**
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks.**

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

- A minimum of **two Internal Assessment Tests (IA)** shall be conducted, carrying a total of **25 marks**.
- In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks.**
- It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students.** These activities shall be:

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Term Work (TW) and Self Learning (SL) components in

Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1.	Formulate a small civil-engineering problem (e.g., sensor layout or traffic-network flow) as a QUBO or quantum-inspired optimization; implement a simple solver or simulator and interpret results	24
2.	Study a real-world infrastructure failure or stress scenario (e.g., bridge collapse, grid failure) and discuss how quantum-enhanced or quantum-inspired analytics could improve prediction or resilience planning;	24
3.	Seminar and presentations.	24
4.	Lectures (if available) on digital-twin/quantum-hybrid platforms.	24

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1.	NPTEL/SWAYAM MOOCs, self-learning in quantum-inspired optimization tool	24
2.	software tutorials (Qiskit, or equivalent) and small integrated tasks;	24
3.	student-initiated micro-projects on “What if my bridge/road network was optimized by a quantum-inspired solver?	24

A Rubrics for Student Learning Activities - TW/SL

A. Integrated Design Mini-Project – Rubric

Criterion	Exemplary (3)	Proficient (2)	Basic (1)	Weight
Problem formulation & mapping (CO2, CO3)	Cleanly maps infrastructure problem into a quantum-inspired/QUBO form; variables, objectives, constraints clearly defined.	Generally correct mapping; minor unclear or missing constraints.	Weak mapping; largely descriptive without clear mathematical form.	25%

Technical implementation (Qiskit / classical solver) (CO5)	Code runs correctly; sensible outputs; comments and documentation present.	Code mostly correct; minor bugs or unclear logic.	Code incomplete or non-functional; major errors.	25%
Technical implementation (Qiskit / classical solver) (CO5)	Code runs correctly; sensible outputs; comments and documentation present.	Code mostly correct; minor bugs or unclear logic.	Code incomplete or non-functional; major errors.	25%
SDG & resilience linkage (CO6)	Explicitly connects results to SDG 9, 11, 13 and discusses ethical/sustainability aspects.	Mentions SDGs or resilience briefly without depth.	No meaningful linkage.	15%
Presentation & organization	Well-structured report with clear sections, figures, code snippets, and references.	Generally organized; minor presentation issues.	Disorganized; figures or code poorly explained.	10%

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

i. For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
ii. For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks **(out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40** marks.
iii. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

Professional Elective Course-IV

Urban Mobility and Smart Traffic Infrastructure Management			
Course Code	1BIF703A	Scheme	2025
Type of Course	Profession Elective Course (PEC)	Semester	VII
Teaching Hours/Week(L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per semester CI (L /T) :LI(P):SL&TW:	90(42:0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Examination type(SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. **CO1 (L2 – Understand):** Identify and explain the fundamental concepts of urban mobility, sustainable transportation principles, and smart city frameworks relevant to modern transportation infrastructure planning and management.
2. **CO2 (L3 – Apply):** Apply Intelligent Transportation Systems (ITS) technologies, including IoT sensors, traffic management systems, connected and autonomous vehicles, and smart parking solutions for urban traffic optimization.
3. **CO3 (L3 – Apply):** Develop and calibrate travel demand models including trip generation, trip distribution, modal split, and traffic assignment for urban mobility planning and traffic forecasting
4. **CO4 (L3 – Apply**): Design sustainable and multimodal transportation systems including public transit, non-motorized transport (pedestrian and bicycle infrastructure), and Mobility-as-a-Service (MaaS) platforms.
5. **CO5 (L4 – Analyze):** Assess traffic safety management, urban freight logistics, institutional frameworks, financing models, and environmental impacts to develop holistic sustainable urban mobility solutions aligned with SDG.

Module-1

Introduction to Urban Transport & Smart Cities:

- Concepts of Urban Mobility: Mobility vs. Accessibility, sustainable urban transport, challenges in urban transportation.
- Smart City Frameworks: Key pillars of smart cities (governance, mobility, environment, living), policies (e.g., India's "100 Smart Cities" mission).
- Urban Form & Infrastructure: Hierarchy of road infrastructure, land-use transportation interaction, transit-oriented development (TOD)

Linked COs: CO1, CO2, CO4, CO5 **Number of Hours Required (CI): 8 hrs**

Module-2

Intelligent Transportation Systems (ITS) & Technology:

- ITS Components: IoT sensors, connected cameras, Variable Message Signs (VMS), GPS, and communication networks.
- Traffic Management & Optimization: Real-time adaptive traffic signal control, traffic event detection (accident, roadwork), and incident response.
- Connected & Autonomous Vehicles (CAV): Vehicle-to-Everything (V2X) communication and autonomous transport integration.
- Smart Parking Solutions: Demand-responsive parking, parking data management.

Linked COs: CO2, CO3, CO4, CO5 **Number of Hours Required (CI): 8 hrs**

Module-3

Data Analytics & Traffic Modeling:

- Mobility Data Analytics: Big data in transportation, data collection (GPS, Wi-Fi, sensors), privacy and security.
- Travel Demand Modeling: Trip generation, trip distribution, modal split, and traffic assignment models.
- Traffic Simulation: Microscopic and macroscopic simulation tools (e.g., VISSIM, SUMO).

Linked COs: CO3, CO4, CO5 **Number of Hours Required (CI): 8 hrs**

Module-4
Sustainable and Multimodal Transport Planning: • Public Transportation Planning: Bus Rapid Transit (BRT), rail transit, para-transit, fleet management. • Non-Motorized Transport (NMT): Pedestrian infrastructure design, bicycle facility design, walkability audits. • Mobility-as-a-Service (MaaS): Integration of public transport, bike-sharing, and car-pooling into a single digital platform. **Linked COs: CO1, CO2, CO4, CO5** **Number of Hours Required (CI): 9 hrs**
Module-5
Management, Logistics, and Policy: • Traffic Safety Management: Road safety audits, Safe System Approach, accident data analysis. • Urban Freight & Logistics: Last-mile delivery solutions, city logistics planning. • Institutional Frameworks & Financing: Public-Private Partnerships (PPP) in smart mobility, policy implementation, and regulation. • Environmental Impact: Low-carbon transport, air quality monitoring, and noise management. **Linked COs: CO1, CO2, CO4, CO5** **Number of Hours Required (CI): 9 hrs**
Suggested Learning Resources **Textbooks:** 1. Kadiyali, L.R., Traffic Engineering and Transportation Planning, Khanna Publishers, New Delhi 2. Hutchinson, B.G., Introduction to Urban System Planning, McGraw-Hill Education 3. Khisty, C.J., Transportation Engineering – An Introduction, Prentice-Hall 4. Papacostas, C.S., Fundamentals of Transportation Planning, Tata McGraw-Hill 5. Sharma, S., Urban Transport in India: A Comprehensive Review, Springer Publications **Reference Books**: 1. Mayer, M. and Miller, E., Urban Transportation Planning: A Decision-Oriented Approach, McGraw-Hill 2. Bruton, M.J., Introduction to Transportation Planning, Hutchinson of London 3. Dickey, J.W., Metropolitan Transportation Planning, Tata McGraw-Hill 4. Cervero, R., The Transit Metropolis: A Global Inquiry, Island Press 5. Litman, T., Transportation Demand Management: Strategies and Tactics, Victoria Transport Policy Institute 6. Banister, D., Sustainable Transport: Planning for 21st Century, Routledge
Web links and e-Resources: 1. NPTEL Courses on Urban Transportation: https://onlinecourses.nptel.ac.in/ 2. Sustainable Urban Mobility Plans (SUMP): https://www.sutp.org/ 3. Smart City Mission – MoUD: https://smartcities.gov.in/

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

Suggested Innovative Delivery Methods may include(but are not limited to):

- Flipped Classroom
- Problem-Based Learning(PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/industrial visits
- ICT-Enabled Teaching
- Role Play

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks.**
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks.**
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+Internal Assessment Test (IA)= Continuous Internal Evaluation CIE [25+25=50 marks]

- A minimum of **two Internal Assessment Tests (IA)** shall be conducted, carrying a total of **25 marks.**
- In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks.**
- It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development.**

Students' Learning activities: These activities shall be:

- Industrial Visit reports.
- Micro projects.
- Internship reports
- Field surveys for real time assessmentt
- Video analysis of transit analysis.
- Case Study Presentation
- Seminars/Quiz (To assist in GATE Preparations)
- Assignment(at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Students' activities for TW/SL under NCrF: Samples only

As per National credit farm work (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below.

Term Work (TW)and Self Learning (SL)components in Number of Hours per semester		
Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours/Semester**
1.	**Urban Mobility Data Collection & Analysis:** Conduct O-D survey, GPS tracking, and traffic volume counts at 2 urban intersections; classify vehicles; analyze modal split and peak patterns using Excel/SPSS; prepare demand forecasts.	24
2.	**ITS Traffic Signal Optimization Project:** Design adaptive signal control for congested corridor using IoT sensors/VMS; simulate using VISSIM/SUMO; optimize cycle lengths; evaluate congestion reduction.	24
3.	**Sustainable Multimodal Mobility Plan:** Develop TOD plan for 5 km corridor: BRT + NMT + MaaS integration; pedestrian audits, bike lane design; environmental impact assessment; policy recommendations.	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours/Semester**
1.	**MOOC + GATE/Data- Driven Track**: Complete mapped NPTEL/MOOC modules, solve GATE-style and open-ended analysis problems involving probability and statistics in civil Engineering, culminating in an integrated open-book test.	24
2.	Literature review on emerging tools; reflective learning journal	24

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

1. Sample Rubrics- Integrated Urban Mobility Data Collection and Analysis Design Mini-Project–Rubric:

Criterion	**Exemplary (3)**	**Proficient (2)**	**Basic (1)**	**Weight**
Data Collection Methodology	Comprehensive methodology with multiple sources; systematic documentation; quality control measures	Adequate methodology with 2+ sources; mostly systematic; some quality measures	Limited sources; incomplete documentation; minimal quality control	20%
Data Analysis and Accuracy (CO3, CO4)	Accurate processing; advanced analysis techniques; correct interpretation; robust findings	Mostly accurate; standard analysis; some interpretive gaps; sound findings	Significant errors; basic analysis; limited accuracy	25%
Travel Pattern Insights (CO1)	Clear identification of patterns and demand drivers; connects to urban planning; actionable insights	Identifies main patterns; some interpretation; links partly clear	Limited pattern identification; minimal planning connection	25%

Sustainability and Policy Relevance (CO6)	Discusses environmental implications, equity, and policy recommendations; explicit SDG links	Mentions sustainability or policy briefly; somewhat relevant links	No or superficial sustainability mention	15%
Report Organization and Presentation	Well-structured with clear sections, labeled figures, comprehensive documentation, professional presentation	Generally organized; some missing labels or clarity issues; adequate documentation	Disorganized, hard to follow; poor figure quality or labeling	15%

Continuous Internal Evaluation (CIE):

i. The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

ii. Out of 50marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

iii. The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

iv. A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE:

i. For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

ii. For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

iii. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

Earthquake Resistant Design of Infrastructure Structures			
Course Code	1BIF703B	Scheme	2025
Type of Course	Profession Elective Course (PEC)	Semester	VII
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per semester CI (L /T) :LI(P):SL&TW:	90(42:0:0:48)	SEE Marks	50
Credits	03	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course Outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. **CO1 (L2 -- Understand):** Explain earthquake fundamentals including seismic waves, plate tectonics, magnitude scales, intensity scales, and Indian seismic zones per IS 1893:2016; understand ground motion characteristics and seismic hazard assessment methodologies.
2. **CO2 (L3 -- Apply):** Apply response spectrum method and time history analysis for seismic load determination; calculate design forces for buildings, bridges, towers, and other structures per IS 1893:2016 provisions; incorporate site-specific ground motion data.
3. **CO3 (L3 -- Apply):** Design and detail earthquake-resistant reinforced concrete (RCC) structures including moment resisting frames (MRF), shear walls, and dual systems with proper ductility requirements and detailing per IS 456:2000 and IS 1893:2016.
4. **CO4 (L3 -- Apply):** Design and detail earthquake-resistant steel structures including special moment frames (SMF), braced frames (CBF), and connections for seismic resistance per IS 800:2007 and IRC bridge design guidelines.
5. **CO5 (L4 -- Analyze):** Analyse seismic performance of bridges, foundations, and geotechnical structures; evaluate liquefaction potential, soil-structure interaction, and foundation design under seismic loading per IS 1893:2016 and site investigation standards.
6. **CO6 (L5 -- Evaluate):** Evaluate earthquake resilience of infrastructure systems; design innovative seismic protection systems (dampers, isolators, base isolation); assess damage potential and recovery strategies; integrate sustainability and climate resilience (SDG 9, SDG 11, SDG 13).

