राष्ट्रीय प्रौद्योगिकी संस्थान मिजोरम

NATIONAL INSTITUTE OF TECHNOLOGY MIZORAM

(An Institute of National Importance under Ministry of Education, Govt. of India)
Chaltlang, Aizawl, Mizoram – 796012

Course Structure & Syllabus for M. Tech Programme in Structural Engineering
BATCH: 2023-