Module-1

Seismology, Ground Motion and Hazard Assessment

- **Plate Tectonics and Earthquake Generation:** Earth's internal structure; lithospheric plates; plate boundaries (convergent, divergent, transform); stress accumulation and release; strain energy concept; mechanism of earthquake generation.
- **Seismic Waves:** Body waves (P-waves and S-waves); characteristics and velocity; surface waves (Rayleigh and Love waves); attenuation; propagation through different media; wave amplification in soft soils.
- **Earthquake Magnitude Scales:** Local magnitude (Richter scale, ML); body-wave magnitude (mb); surface-wave magnitude (Ms); moment magnitude (Mw); relationship between magnitudes; magnitude-frequency relationships.
- **Earthquake Intensity Scales:** Modified Mercalli Intensity Scale (MMI); European Macroseismic Scale (EMS); intensity vs magnitude distinction; intensity mapping; structural damage correlation with intensity levels.
- **Indian Seismic Zones:** Seismic zonation per IS 1893:2016; Zone II, III, IV, V characteristics; acceleration response spectrum ordinates; zone factor (Z); soil hazard factors; critical facilities zone requirements.
- **Ground Motion Characteristics:** Peak ground acceleration (PGA); peak ground velocity (PGV); peak ground displacement (PGD); spectral acceleration; spectral velocity; spectral displacement; acceleration response spectra; design spectra; elastic vs inelastic spectra.
- **Seismic Hazard Assessment:** Deterministic vs probabilistic approaches; hazard analysis methodology; recurrence intervals; ground motion prediction equations (GMPE); epistemic and lavatory uncertainty; hazard curves; uniform hazard spectra.
- **Site Response and Ground Amplification:** Soil amplification; site classification per IS codes; soft soil effects; resonance; liquefaction potential; foundation effects; local site conditions impact on ground motion; micro zonation studies.

Linked COs: CO1, CO5 | **Number of Hours Required (CI): 08 Hours**

Module-2

Dynamics of Structures and Response Analysis

- **Single Degree of Freedom (SDOF) Systems:** Equation of motion; free vibration; undamped and damped oscillations; damping ratio; natural frequency; period of vibration; critical damping.
- **Response to Seismic Excitation:** Equation of motion for earthquake input; relative displacement concept; absolute acceleration; response spectrum definition; construction of response spectra; elastic response spectra.
- **Response Spectrum Method:** Development from time history analysis; horizontal and vertical components; spectral shapes (elastic, design); code spectra per IS 1893:2016; spectral ordinates for different damping values; practical application to design.
- **Multi-Degree of Freedom (MDOF) Systems:** Modal analysis; eigenvalues and eigenvectors; natural frequencies and mode shapes; modal participation; effective mass; modal superposition; equivalent lateral force method.
- **Equivalent Lateral Force (ELF) Method:** Simplified approach per IS 1893:2016; seismic weight; base shear calculation; distribution of lateral forces along height; design force determination; limitations and applicability.
- **Damping in Structures:** Sources of damping; modal damping; hysteretic damping; structural damping vs material damping; equivalent viscous damping; damping ratio for different materials; Rayleigh damping formulation.
- **Ductility and Behavior Factor:** Importance of ductility in seismic design; ductility ratio; behavior factor (R); reduction factors; reduction for strength, displacement capacity, and over strength; safe-side assumptions.

Linked COs: CO2, CO5 | **Number of Hours Required (CI): 08 Hours**

Module-3

Seismic Design of RCC Buildings and Frames

- **Moment Resisting Frames (MRF):** Configuration and advantages; behavior under seismic loading; lateral load resisting mechanism; plastic hinge formation; capacity design approach; ductile design requirements per IS 456:2000.
- **Shear Wall Systems:** Functions in seismic design; types (coupled, uncoupled); lateral stiffness contribution; design for shear and moment; reinforcement requirements; detailing for ductility; coupling beam design; foundation connection.
- **Dual Systems:** Combination of frames and shear walls; load distribution between components; interaction effects; advantages in seismic design; analysis methodology; design code provisions per IS 1893:2016.
- **Soft Story and Weak Story Effects:** Definition and consequences; avoidance during design; uniform stiffness distribution; weak story mechanism; strength and stiffness requirements; design checks per IS codes.
- **Seismic Design Forces:** Calculation of base shear per IS 1893:2016; distribution of base shear among storeys; horizontal force determination; torsional effects; accidental eccentricity; design eccentricity; P-Delta effects; second-order analysis.
- **Reinforcement Detailing for Ductility:** Special requirements in plastic hinge zones; confinement reinforcement; shear reinforcement density; lap splice details; anchorage requirements; construction joint details; bar bundling restrictions per IS 456.
- **Beam-Column Joint Design:** Shear transfer mechanism; joint shear stress limits; reinforcement through joint; anchorage provisions; construction considerations; detailing for earthquake resistance; column size requirements.
- **Column Design:** Axial force and bending moment interaction; design per IS 456; minimum reinforcement ratio; lateral tie spacing in seismic zones; confinement requirements; detailing for ductility; capacity design approach.
- **Foundation Design and Detailing:** Connection between superstructure and foundation; moment transfer; anchor bolt design; bearing plate sizing; foundation detailing for ductility; pile cap and footing reinforcement; soil-structure interaction.

Linked COs: CO2, CO3, CO6 | **Number of Hours Required (CI): 08 hours**

Module-4

Seismic Design of Bridges, Steel Structures and Foundations

- **Bridge Seismic Design Considerations:** Unique requirements compared to buildings; multi span systems; bearing function; expansion joint design; abutment-structure interaction; longitudinal and transverse loads; vertical load effects.
- **Bridge Superstructure Design:** Design of deck slabs and girders under seismic forces; longitudinal restraint; transverse restraint; bearing capacity for multidirectional forces; expansion joint limits; connecting elements (shear keys, restrainers).
- **Bridge Substructure Design:** Abutment design for seismic forces; pier design under combined loading; wall-type piers; column-type piers; capacity design approach; reinforcement detailing; foundation design.
- **Special Moment Frames (SMF) in Steel:** Configuration and behavior; moment connections; connection design per IS 800:2007; reduced beam section (RBS) connections; bolted moment connections; welding requirements; ductility considerations.
- **Concentrically Braced Frames (CBF) in Steel:** Brace configuration (X-bracing, inverted V); buckling behavior; design of braces and connections; ductility requirements; over-strength ratio; practical detailing per IS codes.
- **Eccentrically Braced Frames (EBF):** Concept of shear link; link behavior; inelastic action in links; link design; inelastic deformation capacity; detailing requirements; advantages in seismic design.
- **Steel Connection Design:** Bolted connections; welded connections; connection categorization (ductile, limited ductile); detailing for ductility; through-bolts; friction-grip bolts; quality control requirements; inspection procedures.
- **Geotechnical Seismic Design:** Liquefaction potential evaluation; simplified and detailed procedures per IS 1893:2016; remedial measures (surcharge, compaction, geosynthetics); ground improvement techniques; monitoring requirements.
- **Foundation Design Under Seismic Loading:** Bearing capacity reduction; settlement calculations; ground acceleration effects; inertial forces from structure; P-Delta effects; foundation detailing for ductility; pile design for seismic resistance.
- **Liquefaction Characteristics:** Triggering mechanism; cyclic stress ratio; pore pressure buildup; flow liquefaction; cyclic mobility; remediation strategies; performance of structures on potentially liquefiable soils.

Linked COs: CO4, CO5, CO6 | **Number of Hours Required (CI): 08 hours**

Module-5

Seismic Resilience, Retrofitting and Innovations

- **Seismic Resilience Concept:** Definition and components (robustness, redundancy, recovery); resilient design objectives; community resilience; economic resilience; social resilience; linkage to disaster risk reduction. **Performance-Based Seismic Design (PBSD):** Performance objectives (immediate occupancy, life safety, collapse prevention); performance levels; fragility curves; damage states; benefit-cost analysis; trade-offs between performance and cost.
- **Retrofitting Existing Structures:** Assessment of existing buildings; vulnerability evaluation; options for strengthening (global, local); retrofitting techniques (shear walls, bracing, dampers); cost-effectiveness; phased implementation; case studies.
- **Active and Passive Control Systems:** Passive systems (dampers, isolators, base isolation); active systems (active bracing, active tuned mass dampers); semi-active systems; real-time applications; effectiveness; cost considerations.
- **Base Isolation Systems:** Friction pendulum systems; elastomeric bearings; properties and design; isolated building behavior; advantages and limitations; practical implementation; maintenance requirements; Indian case studies.
- **Damping Systems:** Viscous dampers; tuned mass dampers (TMD); friction dampers; magnetorheological dampers; performance verification; applications in India; effectiveness studies; design procedures.
- **Innovative Materials for Seismic Design:** High-performance concrete (HPC); self-centering concrete; shape memory alloys; fiber-reinforced polymers (FRP); composite materials; sustainability aspects; durability in aggressive environments.
- **Non-Structural Elements:** Importance in safety and function preservation; design and detailing requirements per IS codes; equipment securing; utility line design; partition walls; ceiling systems; fire safety integration.
- **Smart Structures and Monitoring:** Real-time monitoring systems; structural health monitoring (SHM); sensor placement strategies; IoT integration; data analysis; predictive maintenance; early warning systems; applications in Indian structures.
- **Linked COs: CO5, CO6 |** **Number of Hours Required (CI): 10 hours**

Suggested Learning Resources

Text Books:

1. Chopra, A. K. (2017). *Dynamics of Structures: Theory and Applications to Earthquake Engineering* (5th ed.). Prentice Hall.
2. Paulay, T., & Priestley, M. J. N. (1992). *Seismic Design of Reinforced Concrete and Masonry Buildings*. John Wiley & Sons.
3. Nagarajan, P. (2015). *Earthquake Resistant Design of Structures* (2nd ed.). PHI Learning.
4. Indira, P. V., & Reddy, G. R. (2014). *Earthquake Resistant Design of Structures*. Universities Press.
5. IS 1893:2016. *Code of Practice for Earthquake Resistant Design and Construction*. Bureau of Indian Standards.
6. IS 456:2000. *Code of Practice for Plain and Reinforced Concrete*. Bureau of Indian Standards.

Reference Books:

1. Clough, R. W., & Penzien, J. (2003). *Dynamics of Structures* (3rd ed.). Computers & Structures.
2. Seismic Design Manual (2017). American Society of Civil Engineers (ASCE).
3. Earthquake Engineering: From Engineering Seismology to Performance-Based Engineering (2013). CRC Press.
4. Priestley, M. J. N., et al. (2007). *Displacement-Based Seismic Design of Structures* (2nd ed.). IUSS Press.
5. IRC 6:2014. *Road Bridges - General Features*. Indian Roads Congress.
6. IRC 19:2013. *Road Bridges - Concrete Bridges*. Indian Roads Congress.

Web Links and e-Resources:

1. NPTEL Courses on Earthquake Engineering and Seismic Design
2. Bureau of Indian Standards (BIS) website (www.bis.org.in) for IS codes
3. United States Geological Survey (USGS) for earthquake information
4. European Strong-Motion Database (ESD)
5. Indian Strong Motion Instrumentation Network (ISMIN) data
6. Geospatial databases for seismic hazard mapping
7. SAP2000, ETABS, STAAD Pro for structural analysis
8. PLAXIS for geotechnical seismic analysis
9. Video tutorials on seismic design software
10. Academic journals on earthquake engineering

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.
Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits

- ICT-Enabled Teaching
- Role Play

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks.**
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**..

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

- A minimum of **two Internal Assessment Tests (IA)** shall be conducted, carrying a total of **25 marks**.
- In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.
- It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development.**

Students' Learning activities: These activities shall be:

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)

Any other relevant and innovative academic activity.

Students' Activities for TW/SL under NCrF: Samples Only

As per National credit framework (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Selfe learning (TW/Sl-48 hours). Hence, students must complete two actives as part of NCrF as part of CCA, which carries 25 marks. The evaluations of these activities will be done using set of rubrics developed for each activity. The following sample activities are listed below.

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester
Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours/ Semester
1.	**Integrated Seismic Design Mini-Project-**Design and detail an earthquake-resistant building structure (RCC/steel frame) including seismic load calculation, member design per IS 1893:2016 and IS 456/800, reinforcement detailing for ductility, foundation design, working drawings, and seismic resilience assessment (CO1-CO6)	24
2.	**Case Study & Seminar Presentation-**Research and present a case study on (a) building/bridge performance in actual earthquake, (b) seismic retrofit of existing structure, (c) innovative seismic protection systems, or (d) liquefaction and foundation failure case. Includes written report and 10-12 min presentation (CO5, CO6)	24

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1.	**MOOC + GATE/Data- Driven Track**: Complete mapped NPTEL/MOOC modules, solve GATE-style and open-ended analysis problems involving probability and statistics in civil engineering, culminating in an integrated open-book test.	24
2.	Literature review on emerging tools; reflective learning journal	24

A. Rubrics for Students learning activities -TW/SL - (Samples)

1. Integrated Seismic Design Mini-Project Rubric (25 marks)

Criterion	Exemplary (3)	Proficient (2)	Basic (1)	Weight
Problem Understanding & Site Assessment (CO1-CO2)	Correctly identifies seismic zone, soil profile, hazard level; applies IS 1893:2016 provisions accurately; selects appropriate structural system; all design assumptions justified and documented clearly	Generally understands seismic requirements; mostly correct site assessment; appropriate structural system selection; most assumptions justified	Limited understanding of seismic hazard; site assessment incomplete; structural system selection not fully justified	15%
Seismic Load Calculation & Response Analysis (CO2)	All seismic loads correctly calculated per IS 1893; response spectrum or time history properly applied; base shear, story forces accurately determined; accidental eccentricity and P-Delta effects included; calculations clearly documented	Mostly correct seismic load calculations; minor errors not affecting design; IS provisions mostly correctly applied; most effects considered	Several calculation errors; seismic load method not fully applied; some effects missing; calculations incomplete	20%
Member Design & Capacity Approach (CO3, CO4)	All members designed per IS 456/800; capacity design approach correctly applied; member proportions appropriate; design strength properly calculated; all limit states checked; verification complete; safety margins adequate	Member design mostly correct; capacity approach mostly applied; design checks mostly complete; some minor oversights in proportioning	Several design errors; capacity approach incompletely applied; design checks incomplete; proportioning questionable	20%
Reinforcement Detailing for Ductility (CO3, CO4)	Reinforcement detailing accurate per IS codes; confinement specifications met; joint detailing correct; anchorage lengths appropriate;	Reinforcement mostly correct per standards; detailing mostly compliant; minor gaps in confinement; BBS	Incomplete reinforcement detailing; some non-standard provisions; confinement insufficient;	15%

	shear reinforcement adequate; construction details practical and fabrication-ready; bar bending schedules comprehensive	mostly complete; construction details logical	construction details unclear; interpretation difficult	
Foundation Design Under Seismic Loading (CO5)	Foundation design thorough; bearing capacity verified; liquefaction assessment completed where applicable; soil-structure interaction considered; detailing appropriate for seismic resistance; settlement analysis included	Foundation design mostly correct; bearing capacity check adequate; liquefaction potential assessed; foundation detailing appropriate	Foundation design incomplete; bearing capacity verification questionable; liquefaction assessment missing; seismic detailing insufficient	10%
Drawings & Technical Presentation (CO3, CO4)	Professional drawings (plans, elevations, sections, details); all dimensions and labels present; reinforcement clearly shown; connection details complete; material specification clear; conform to standards; ready for construction	Generally complete drawings; most dimensions shown; reinforcement mostly indicated; connection details mostly shown; generally clear	Incomplete drawings; missing dimensions or labels; reinforcement details unclear; difficult to interpret for construction	10%
Resilience & Sustainability (CO6)	Explicitly addresses seismic resilience objectives; discusses SDG linkage (9, 11, 13); evaluates cost-effectiveness; considers post-earthquake functionality; discusses sustainability measures; includes performance-based design aspects	Addresses resilience and sustainability aspects; SDG linkage mentioned; cost-effectiveness considered; performance levels discussed	Minimal resilience discussion; limited sustainability considerations; no SDG linkage; performance aspects absent	10%

Continuous Internal Evaluation (CIE):

i. The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous inter evaluation shall be carried out by the teacher handling the course.
ii. Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.
iii. The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.
iv. A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE:

i. For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
ii. For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.
iii. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

Prefabricated Structural Elements for Modern Infrastructure			
Course Code:	1BIF703C	Scheme	2025
Type of Course	Profession Elective Course (PEC)	Semester	VII
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per semester CI (L /T) :LI(P):SL&TW:	90 (42:0:0:48)	SEE Marks	50
Credits	03	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

1. CO1 (L2 - Understand): Understand principles of prefabrication, modular coordination, and production techniques for structural elements.
2. CO2 (L3 - Apply): Apply design methods for prefabricated components like slabs, beams, columns, and panels.
3. CO3 (L4 - Analyze): Analyze joints, connections, and structural systems in prefab buildings.
4. CO4 (L3 - Apply): Design and detail prefab elements considering transportation, erection, and load effects.
5. CO5 (L4 - Analyze): Evaluate prefab structures for modern infrastructure under abnormal loads like earthquakes.
6. CO6 (L2 – Understand): Explain production, transportation, erection methods, and quality control in prefabrication systems.

Module-1

Introduction to Prefabrication:

- Need for prefabrication in modern infrastructure: advantages (speed, quality control, cost savings); limitations (transportation, crane dependency).
- Principles: modular coordination, standardization, disuniting of prefabricates.
- Materials: concrete (precast, prestressed), steel, composites (FRP); sustainability aspects (recyclability, low-carbon mixes).
- Production techniques: factory setups, quality assurance (ISO standards).
- Transportation logistics and constraints; erection planning basics; codal provisions (IS 15916, NBC); prefab history and global trends; economic analysis (LCC vs. cast-in-situ); environmental impact (waste reduction).

Linked COs: CO1, CO6. **Number of Hours Required (CI): 8 hours.**

Module-2

Prefabricated Components:

- Behavior of structural components: roof/floor slabs, wall panels, columns, shear walls, beams.
- Large panel constructions and structural schemes (linear, grid systems).
- Types of prefabrication systems: open, semi-open, closed factories.
- Component manufacturing processes (molds, curing); precast vs. prestressed elements; hybrid systems (steel-concrete); quality control in factories (NDT methods); modular coordination examples (tolerances, grids); software tools for component design (STAAD, ETABS).

Linked COs: CO1, CO2. **Number of Hours Required (CI): 8 hours.**

Module-3

Design Principles

- Design considerations: joint flexibility, tolerances, stages of loading, deflection control.
- Material properties, safety factors, lateral load resistance.
- Functional design: location of shear walls, modular planning for infrastructure (bridges, buildings).
- Load combinations per IS 456/IS 875; serviceability limits (crack width, vibration); BIM integration for modular design; seismic zoning effects on prefab; sustainable design (green materials, energy efficiency); case studies of bridge prefab (e.g., modular girders).

Linked COs: CO2, CO3. **Number of Hours Required (CI): 8 hours.**

Module-4

Joints and Connections:

- Types of joints: wet, dry, mechanical; bearings and connections in beams, columns, slabs.
- Forces on joints, anchorage, detailing.
- Design for strength and ductility in multi-story prefab structures.
- Grouted vs. un-grouted sleeves; shear keys and dowels; fatigue and durability checks; connection hardware (welded, bolted); fire resistance detailing; experimental testing (push-out tests); code comparisons (Euro code vs. IS).

Linked COs: CO3, CO4. **Number of Hours Required (CI): 8 hours.**

Module-5

Erection, Loads and Applications:

- Erection methods, equipment, sequencing for industrial buildings, multi-story structures, silos.
- Design for abnormal loads: progressive collapse, earthquakes, cyclones; equivalent loads and code provisions.
- Applications in modern infrastructure: sustainable prefab for bridges, housing.
- New subtopics: Crane types and lifting analysis; erection sequencing software (4D BIM); temporary bracing systems; post-erection monitoring (IoT sensors); disaster resilience case studies (e.g., cyclone-prone areas); lifecycle assessment (LCA) for prefab; future trends (3D-printed prefab, automation).

Linked COs: CO4, CO5, CO6 **Number of Hours Required (CI): 10 hours.**

Suggested Learning Resources

Text Books

1. Gerostiza et al., "Prefabricated Structures," VTU recommended.
2. "Precast Concrete Structures," NIT course material.

Reference Books

1. IS 15916: Prefabricated concrete construction.
2. NPTEL lectures on Prefabricated Structures.

Web links and Video Lectures (e-Resources):

1. VTU Resource: Prefabricated Structures syllabus.
2. NPTEL: Industrial Structures and Prefab Construction.

Teaching-Learning Process (Innovative Delivery Methods):
The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.
Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Assessment Structure: The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

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Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

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- It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development.**

Students' Learning activities: These activities shall be:

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Students' activities for TW/SL under NCrF: Samples only

As per National credit framework (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48hours). Hence, students must complete minimum of two actives as part of NCrF. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	**Prefabricated Structural System Assessment Mini-Project:** Study a prefab structure (building/bridge component), identify modular coordination, component types, joints and connections; document production, transport and erection aspects with sketches.	24
2	**Prefab Design & Case Study Portfolio:** Prepare case studies on prefabricated systems (housing, bridges, industrial structures); analyse component behaviour, joint detailing, load considerations and sustainability aspects with engineering justification.	24
3	**Tools / Design & Detailing Workbook:** Develop a technical workbook covering prefab component design (slabs, beams, panels), joint detailing, modular coordination, and simple	24

	load calculations using software (STAAD/ETABS/Excel) or IS 15916 guidelines.	
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1	**MOOC / NPTEL + GATE / Data-Driven Track:** Complete modules on prefabrication, modular construction and structural systems; solve application-based problems related to prefab design and analysis.	24
2	**Literature Review & Reflective Learning Journal:** Review recent prefab infrastructure projects (IIT/NIT/industry/global case studies); document insights on sustainability, construction efficiency, and modern trends.	24

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):
Sample Rubrics - Integrated Design Mini-Project

Criterion	Exemplary (3)	Proficient (2)	Basic (1)	Weight
Field/Design Data Coverage (CO1, CO2)	Designs multiple prefab components (slabs, beams, joints) with accurate dimensions, modular coordination, and tolerances.	Designs 2-3 components; minor gaps in coordination or tolerances.	Limited to one component; incomplete specs.	20%
Prefab Detailing Accuracy (CO2, CO3)	Precise joint/connection details (wet/dry, anchorage) using IS codes; correct material properties and tolerances.	Mostly accurate details; small code or tolerance errors.	Frequent errors in detailing or codes.	25%
Engineering Analysis (CO3, CO4)	Analyzes loads, deflections, erection stresses qualitatively/quantitatively; realistic feasibility comments.	Some load analysis; partial justification.	Descriptive only; little analysis.	25%
Sustainability Linkage (CO5)	Links prefab to modern infra (speed, waste reduction, SDG 9); thoughtful modular grid reflection.	Brief sustainability mention.	No linkage.	15%
Portfolio Organization	Well-structured with labeled sketches, calculations, references; clear modular grids.	Generally organized; minor labeling issues.	Disorganized; poor visuals.	15%

Continuous Internal Evaluation (CIE):

i. The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

ii. Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

iii. The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

iv. A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

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i. For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

ii. For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

iii. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

Heritage Buildings and Infrastructure Preservation, Restoration and Rehabilitation			
Course Code	1BIF703D	Scheme	2025
Type of Course	Profession Elective Core (PEC)	Semester	VII
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per semester CI (L /T) :LI(P):SL&TW:	90 (42:0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. **CO1 (L2 -- Understand):** Explain the concepts, principles and international frameworks of heritage conservation, preservation, restoration and rehabilitation.
2. **CO2 (L3 -- Apply):** Identify and assess heritage buildings, monuments and infrastructure through documentation, listing and significance evaluation methods.
3. **CO3 (L4 -- Analyze):** Analyze causes of decay, structural distress and deterioration in heritage buildings and historic infrastructure using appropriate investigation techniques.
4. **CO4 (L3 -- Apply):** Apply conservation approaches including repair, restoration, rehabilitation and adaptive reuse strategies for heritage structures.
5. **CO5 (L4 -- Analyze):** Evaluate structural conservation techniques for historic masonry, timber and traditional building materials under various loading conditions.
6. **CO6 (L4 -- Analyze/Evaluate):** Assess heritage impact in urban contexts, design interventions in historic settings and relate conservation to sustainable development goals (SDG 11, SDG 13) and community participation.

Module-1

Introduction to heritage conservation and international frameworks

- Heritage conservation -- need, debate and purpose; understanding heritage and types of heritage resources (tangible and intangible).
- Values and significance in heritage -- architectural, cultural, historical, associational, social, aesthetic and economic values. Concepts and definitions -- conservation, preservation, restoration, reconstruction, rehabilitation, adaptation and retrofitting.
- Ethics and principles of conservation -- authenticity, integrity, minimal intervention, reversibility and compatibility.
- History of conservation movement -- evolution from restoration to conservation; ICOMOS, UNESCO, ICCROM and their role in conservation.
- International charters and guidelines -- Athens Charter (1931), Venice Charter (1964), Burra Charter (1979), Washington Charter (1987), Nara Document on Authenticity (1994).
- World Heritage Sites -- selection criteria, Outstanding Universal Value (OUV), authenticity and integrity requirements; endangered sites.

Linked COs: CO1, partial CO6 **Number of Hours (CI+TW/SL): = 8 hours**

Module-2

Heritage assessment, documentation and significance evaluation

- Primary and secondary structures; bedding, laminations and joints – types, spacing, infilling and their effect on strength and permeability.
- Folds – terminology, classification based on attitude; impact on tunnels, slopes and foundations.
- Faults – elements, types and recognition in field and maps; engineering problems due to faults.
- Unconformities and their recognition; importance in site selection and groundwater.
- Interpretation of simple geological maps and sections (qualitative). Categories and typology of heritage buildings -- religious, residential, institutional, military, industrial and infrastructure heritage.
- Listing and grading of heritage structures -- national monuments, state-protected monuments, Grade I, II and III classification.

- Documentation methods -- measured drawings, photographic surveys, photogrammetry, 3D laser scanning and GIS-based documentation.
- Building assessment and significance evaluation -- architectural analysis, historical research, material investigation and structural condition survey.
- Heritage Impact Assessment (HIA) -- process, methodology and case studies of development projects affecting heritage sites.

Linked COs: CO2, CO6 **Number of Hours = 8 hours**

Module-3

Investigation, causes of decay and condition assessment

- Causes of decay in heritage buildings -- physical weathering (thermal stress, freeze-thaw, salt crystallization), chemical deterioration (carbonation, sulfation, acid attack), biological decay (vegetation, insects, fungi).
- Structural distress -- foundation settlement, deferential movement, overloading, earthquake damage, material degradation and structural alterations.
- Environmental factors -- pollution, moisture ingress, rising damp, condensation and climate change impacts.
- Site investigation methods -- visual inspection, non-destructive testing (NDT) techniques (ultrasonic pulse velocity, rebound hammer, ground-penetrating radar, thermography).
- Material characterization -- petrographic analysis, chemical analysis, strength testing and compatibility assessment.
- Crack pattern analysis and damage mapping -- crack width measurement, damage state classification and damage prioritization.
- Preparing conservation reports -- condition assessment documentation, damage inventory, risk assessment and intervention recommendations.

Linked COs: CO3, CO4 **Number of Hours = 8 hours.**

Module-4

Conservation approaches, repair and restoration techniques

- Divergent approaches to conservation -- minimal intervention, like-for-like replacement, consolidation versus reconstruction. Guidelines for maintenance and repair -- routine maintenance, preventive conservation, emergency stabilization and long-term repair strategies.
- Traditional building materials and techniques -- lime mortars and plasters, traditional masonry techniques, timber joinery, traditional roofing systems (terracotta tiles, slate, thatch).
- Material conservation -- stone conservation (cleaning, consolidation, surface treatment, desalination), brick and terracotta conservation, timber preservation and treatment.
- Structural repair techniques -- crack stitching, grouting, jacketing, strengthening of walls and columns, floor and roof stabilization.
- Foundation and ground interventions -- underpinning, micro- piling, soil stabilization and drainage improvements.
- Compatible materials -- selection criteria, testing for compatibility, use of traditional versus modern materials.
- Case studies -- successful restoration projects in India and abroad (Taj Mahal conservation, Humayun's Tomb, Victoria Memorial, Mysore Palace, global examples)

Linked COs: CO2, CO5, CO6. **Number of Hours (CI+TWSL): = 10 hours.**

Module-5

Structural conservation, adaptive reuse and heritage management

- Structural mechanics of historic constructions -- behavior of masonry walls, arches, vaults, domes and timber structures under compression, tension, exude and shear.
- Load-bearing systems in heritage buildings -- load path analysis, understanding structural behavior and failure mechanisms (in- plane and out-of-plane).
- Seismic vulnerability assessment -- qualitative and quantitative methods, seismic retro fitting strategies for heritage buildings, base isolation and dampers (awareness level).
- Structural strengthening interventions -- FRP wrapping, steel/timber reinforcement, ring beams, tie rods and buttressing (component and system level).
- Adaptive reuse of heritage buildings -- concept, importance, design logic, strategies for remodeling and change of use while respecting heritage values.
- Design of new buildings in historic settings -- contextual design, townscape analysis, visual integration and design guidelines.
- Heritage site management -- management plans, presentation and interpretation of historic sites, heritage tourism opportunities.

Linked COs: CO4, CO5, CO6. **Number of Hours (CI+TWSL): = 8 hours.**

Suggested Learning Resources

Textbooks:

1. Feilden, Bernard M. Conservation of Historic Buildings (3rd edition). Architectural Press.
2. Croci, Giorgio. The Conservation and Structural Restoration of Architectural Heritage. WIT Press.
3. Ashurst, John & Ashurst, Nicola. Practical Building Conservation (5 volumes). English Heritage.
4. Chakrabarti, Vibhuti & Piplani, G.K. Conservation of Built Heritage in India. INTACH

Reference Books:

1. ICOMOS. International Charters for Conservation and Restoration. ICOMOS Publications.
2. Forsyth, Michael. Structures and Construction in Historic Building Conservation. Blackwell Publishing.
3. Purdon, Theodore H.M. Preservation of Modern Architecture. Wiley.
4. Archaeological Survey of India. Conservation Manual -- guidelines and case studies of monument conservation in India.
5. Indian Standards (IS Codes) on structural assessment and repair of buildings (IS 13935, IS 15988).

Web links and e-Resources:

Web links and Video Lectures (e-Resources):

1. NPTEL course: Architectural Conservation and Historic Preservation -- IIT Roorkee/IIT Delhi.
2. NPTEL course: Rehabilitation of Heritage Structures -- IIT Madras.
3. UNESCO World Heritage Centre resources -- https://whc.unesco.org
4. ICOMOS International Charters and Documents -- https://www.icomos.org/en/
5. INTACH (Indian National Trust for Art and Cultural Heritage) resources and guidelines.
6. Getty Conservation Institute publications and resources -- https://www.getty.edu/conservation/
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Teaching-Learning Process (Innovative Delivery Methods):
The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.
Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Site Visit
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Assessment Structure:
The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks.**
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks.**
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks..**

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

- A minimum of **two Internal Assessment Tests (IA)** shall be conducted, carrying a total of **25 marks.**
- In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks.**
- It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development.**

Students' Learning activities: These activities shall be:

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Students' activities for TW/SL under NCrF: Samples only

As per National credit farmwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Selfe learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below.

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1.	Heritage Documentation Mini-Project: Conduct onsite or virtual documentation of a selected heritage building/infrastructure, including measured drawings, material surveys, photographic evidence, structural condition mapping, and historical significance report. Prepare a digital or physical dossier following conservation standards (e.g., UNESCO/INTACH guidelines)..	24
2.	Conservation Case Study Portfolio: Analyze case studies involving preservation, restoration, or adaptive reuse projects of heritage structures. Identify key challenges such as material decay, structural intervention, or stakeholder conflicts. Evaluate the adopted conservation philosophy and sustainability outcomes, and present findings through a seminar.	24
3.	Rehabilitation Tools Workbook: Prepare a computational or analytical workbook (Excel/Python/CAD-BIM plugin) for quantifying deterioration indices, cost-benefit analysis of rehabilitation options, embodied energy, lifecycle maintenance cost, and resilience metrics for heritage infrastructure.	24

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1.	Study online modules on heritage conservation principles, charters (like UNESCO guidelines), and traditional building materials through NPTEL/Coursera.	24
2.	Explore standards and case studies on restoration and rehabilitation practices from organizations like ICOMOS via webinars and spoken tutorials.	24
3.	Complete self-paced tutorials on digital documentation tools (e.g., BIM for heritage structures, photogrammetry, and AI-based structural assessment for conservation projects).	24

A. Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

1. Heritage Building Documentation Portfolio -- Rubric

Criterion	Exemplary (3)	Proficient (2)	Basic (1)	Weight
Documentation completeness(drawings, photos ,historical research)	Comprehensive documentation with measured plans, elevations, sections, detailed photographic survey, thorough historical research with references; all elements well-integrated.	Most documentation elements present; minor gaps in drawings or photos; historical research adequate but could be more detailed	Incomplete documentation; missing key drawings or photos; historical research superficial or poorly referenced	25%

Condition assessment accuracy (CO3)	Accurate identification of decay patterns, structural distress and material deterioration using appropriate terminology; damage mapping systematic and well-documented.	Generally accurate condition assessment; minor misidentification or weak terminology damage mapping present but incomplete.	Inaccurate or super special condition assessment; poor understanding of decay mechanisms; damage mapping missing or inadequate.	25%
Conservation recommendations (CO4)	Conservation recommendations are well-Justified, practical and based on. assessed condition; appropriate repair techniques suggested with consideration of authenticity and compatibility.	Recommendations Generally appropriate but some lack. Justification or detail; basic understanding of conservation principles evident.	Recommendations generic impractical or poorly justified; limited understanding of conservation approaches.	25%
Presentation quality And organization	Well-structured portfolio with clear sections, professional presentation, properly labeled drawings/photos, consistent formatting, proper citations.	Generally organized; some inconsistencies in formatting or labeling; readable and understand able.	Disorganized, di cult to follow; poor labeling; unprofessional presentation.	15%
SDG linkage And sustainability reaction(CO6)	Explicitly connects heritage conservation to sustainable development (SDG 11, 13); thoughtful reaction on community value and cultural sustainability.	Mentions sustainability y or community aspects briefly; linkage somewhat superficial.	No or minimal mention of sustainability y or community value.	10%

Continuous Internal Evaluation (CIE):

(i) The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii) Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE:

i. For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

ii. For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

iii. If the total (CIE + SEE) is less than 40 marks is less than 40 marks, the student shall be awarded the grade 'F' (Fail).

Environmental Impact Assessment and Climate Policies for Infrastructure			
Course Code	1BIF703E	Scheme	2025
Type of Course	Professional Elective Course (PEC)	Semester	VII
Teaching Hours/Week (L:T:P)	3:0:0	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	42:0:0:48	SEE Marks	50
Credits	3	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. **CO1 (L2 – Understand)** Explain principles, process steps and legal framework of Environmental Impact Assessment (EIA) and its relevance to infrastructure projects, linking to SDG 6, SDG 9, SDG 11 and SDG 13.
2. **CO2 (L3 – Apply)** Apply screening, scoping, baseline data collection and impact identification methods (checklists, matrices, networks, GIS) to typical infrastructure projects (roads, metro, dams, industrial estates).
3. **CO3 (L4 – Analyze)** Analyze environmental impacts on air, water, land, ecology and socio-economic components for infrastructure projects and evaluate prediction/mitigation measures (including modeling inputs).
4. **CO4 (L4 – Analyze)** Examine EIA documentation (EIA/EMP, risk assessment, public consultation, environmental clearance conditions) and assess compliance with Indian regulations and standards.
5. **CO5 (L3 – Apply)** Apply concepts of Strategic Environmental Assessment (SEA), Life Cycle Assessment (LCA) and climate risk screening in planning climate-compatible infrastructure.
6. **CO6 (L4 – Analyze)** Assess key international and national climate policies (UNFCCC, Paris Agreement, IPCC, NDCs, NAPCC/SAPCC) and their implications for infrastructure planning, financing and governance in India.

Module-1

Introduction to EIA and Regulatory Framework

- EIA basics: need, objectives, principles, benefits and limitations; EIA vs environmental management and sustainable development.
- Evolution of EIA: global and Indian context; project vs regional vs strategic assessment.
- Legal and institutional framework in India: Environment (Protection) Act 1986, EIA Notification 2006 and subsequent amendments (screening categories, schedule of projects, General/Specific conditions), roles of MoEFCC, SEIAA, SPCB, Expert Appraisal Committees.
- Environmental clearance (EC) process overview: prior EC, Terms of Reference (ToR), public consultation, appraisal, EC conditions, post-clearance monitoring; introduction to other relevant laws (Water Act, Air Act, Wildlife Act, Forest Conservation Act) affecting infrastructure EIA

Linked COs: CO1, partial CO4, CO6 **Number of Hours: 08 hrs**

Module-2

EIA Process, Methods and Baseline Studies

- EIA process steps: screening, scoping, baseline data generation, impact identification, prediction, mitigation, alternatives, documentation, review, decision-making, monitoring/auditing.
- Scoping and ToR: identification of key issues, stakeholder analysis, significance criteria; preparation of scoping matrices for typical infrastructure sectors.
- Baseline studies: environmental components (air, noise, water, soil, land use, ecology, socio-economic); spatial and temporal boundaries; data sources, sampling design; use of standards (IS, CPCB, BIS) for baseline comparison.
- Impact identification methods: simple checklists, Leopold matrix, interaction matrices, network diagrams, overlays and GIS-based methods; introduction to risk assessment and health impact considerations

Linked COs CO2 **Number of Hours: 08 hrs**

Module-3

Impact Prediction, Mitigation and Environmental Management Plans

- Impact prediction: qualitative and semi-quantitative approaches; introduction to models for air quality, noise, water quality, hydrology and ecology for EIA purposes.
- Significance evaluation: criteria and thresholds, magnitude–duration–frequency–reversibility; cumulative impact assessment concepts; uncertainty in prediction.
- Mitigation hierarchy: avoid–minimize–restore–offset; typical mitigation measures for construction and operation phases (sediment control, noise barriers, green belts, wastewater treatment, traffic management, and occupational health and safety measures).
- Environmental Management Plan (EMP): structure and contents (mitigation, monitoring, institutional arrangements, capacity building, budget, reporting); environmental auditing and performance indicators; introduction to Environmental Management Systems (EMS/ISO 14001) linkages.

Linked COs: CO2, CO3, CO4 **Number of Hours: 08 hrs.**

Module-4

EIA for Infrastructure Projects and Compliance

- Sectoral EIA:
- – Transport: national/state highways, metro/rail, airports, ports, inland waterways (alignment, land acquisition, fragmentation, noise/air, water crossings).
- – Water resources: dams, hydropower, irrigation, river interlinking (hydrological alteration, sedimentation, displacement, biodiversity).
- – Urban and industrial infrastructure: SEZs, townships, industrial estates, power plants, solid waste and wastewater infrastructure (air/water pollution, risk, cumulative issues).
- Case studies of EIA reports: structure, key findings, typical deficiencies; role-play or critical review of one infrastructure EIA.
- Public consultation and social impact: public hearing process, documenting concerns, integrating social impact assessment (SIA) findings; resettlement and rehabilitation (R&R) linkages.

Linked COs: CO3, CO4, partial CO5 **Number of Hours: 08 hrs**

Module-5

Climate Policies, SEA/LCA and Climate-Responsive Infrastructure EIA

- Climate policy architecture: UNFCCC, Kyoto Protocol (brief), Paris Agreement (NDCs, global stock take), IPCC assessments; overview of carbon budgets and climate risk framing.
- Indian climate policies: National Action Plan on Climate Change (NAPCC) and missions (Solar, Energy Efficiency, Sustainable Habitat, Water), State Action Plans on Climate Change (SAPCC), sectoral climate policies affecting infrastructure (transport, urban development, power).
- Integrating climate into EIA: climate change as a source of impact (GHG emissions) and as a risk factor for project performance; climate risk screening for infrastructure; concepts of "climate-proofing" projects.
- Strategic Environmental Assessment (SEA): principles, steps, advantages over project EIA; application to policies, plans and programmes for infrastructure corridors, master plans, regional development.
- Life Cycle Assessment (LCA) and carbon footprint: basic concepts, goal & scope, inventory, impact assessment, interpretation; examples for roads, buildings, water systems and energy infrastructure; link to green ratings and climate-smart design.

Linked COs: CO5, CO6 **Number of Hours: 10 hrs**

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Environmental Impact Assessment: Theory and Practice – Peter Wathern (ed.), Routledge (1990/updated editions
2. Fundamentals of Environmental Impact Assessment: Principles and Practices – Lawrence W. Canter, McGraw-Hill
3. Environmental Impact Assessment Methodologies – Y. Anjaneyulu & V. Manickam, CRC Press (2011)

Reference Books:

1. Introduction to Environmental Impact Assessment – John Glasson, Riki Therivel & Andrew Chadwick, Routledge (4th ed., 2012).
2. EIA Notification 2006 & Amendments – MoEFCC, Government of India (official manual) National Disaster Management Plan (NDMP) – NDMA, Government of India (2019).
3. Routledge Handbook of Resilient Urban Planning for Small and Medium-Sized Cities – Asare-Okyere et al., Routledge (2025)

Web links and Video Lectures (e-Resources):

1. Environmental Impact Assessment (NPTEL 2023/26, IIT Roorkee/Architecture)/ onlinecourses.nptel.ac.in/noc23_ar04

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
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- Role Play

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

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- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests (IA)** shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks.**

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Students' Learning activities: These activities shall be:

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platform

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester		
Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1	Infrastructure EIA Scoping Portfolio, prepare a scoping document and issue matrix for a chosen infrastructure project (e.g., highway, metro corridor, industrial estate), including draft ToR and stakeholder map	24
2	EIA/EMP Case Study and Gap Analysis, Critically review a real EIA/EMP of an infrastructure project, assess quality (methods, baseline, mitigation, monitoring), identify gaps vs EIA Notification and good practice, and propose improvements.	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	Self-learning modules on NPTEL/SWAYAM; completion of online certification courses.	24
2	Literature review on emerging technologies; reflective learning journal	24

Rubrics for Students learning activities -TW/SL - (Samples)

1. Integrated Design Mini-Project – Rubric

Criterion	Exemplary (3)	Proficient (2)	Basic (1)	Weight
Baseline data collection/scoping (CO1, CO2)	Comprehensive environmental baseline (air/water/noise/land/ecology/socio-economic), spatial/temporal coverage, standards comparison (CPCB/IS); infrastructure project-specific (highway/metro/dam).	Adequate data from secondary sources; basic scoping matrix; some gaps in coverage.	Limited/generic data; weak scoping or missing key components.	20%
Impact identification/prediction (CO2, CO3)	Detailed impact analysis (matrices/networks), construction/operation phases, magnitude-duration-significance; quantitative modeling inputs prepared.	Basic checklists/matrices applied; qualitative assessment; limited prediction.	Incomplete impacts; missing phases or significance criteria.	25%
Mitigation/EMP design (CO3, CO5)	Mitigation hierarchy applied (avoid-minimize-mitigate-offset), EMP with monitoring plan, budget, institutional roles; alternatives compared technically/economically.	Reasonable mitigations with basic EMP outline; some standards referenced.	Superficial mitigations; incomplete EMP elements.	25%
Compliance/reporting (CO4, CO6)	Full ToR/EC checklist compliance, public consultation plan, regulatory gaps addressed (EIA 2006); professional report with diagrams/maps.	Basic compliance check; regulations mentioned.	Superficial; regulations overlooked.	15%
Climate policy integration/reflection (CO5, CO6)	GHG assessment, climate risk screening (NAPCC/NDC), SEA/LCA concepts applied; SDG linkages with innovative low-carbon design.	Basic climate noted; limited policy integration.	No climate/policy consideration.	15%

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

i. For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
ii. For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.
iii. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

Design of Offshore Infrastructure Structures			
Course Code:	1BIF703F	Scheme	2025
Type of Course	Profession Elective Course (PEC)	Semester	VII
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per semester CI(L/T): LI (P): SL&TW:	90(42:0:0:48)	SEE Marks	50
Credits	03	Total Marks	100
Examination type (SEE)	**Theory**	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. CO1 (L2 – Understand): Explain classification, materials, loading conditions, and environmental forces acting on offshore infrastructure structures.
2. CO2 (L3 – Apply): Interpret oceanographic data and site investigation results for conceptual planning and preliminary design of offshore structures.
3. CO3 (L3 – Apply): Identify and describe design considerations for fixed, floating, and compliant offshore platforms including tubular members and joints.
4. CO4 (L4 – Analyze): Analyse offshore structures for static/dynamic loads, stability, and fatigue using relevant codes and simplified methods.
5. CO5 (L3 – Apply): Apply design principles for foundations, pipelines, moorings, and corrosion protection in offshore projects.
6. CO6 (L4 – Analyze/Evaluate): Assess risks from accidental loads, sustainability issues, and relate designs to resilient marine infrastructure in line with SDG 9, SDG 11, and SDG 14.

Module-1

Introduction to Offshore Infrastructure Structures

- Classification: fixed (jackets, gravity), compliant (towers), floating (FPSO, spars, semi-submersibles); applications (oil/gas, wind farms, ports).
- Materials: high-strength steels, corrosion-resistant alloys, concrete; fabrication and installation methods.
- Codes/standards: API RP 2A, DNV, ISO 19900 series, Indian regulations for offshore structures.
- Overview of sustainability: life-cycle assessment, decommissioning, marine ecosystem impacts.

Linked COs: CO1, CO6| **Number of Hours: 8 hours**

Module-2

Oceanographic Loads and Site Investigation

- Environmental loads: waves (design wave, spectra), wind, currents, earthquakes, ice; Morison equation, diffraction theory basics.
- Site investigation: marine geophysics (seismic, sonar), soil sampling (boreholes, CPT), in-situ tests for seabed soils.
- Load combinations: WSD/LRFD, extreme/operational states; return period waves, base shear/overturning moments.
- Oceanographic data interpretation for platform siting and preliminary sizing.

Linked COs: CO1, CO2| **Number of Hours: 8 hours**

Module-3

Design of Fixed Platforms

- Jacket platforms: configuration, tubular members (axial, bending, combined), local buckling (API formulas).
- Tubular joints: chord/brace design, stress concentration factors (SCF), fatigue checks.
- Deck design: framing, plating, crane loads; pile-soil interaction basics.
- Simplified static analysis: member forces, simplified dynamic amplification.

Linked COs: CO3, CO4 | **Number of Hours: 8 hours**

Module-4

Floating and Compliant Structures

- Floating platforms: semi-submersibles, FPSO, tension-leg platforms (TLP); buoyancy, stability (metacentric height).
- Compliant towers: motion characteristics, dynamic response (DAF, frequency domain basics).
- Mooring systems: catenary, taut-leg; line forces, synthetic ropes, anchors.
- Hydrodynamic analysis overview: added mass, damping, RAOs.

Linked COs: CO3, CO4| **Number of Hours : 8 hours**

Module-5

Foundations, Pipelines, Moorings and Special Topics

- Offshore foundations: monopiles, jackets with piles, suction caissons; capacity under vertical/lateral loads.
- Subsea pipelines/risers: wall thickness, buckling, on-bottom stability, spanning.
- Corrosion protection: cathodic (sacrificial/impressed current), coatings; monitoring.
- Accidental loads: collision, dropped objects, fire/explosion; risk assessment, pushover analysis; sustainability/SDG linkages

Linked COs: CO4, CO5, CO6| **Number of Hours = 10 hours**

Suggested Learning Resources

Text books:

1. Chakrabarti, S.K., "Hydrodynamics of Offshore Structures." WIT Press.
2. Graff, W.F., "Introduction to Offshore Structures." Gulf Publishing.
3. API RP 2A-WSD/LRFD, "Planning, Designing and Constructing Fixed Offshore Platforms."

Reference Books:

1. DNV-OS-C101, "General Structural Integrity."
2. ISO 19900 series, "Petroleum and Natural Gas Industries – Offshore Structures."

Web links and Video Lectures (e-Resources):

1. NPTEL – Ocean Structures & Materials (IIT Madras).
2. NPTEL – Offshore Structures Design (IIT Madras).

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

- **Flipped Classroom** – Pre-class videos/notes; in-class problem solving.
- **PBL** – Group work on realistic offshore design scenarios.
- **Case-Based Teaching** – Analyze Indian and global offshore project case studies.
- **Simulation / Virtual Labs** – Simple tools for wave forces, responses and joint stresses.
- **Industry Expert / Visits** – Talks and port/fabrication/OSB visits or virtual tours.
- **ICT-Enabled Teaching** – LMS, NPTEL videos, digital codes, spreadsheets, quizzes.
- **Role Play** – Simulated operator–designer–regulator–environment stakeholder meeting.

Assessment Structure: The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
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- **Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]**
- A minimum of **two Internal Assessment Tests (IA)** shall be conducted, carrying a total of **25 marks.**
- In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.
- It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development.**

Students' Learning activities: These activities shall be:

Course Project – Mini smart-city intervention plan for a selected area (problem, data, smart solution, basic feasibility).

- **Course Project** – Conceptual design of an offshore platform for a given site.
- **Case Study Presentation** – Group presentation on an Indian/global offshore project and its lessons.
- **Programming Assignment** – Spreadsheet/Python calculations for wave forces and basic structural response.
- **Tool / Software Exploration** – Guided use of demo/educational offshore analysis tools with a short note.
- **Literature Review** – Study of offshore wind, moorings, corrosion, and decommissioning and SDG links.
- **Open Book Test** – Scenario-based questions using met ocean data, codes and structural sketches.
- **GATE-based Aptitude Test** – GATE-style numerical on offshore loads and basic analysis.
- **Assignment** – Reflective/analytical write-up on fixed vs floating solutions or major failures.

Students' activities for TW/SL under NCrF: Samples only

As per National credit framework (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI- 42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below.

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	**Offshore Portfolio Document:** Compile information on 2–3 Indian/global offshore projects (e.g., Bombay High jacket, KG Basin platform, offshore wind monopile) including photos/sketches, metocean conditions, structure type and key design notes.	24
2	**Offshore Case Study**: Short case on fixed or floating platform design with simplified wave/wind load calculations, stability comments and foundation scheme.	24
3	**Offshore Case Study:** Short case on fixed or floating platform design with simplified wave/wind load calculations, stability comments and foundation scheme.	24

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1	**MOOC + GATE / Offshore Track:** Complete mapped NPTEL/SWAYAM modules on Offshore Structures/Ocean Structures Materials; solve GATE-style and application-oriented problems on loads and basic design; conclude with a short online/open-book test or reflection quiz.	24
2	**Literature Review on Offshore Technologies + Reflective Journal:** Review standards and papers on jackets, monopoles, moorings, corrosion protection and marine sustainability; maintain a reflective journal linking them to course modules and SDG 9, 11, 14.	24

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

1. Sample Rubrics -Integrated Design Mini-Project

Criterion	Exemplary (3)	Proficient (2)	Basic (1)	Weight
Field/Literature Data Collection & Coverage (CO1, CO2)	Reviews multiple real offshore projects/sites; systematically records metocean data, structure types, load cases with references/locations/dates; marine safety/regulations considered.	Reviews 2–3 projects; main data/structure details present; minor gaps in sources/metocean.	Limited projects or desk-based only; observations/sources incomplete or unsystematic.	10%
Technical Description & Accuracy (CO1, CO3)	Correct identification of structure types/components; clear descriptions of loads, materials, design parameters using appropriate terms (e.g., Morison eq., SCF).	Mostly correct; minor misclassification or weak terminology, but intent clear.	Frequent misidentification; very limited or incorrect terminology.	25%
Engineering Interpretation (Structure Selection, Loads, Design) (CO2,	Clearly relates site conditions to platform choice, load calculations, stability; realistic quantitative/qualitative	Provides some links to selection/design; comments partly relevant but not	Little/no engineering interpretation; mostly descriptive.	30%

CO3)	comments with basic analysis.	fully justified.		
Sustainability/SDG Linkage & Reflection (CO5, CO6; SDG 9, 11, 14)	Explicitly connects to resilient/sustainable marine infra (e.g., corrosion protection, decommissioning, ecosystem impact) with thoughtful analysis/reflection.	Mentions sustainability/SDG briefly; links somewhat general.	No or very superficial mention of sustainability/resilience.	20%
Portfolio Organisation & Presentation	Well-structured document/digital portfolio; clear sections, labelled figures/charts (e.g., wave spectra, jacket layout), maps, references; language clear/concise.	Generally organised; some missing labels or minor clarity issues.	Disorganised; hard to follow; figures poorly labelled or missing.	15%

Continuous Internal Evaluation (CIE):

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii) Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE:

i. For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

ii. For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

iii.If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

Design and Drawing of Irrigation and Hydraulic Infrastructure Structures			
Course Code	1BIF703G	Scheme	2025
Type of Course	Profession Elective Course (PEC)	Semester	VII
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	90(42:0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. **CO1 (L3 -- Apply)**: Apply hydraulic principles to design irrigation structures like weirs/diversion heads.
2. **CO2 (L3 -- Apply):** Design cross-drainage works and canal regulators
3. **CO3 (L4 -- Analyze):** Analyze and draw components of earthen/reservoir dams
4. **CO4 (L3 -- Apply):** Prepare detailed drawings for hydraulic infrastructure.
5. **CO5 (L4 -- Analyze):** Integrate sustainability in designs for resilient water systems (SDG 6, 9).
6. **CO6 (L5 -- Evaluate/Create):** Evaluate modern tools like HEC-RAS for hydraulic modeling.

Module-1

Irrigation Fundamentals

Necessity of irrigation, types (surface/groundwater), duty/base period. Hydrology basics: runoff estimation, water requirements. Canal systems: alignment, design discharge. Sustainable irrigation: drip/micro, conjunctive use aligned with SDG 6.

Linked COs: CO1, partial CO2, CO5, CO6. **Number of Hours: 08 hours**

Module-2

Weirs and Cross-Drainage Works

Types of weirs/diversion heads (gravity, vertical drop). Components: crest, shutters, upstream/downstream aprons. Bligh/Khanna's theory for seepage. Cross-drainage: aqueducts, super/syphon passages. Drawings: weir cross-section, CD works plan/elevation

Linked COs: CO2, CO3, CO6 **Number of Hours :08 hours**

Module-3

Canals and Regulators

Design of unlined/lined canals (Manning/Kennedy). Regime theories (Lacey/Kennedy). Cross-regulators, head/surge tanks. Off-taking structures. Drawings: canal x-section, regulator plan.

Linked COs: CO1, CO2, CO4, CO6. **Number of Hours :08 hours**

Module-4

Dams and Spillways

Types: earthen/gravity/arch. Forces: water pressure, uplift, silt, earthquake. Stability criteria (FOS). Elementary profile of gravity dam. Spillways: ogee, chute, side-channel. Drawings: dam x-section, spillway details)

Linked COs: CO2, CO5, CO6. **Number of Hours hrs.** – 09 hour

Module-5

Hydro Power and Sustainable Infrastructure

Hydro power plants: components, types. Reservoir sedimentation control. Climate-resilient designs, GIS/remote sensing in planning. Case studies: Indian projects (Sardar Sarovar). Alignment with SDG 9 for resilient hydraulic infrastructure.

Linked COs: CO1, CO5, CO6. **Number of Hours :09 hours**

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Garg, S.K., Irrigation Engineering & Hydraulic Structures, Khanna Publishers.
2. Punmia & Lal, Irrigation & Water Power Engineering, Laxmi Publications

Reference books / Manuals:

1. Modi, P.N., Irrigation, Water Resources & Water Power, Standard Book House.
2. NPTEL: IIT Kharagpur Hydraulic Structures course.
3. IS Codes: 6517 (canals), 6966 (spillways).

Web links and Video Lectures (e-Resources):

1. Hydraulic Structures (IIT Kharagpur): Covers weirs, spillways, dams. Full playlist: https://nptel.ac.in/courses/105105110.
2. Key videos: Lecture 30 (Drop Spillway Design) https://www.youtube.com/watch?v=CuNigj4nPZc
3. Hydraulics (IIT Guwahati): Intro to hydraulics for irrigation. Lec-1: https://www.youtube.com/watch?v=z9wsUWaN-oY.
4. NPTEL: "Irrigation and Drainage Engineering" https://nptel.ac.in
5. https://archive.nptel.ac.in/content/storage2/courses/105105110/
6. https://www.youtube.com/playlist?list=PLO4TWepMw7giNZQzBfyLgLTnbFxOh8l1v
7. https://vtu.ac.in/pdf/cbcs/pg/2024/wree2syll.pdf

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

- Flipped Classroom
- Field-Based Mini Study
- Problem-Based Learning (PBL)
- Flipped classroom.
- Virtual Lab / Simulation
- Industry Expert Talk (Virtual/Offline

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks.**

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests (IA)** shall be conducted, carrying a total of **25 marks.**

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks.**

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students.** These activities shall be:

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Term Work (TW) and Self Learning (SL) components in
Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1.	Design and draw a sustainable weir/cross-drainage work (e.g., vertical drop weir with apron/seepage control). Include hydraulic cals (Bligh's theory), AutoCAD sections/plan, sustainability notes (sediment trap, climate-resilient materials). Document local site	24

	photos if possible	
2.	Analyze an Indian project (e.g., Sardar Sarovar Dam spillway or Indira Gandhi Canal regulator). Cover design features, stability (FOS calcs), failures/lessons, SDG alignment (water efficiency, resilient infra). Include simple HEC-RAS model output and recommendations.	24
3.	Seminar and presentations.	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	NPTEL/SWAYAM MOOCs, self-learning in quantum-inspired optimization tool	24
2	software tutorials (Qiskit, or equivalent) and small integrated tasks;	24
3	student-initiated micro-projects on “What if my bridge/road network was optimized by a quantum-inspired solver?	24

Rubrics for Student Learning Activities - TW/SL

A. Irrigation Structure Design Portfolio – Rubric

Criterion	**Exemplary (3)**	**Proficient (2)**	**Basic (1)**	**Weight**
sign Calculations (discharge, seepage, FOS)	Accurate Manning/Bligh calcs; correct scales/dims; verifies stability.	Mostly correct; minor arithmetic slips.	Partial calcs; notable errors.	25%
Drawing Quality (plan, x-section, labels)	Precise AutoCAD/scale drawings; full annotations, proportions exact.	Clear drawings; minor labeling gaps.	Rough sketches; missing details.	25%
Sustainability Integration (SDG 6/9)	Explicit resilient features (e.g., flood-proof apron, low-carbon concrete); thoughtful reflection.	Basic green notes (e.g., lined canal).	Superficial mention.	20%
Originality & Feasibility	Innovative (e.g., micro-irrigation integration); practical for India.	Standard design; feasible.	Generic copy.	20%
Report quality & sustainability metrics	Well-structured report with clear drawings, energy savings quantified, water savings calculated, carbon reduction estimated, cost-benefit analysis; excellent presentation	Acceptable structure and metrics; minor clarity issues; presentation adequate	Disorganized report; missing key metrics or drawings; weak presentation	10%

Hydraulic Infrastructure Case Study – Rubric

Criterion	**Exemplary (3)**	**Proficient (2)**	**Basic (1)**	**Weight**

Technical Analysis (design, hydraulics, stability)	Deep insight: explains forces, HEC-RAS validation, failure root causes.	Covers key aspects; some calcs.	Descriptive; basic facts.	35%
SDG Linkage (resilient water infra)	Strong ties to SDG 6/9/11; quantifies efficiency gains/mitigation.	Mentions sustainability.	Vague reference.	20%
Visuals & Modeling	HEC-RAS screenshots sketches/sections; clear flow profiles.	Basic diagrams.	Few/no visuals.	20%
Research Quality (sources, IS codes)	Multiple credible refs (NPTEL, IS 6517); critical evaluation.	Few sources.	Web-only; united.	15%
Report Structure & Clarity	Logical flow; executive summary; professional format.	Readable; minor issues.	Disorganized.	15%

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

- For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
- For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks **(out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40** marks.
- If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

Open Elective Course-I Syllabus

Satellite Remote Sensing and GIS for Infrastructure Monitoring			
Course Code	1BIF704A	Scheme	2025
Type of Course	Open Elective Course (OEC)	Semester	VII
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	90(42:0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. **CO1 (L2 – Understand):** Explain basic principles of satellite remote sensing, electromagnetic spectrum, sensors and platforms, and data characteristics relevant to civil infrastructure.
2. **CO2 (L3 – Apply):** Apply visual and digital image interpretation techniques to extract land use, terrain and structural information for infrastructure planning and monitoring.
3. **CO3 (L3 – Apply):** Create and manage geospatial databases in GIS (vector/raster, projections, attribute linkage) and perform essential spatial analyses for infrastructure corridors and assets
4. **CO4 (L4 – Analyze):** Analyze multi-temporal remote sensing and GIS data to monitor infrastructure condition, land use/land cover change and hazards affecting infrastructure (subsidence, landslides, flooding).
5. **CO5 (L3 – Apply)** : Use integrated RS-GIS-GNSS workflows for alignment planning, asset inventory and performance indicators for transport, water and urban infrastructure
6. **CO6 (L4 – Analyze)**: Assess suitability, limitations and data quality of RS/GIS products and tools for decision-support in resilient, sustainable infrastructure management in line with SDG 9 and SDG 11.

Module-1

Remote Sensing Fundamentals & Platforms

- Concepts of remote sensing: definition, data vs information, remote sensing process, advantages & limitations for civil infrastructure.
- Electromagnetic spectrum, bands used in Earth observation; energy interactions with atmosphere and earth surface (soil, water, vegetation, built-up); spectral signatures of key infrastructure materials (concrete, asphalt, roofing).
- Resolution concepts: spatial, spectral, radiometric, temporal; implications for infrastructure scale (city, corridor, structure).
- Satellite platforms and sensors: optical, thermal, microwave (SAR); overview of Indian missions (IRS, Resource sat, Cart sat, RISAT) and global missions (Landsat, Sentinel) relevant to infrastructure mapping; basics of UAV/drone data acquisition for asset surveys

. **Linked COs: CO1, partial CO2, CO6** Number of Hours: 8 Hrs

Module-2

Image Interpretation & Digital Image Processing

- Image types and formats; false color composites (FCC), standard band combinations for urban and water applications; elements of visual interpretation (tone, texture, pattern, shape, size, shadow, association, site) for roads, railways, canals, buildings and landforms.
- Georeferencing and image registration; resampling; mosaicking; basics of radiometric and atmospheric correction (awareness level).
- Image enhancement: contrast stretching, filtering, edge enhancement; visual vs digital approaches.
- Classification: supervised and unsupervised classification for land use/land cover; accuracy assessment (error matrix, kappa); introduction to change detection for urban growth and corridor encroachments

Linked COs: CO2, Partial CO7 Number of Hours: 8 Hrs

Module-3

GIS Concepts, Data Models and Spatial Analysis

- GIS basics: definitions, components, functions; types of GIS; role in civil and infrastructure engineering.
- Spatial and attribute data: sources (survey, RS, GNSS, open data), data input (digitizing, scanning, imports); database concepts, attribute tables and relational databases for infrastructure assets (road segments, bridges, pipelines).
- Data models: vector (points, lines, polygons, topology, shape files, feature classes), raster (grids, DEM); map projections, geographic vs projected coordinate systems, UTM and Indian datum's; importance of consistent projection for corridor studies.
- GIS operations: overlay, buffering, network analysis, proximity, spatial queries; creation of thematic maps (land use, slope, drainage, service coverage) supporting infrastructure planning.

Linked COs: CO3, Partial CO5 Number of Hours: 8 Hrs

Module-4

RS-GIS Integration for Infrastructure Planning & Design

- Terrain analysis from DEM/DSM: contour generation, slope, aspect, watershed delineation; applications to road, rail and canal alignment planning and site selection for dams, reservoirs, treatment plants.
- RS-GIS based route selection using constraints (settlements, protected areas, slopes, geology, and hydrology) and multi-criteria evaluation; right-of-way mapping and encroachment analysis.
- Urban and regional planning: land use/land cover mapping, urban sprawl, density, accessibility; support to master plans, smart city proposals and transit-oriented development.

Linked COs: CO3, CO4, CO5 Number of Hours: 9 Hrs

Module-5

Infrastructure Monitoring, Asset Management & Emerging Tools

- Monitoring of linear and areal infrastructure:
  - Roads/rail: pavement condition mapping (cracking, rutting via high-resolution imagery/UAV), right-of-way management.
  – Bridges/barrages: deformation indicators (SAR/InSAR awareness), scour/geomorphic changes at crossings.
  – Urban utilities: water supply, sewerage, storm water, green infrastructure; service coverage analysis and leak detection support.
- Hazard and risk mapping for infrastructure: landslide susceptibility, flood inundation, erosion, coastal change; support for disaster-resilient design and maintenance (link to SDG 11, SDG 13)
- Emerging trends: cloud-based platforms (Google Earth Engine – awareness), open-source GIS (QGIS), AI/ML for feature extraction; limitations, accuracy issues, ethics and data privacy in infrastructure monitoring

Linked COs: CO4, CO5, CO6 Number of Hours: 9 Hrs

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Lillesand, T. M., Kiefer, R. W., & Chipman, J. – Remote Sensing and Image Interpretation, Wiley
2. Jensen, J. R. – Introductory Digital Image Processing: A Remote Sensing Perspective, Pearson
3. Chang, K. – Introduction to Geographic Information Systems, McGraw-Hill.

Reference Books:

1. Sabin's, F. F. – Remote Sensing: Principles and Interpretation, Waveland Press.
2. Burrough, P. A., & McDonnell, R. A. – Principles of Geographical Information Systems, Oxford University Press.
3. Selected ISRO/IIRS course notes on "Basics of Remote Sensing, GIS & GNSS" and NIT/IIT RS-GIS course handouts for water resources and environmental applications)

Web links and Video Lectures (e-Resources):

1. NPTEL: Introduction to Remote Sensing – IIT Roorkee; fundamentals and civil engineering applications
2. NPTEL / IIRS SWAYAM: Basics of Remote Sensing, GIS & GNSS – IIRS-ISRO..
3. NPTEL: Geographic Information Systems – IITs/NITs; spatial analysis and applications in civil engineering.
4. ISRO Bhuvan, NRSC, and open data portals (USGS Earth Explorer, Copernicus Open Access Hub) for

satellite datasets relevant to infrastructure projects
5. Remote Sensing and GIS Essentials (Civil Engineering) – Prof. D. Nagesh Kumar, IISc Bangalore https://nptel.ac.in/courses/105107201
6. Introduction to Infrastructure Asset Management – Prof. Sudhir Misra & Prof. Chirag Kothari, IIT Kanpur (2025)- https://onlinecourses.nptel.ac.in/noc25_ge56/previe
7. https://onlinecourses.swayam2.ac.in/aic20_ge05/preview.
8. https://www.youtube.com/playlist?list=PLO4TWepMw7giNZQzBfyLgLTnbFxOh8l1v
9. https://vtu.ac.in/pdf/cbcs/pg/2024/wree2syll.pdf

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

- Flipped Classroom
- Interactive Spectrum Visualization
- Problem-Based Learning (PBL)
- Hands-on Lab Sessions (QGIS/ERDAS)
- Case Study Approach
- Industry Expert Talk (Virtual/Offline
- Real-World Case Studies:

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests (IA)** shall be conducted, carrying a total of **25 marks.**

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks.**

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students.** These activities shall be:

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Term Work (TW) and Self Learning (SL) components in

Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1.	Use satellite images and GIS to digitize a road/railway/canal corridor, map land use, sensitive receptors and potential	24

	constraints; prepare thematic maps and brief commentary.	
2.	Perform multi-temporal LULC change detection for a city fringe and analyze implications for transport/water infrastructure service coverage.	24
3.	Seminar and presentations.	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1.	NPTEL/IIRS modules, self-paced tutorials on QGIS,	24
2.	small independent case study (e.g., urban sprawl or flood mapping)	24
3.	Student-initiated mini project Perform supervised classification for land use/land cover mapping.	24

Rubrics for Student Learning Activities - TW/SL

A. Integrated Design Mini-Project – Rubric

Criterion	Exemplary (3)	Proficient (2)	Basic (1)	Weight
Data acquisition & preprocessing (CO1, CO3)	Comprehensive satellite data selection (Landsat/Sentinel/CartoSat) with proper georeferencing, atmospheric correction, and mosaicking; multi-sensor fusion applied; projection accuracy verified.	Adequate data processing with basic georeferencing; minor geometric errors; single sensor used.	Limited/incorrect data processing; projection errors; poor geometric quality.	20%
Spatial analysis & infrastructure mapping (CO2, CO3)	Accurate extraction of infrastructure features (roads, railways, bridges, utilities) using supervised classification, change detection; network analysis, buffering, overlay analysis performed correctly; accuracy assessment (kappa > 0.8).	Basic feature extraction with reasonable accuracy; simple spatial operations; limited accuracy assessment.	Poor feature identification; incorrect spatial analysis; no accuracy assessment.	25%
Infrastructure monitoring & change assessment (CO4, CO5)	Multi-temporal analysis showing pavement condition, encroachment, deformation trends; DEM-based slope/flood analysis integrated; quantitative change statistics with error analysis.	Basic change detection; qualitative assessment; limited temporal coverage.	Superficial change mapping; no temporal analysis or quantitative metrics.	25%
Technical reporting & visualization (CO3, CO6)	Professional GIS maps (thematic layers, layouts, legends); comprehensive report with methods, results, limitations; web-	Adequate maps and report; basic visualization; some methods unclear.	Poor map quality; incomplete reporting; missing analysis explanation.	15%

	GIS dashboard or animated change visualization.			
Innovation & sustainability reflection (CO5, CO6)	Emerging tools applied (Google Earth Engine, QGIS plugins, UAV integration); SDG 9/11 linkages; maintenance optimization recommendations; data quality limitations critically assessed.	Basic tool usage; sustainability mentioned; limited innovation.	No innovation; generic sustainability statements.	15%

B. Urban Growth/Service Coverage Analysis – Rubric

Criterion	Exemplary (3)	Proficient (2)	Basic (1)	Weight
Data processing & classification (CO1, CO2)	Accurate multi-temporal preprocessing (geometric/atmospheric correction); supervised classification (>85% accuracy); NDVI/NDBI indices correctly applied; change matrix complete.	Basic preprocessing; reasonable classification (70-85% accuracy); indices applied with minor errors.	Poor preprocessing; low accuracy (<70%); incomplete change analysis.	25%
Urban growth quantification (CO2, CO3)	Precise change statistics (% growth rate, direction vectors); spatial patterns analyzed (towards highways, greenfield); encroachment on infrastructure buffers quantified.	Basic growth metrics calculated; general patterns identified.	Incomplete statistics; no spatial pattern analysis.	25%
Service coverage gap analysis (CO3, CO5)	Comprehensive overlay analysis (roads/water/power within service radius); gap heat maps; population projection vs capacity; prioritized expansion recommendations.	Basic buffer/overlay analysis; simple gap identification.	Superficial coverage assessment; no prioritization.	20%
GIS visualization & reporting (CO3)	Professional layouts (multi-panel change maps, dashboards); clear legends/scales; executive summary with actionable insights.	Adequate maps; basic reporting.	Poor map quality; unclear presentation.	15%
Interpretation & sustainability (CO6)	Insights linking growth to infrastructure strain; SDG 11 linkages; policy recommendations (TOD, compact development).	Basic interpretation; sustainability mentioned.	Generic conclusions; no policy linkage.	15%

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

i. For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
ii. For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks **(out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40** marks.
iii. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

Sustainable Development and Goals			
Course Code	1BIF704B	Scheme	2025
Type of Course	Open Elective Course (OEC)	Semester	VII
Teaching Hours/Week (L:T:P)	3:0:0	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	42:0:0:48	SEE Marks	50
Credits	3	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. **CO1 (L2)** Understand sustainable development principles, SDGs framework and their relevance to infrastructure engineering, linking to SDG 9 and SDG 11
2. **CO2 (L3)** Apply sustainability assessment tools and metrics for infrastructure projects
3. **CO3 (L3)** Analyze sustainable urban infrastructure strategies
4. **CO4 (L4)** Evaluate circular economy principles and resource-efficient infrastructure design
5. **CO5 (L3)** Apply climate-resilient infrastructure planning concepts aligned with NAPCC, NDCs and Sendai Framework.
6. **CO6 (L4)** Assess SDG integration in infrastructure governance, financing and policy frameworks

Module-1

Sustainable Development Fundamentals

- Definition, principles (Brundtland Report), three pillars (economic, social, environmental); sustainability challenges in infrastructure (resource depletion, urbanization).
- Evolution: Stockholm Conference, Rio Earth Summit, MDGs to SDGs; Indian context (National Sustainability Awards).
- Global trends: population growth, urbanization (India 35%→50% by 2030), infrastructure demands vs planetary boundaries.

Linked COs CO1, partial CO6 **Number of Hours: 08 hrs**

Module-2

SDGs Framework & Infrastructure Linkages

- 17 SDGs overview with infrastructure focus: SDG 6 (Water), SDG 7 (Energy), SDG 9 (Infrastructure), SDG 11 (Cities), SDG 13 (Climate).
- SDG interlinkages/synergies/trade-offs in infrastructure (e.g., SDG 9 vs SDG 13); India's Viksit Bharat@2047 alignment.
- SDG indicators, targets, monitoring; Voluntary Local Reviews (VLRs) for cities; infrastructure sector contribution

Linked COs CO1, CO2 **Number of Hours: 08 hrs**

Module-3

Sustainability Assessment Tools

- Life Cycle Assessment (LCA) basics for infrastructure (roads, buildings, bridges); carbon footprint calculation (Scope 1-3).
- Green building ratings (IGBC/LEED/GRIHA), infrastructure ratings (SuRe); Material Embodied Carbon.
- Cost-Benefit Analysis with sustainability metrics; Multi-Criteria Decision Analysis (MCDA) for project appraisal.

Linked COs CO2, CO3 **Number of Hours: 08 hrs**

Module-4

Sustainable Urban Infrastructure

- Smart cities: IoT, AI in infrastructure (smart grids, waste, water); transit-oriented development (TOD), non-motorized transport.
- Green infrastructure: permeable pavements, urban forests, blue-green corridors; sustainable public transport (BRT, metro).
- Water-sensitive urban design (WSUD), sponge cities; zero-waste urban systems, circular economy in construction

Linked COs CO3, CO4 **Number of Hours: 08 hrs**

Module-5

Climate Resilience & Circular Economy

- Climate-resilient infrastructure: NAPCC missions, India's NDCs, heat/cool islands, flood-resilient design (NDMA guidelines).
- Circular economy: 3R (Reduce-Reuse-Recycle) in construction (C&D waste, recycled aggregates); industrial symbiosis.
- Sustainable finance: green bonds, ESG criteria, multilateral funding (World Bank, ADB); governance (Smart Cities Mission)

Linked Cos CO4, CO5, CO6. **Number of Hours: 08 hrs**

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Ram Kumar Mishra, Ch Lakshmi Kumari, Sandeep Chachra, P.S. Janaki Krishna "Smart Cities for Sustainable Development" Springer, 2022 Edition
2. The Sustainable Development Goals Report 2020 Kindle Edition, Department of Economic and Social Affairs
3. The Sustainable Development Goals" Hardcover – December 4, 2018 United Nations..

Reference Books:

1. The Age of Sustainable Development – Jeffrey Sachs, Columbia University Press.
2. India and SDGs – NITI Aayog reports; SDG India Index.
3. Circular Economy for Infrastructure – World Bank/UNEP guidelines.

Web links and Video Lectures (e-Resources):

1. NPTEL: Engineering Strategies for Sustainability – IIT Madras/ digitalskills.iitmpravartak.org.in/courseID=246
2. NPTEL: Sustainable Design of Buildings – IITM Pravartak/ digitalskills.iitmpravartak.org.in/courseID=52
3. NITI Aayog SDG Dashboard – [sdgindia.gov.in]; UN SDG portal [sdgs.un.org]

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.

- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks.**

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

- A minimum of **two Internal Assessment Tests (IA)** shall be conducted, carrying a total of **25 marks**.
- In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks.**
- It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students.** These activities shall be:

Students' Learning activities: These activities shall be:

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Students' activities for TW/SL under NCrF: Samples only

As per National credit framework (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Selfe learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below.

Term Work (TW) and Self Learning (SL) components in
Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1	SDG Infrastructure Mapping Portfolio, Map SDG contributions/gaps for a city infrastructure project (smart city/metro); create SDG wheel visualization	24
2	Circular Economy Case Study, Analyze C&D waste recycling in highway project; LCA of recycled vs virgin materials	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
3.	Self-learning modules on NPTEL/SWAYAM; completion of online certification courses.	24
4.	Literature review on emerging technologies; reflective learning journal	24

Rubrics for Students learning activities -TW/SL - (Samples)

1. Integrated Design Mini-Project – Rubric

Criterion	Exemplary (3)	Proficient (2)	Basic (1)	Weight
SDG identification/mapping (CO1, CO2)	Comprehensive SDG analysis (9/11/13 primary, interlinkages); infrastructure-specific contributions quantified	Adequate SDG coverage; basic linkages identified	Limited SDGs listed; generic assessment	20%
Sustainability assessment (CO2, CO3)	LCA/carbon footprint calculated accurately; multiple tools applied (GRIHA/LCA software); scenarios compared	Basic metrics calculated; single tool used	Incomplete assessment; no quantification	25%
Circular/resilient design (CO4, CO5)	Circular economy/3R integrated; climate-resilient measures justified (NAPCC); alternatives compared	Reasonable sustainable design; some resilience noted	Superficial design; limited sustainability	25%
Policy/governance reporting (CO6)	Full policy alignment (Smart Cities Mission/NITI); governance/finance recommendations; professional report	Basic policy links; regulations mentioned	Superficial; policies overlooked	15%
Innovation/reflection (CO6)	Innovative solutions (IoT/AI); SDG trade-offs analyzed; reflective insights on India@2047	Basic innovation; limited reflection	No innovation/reflection	15%

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

i. For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
ii. For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.
iii. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade 'F' (Fail).

ENVIRONMENTAL PROTECTION AND MANAGEMENT			
Course Code	1BIF704C	Scheme	2025
Type of Course	Open Elective Course (OEC)	Semester	VII
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per semester CI (L /T) :LI(P):SL&TW:	90 (42:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. **CO1 (L2–Understand):** Explain the multidisciplinary nature of environmental problems and principles of corporate environmental management systems.
2. **CO2 (L3 – Apply):** Apply environmental standards, pollution prevention strategies and cleaner production concepts to evaluate industrial processes.
3. **CO3 (L4 – Analyze):** Analyze Environmental Management Systems (EMS) components as per ISO 14001 and identify aspects for continual improvement.
4. **CO4 (L3&L4 – Apply &Analyze):** Conduct environmental audits, assess compliance and recommend corrective actions per ISO 19011 standards.
5. **CO5 (L4 – Analyze):** valuate EMS applications, waste minimization and pollution prevention strategies in civil engineering and infrastructure projects aligned with SDGs.

Module-1

Environmental standards and principles

Unique characteristics of environmental problems; systems approach to corporate environmental management; classification of environmental impact reduction efforts; Business Charter for Sustainable Production and Consumption – tools, strategy drivers and barriers; evolution of environmental stewardship; Environmental Management Principles; National policies on environment, pollution abatement and resource conservation (EPA 1986, National Environment Policy 2006); Charter on Corporate Responsibility for Environmental Protection; multidisciplinary nature of environmental management in civil engineering projects.

Linked COs: **CO1** **Number of Hours Required (CI)**: **8 hours**

Module-2

Environmental Management Objectives and Standards

Environmental quality objectives; rationale of environmental standards – concentration/mass standards, effluent/stream standards, emission/ambient standards, minimum national standards (CPCB); environmental performance evaluation – indicators, benchmarking; Pollution control vs Pollution Prevention – opportunities, barriers; Cleaner production and clean technology concepts; closing material loops, zero discharge technologies; waste minimization hierarchy (reduce, reuse, recycle); application to construction industry waste management

Linked COs: CO2 **Number of Hours Required (CI): 8 hours**

Module-3

Environmental Management System (EMS)

EMAS and ISO 14000 series overview; EMS as per ISO 14001 – benefits, barriers; concept of continual improvement and pollution prevention hierarchy; environmental policy development; initial environmental review; environmental aspect and impact identification (screening, scoping); legal and other requirements (EIA Notification 2006, consents, CRZ); objectives, targets and environmental management programmes; organizational structure, roles and responsibilities; training, awareness and competence; communication; documentation and document control; operational control; emergency preparedness and response; monitoring, measurement and performance evaluation; management review and certification process..

Linked COs: CO3 **Number of Hours Required (CI): 8 hours**

Module-4

Environmental Audit

EMS audits as per ISO 19011; roles, qualifications and responsibilities of auditors; audit planning, checklist preparation and conduct; environmental performance indicators and evaluation; non-conformance identification, classification (major/minor); corrective and preventive actions; compliance audits (legal requirements); waste audits and waste minimization planning; Environmental Statement (Form V under EPA); due diligence audits; post-audit follow-up and verification; application to civil construction sites and infrastructure projects

Linked COs: CO4 **Number of Hours Required (CI): 9 hours**

Module-5

Applications of EMS, Audits and Pollution Prevention

Case studies of EMS implementation, waste audits and pollution prevention in industries (textile, sugar, pulp & paper, electroplating, tanning) and civil engineering sectors (construction sites, cement plants, ready-mix concrete); hazardous waste classification, characteristics, treatment and disposal methods (incineration, secure landfill); transboundary movement and Basel Convention; zero waste strategies for infrastructure projects; integration with SDGs (SDG 6, 11, 12, 13, 14); corporate sustainability reporting and green procurement in public

Linked COs: CO2 & CO5 **Number of Hours Required (CI): 9 hours**

Suggested Learning Resources

Text books:

1. Christopher Sheldon & Mark Yoxon, Installing Environmental Management Systems – A Step-by-Step Guide, Earth scan.
2. ISO 14001:2015 – Environmental Management Systems – Requirements with Guidance for Use.

Reference Books:

1. ISO 19011:2018 – Guidelines for Auditing Management Systems.
2. Paul L. Bishop, Pollution Prevention: Fundamentals and Practice, McGraw-Hill.

Web links and e-Resources:

- . NPTEL Environmental Management (IISc Bangalore).
- CPCB Guidelines: http://www.cpcb.nic.in.
- ISO 14001 Overview Videos (Bureau of Indian Standards YouTube).

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Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
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1.	**Integrated EMS Mini-Project**: Conduct mock EMS audit or gap analysis for a local construction/infrastructure project; identify aspects/impacts, propose objectives/targets and pollution prevention option	24
2.	**Case Study**: Analyze 2–3 real EMS Analyze projects	24
3.	**Industry Waste Audit Case Study:** Analyze waste minimization in civil-related industry (e.g., cement, RMC); prepare checklist, recommend cleaner tech and SDG linkages	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1.	**MOOC + GATE/Data- Driven Track**: Complete mapped NPTEL/MOOC modules, solve GATE-style and open-ended analysis problems involving probability and statistics in civil Engineering, culminating in an integrated open-book test.	24
2.	Literature review on emerging tools; reflective learning journal	24

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

1. Sample Rubrics -Integrated EMS Mini-Project

Criterion	**Exemplary (3)**	**Proficient (2)**	**Basic (1)**	**Weight**
Problem definition & data	Clear, relevant civil-engineering question; data source and Limitations documented.	Mostly clear; minor gaps in context or data description.	Vague question or poorly documented data.	10%
Data processing & descriptive statistics	Correct cleaning, visualization, and computation of key measures; patterns clearly highlighted.	Mostly correct; minor computational/formatting errors.	Significant errors, missing key measures or plots.	25%
Probabilistic modelling (distributions, inference)	Appropriate distributions and tests used; assumptions stated; results interpreted in context.	Reasonable choice of models; some assumptions implicit; interpretation mostly sound.	Inappropriate or poorly justified models; limited interpretation.	30%

Civil engineering insight / risk framing	Clear link to design/assessment decisions, safety and uncertainty; limitations discussed.	Some discussion of implications; limited treatment of limitations.	Minimal civil-engineering interpretati on on beyond numbers.	20%
Report & communication	Well-structured report, clear figures/tables, reproducible calculations; effective brief presentation.	Acceptable structure; some clarity issues; presentation adequate.	Disorganized or incomplete report; weak presentation.	15%

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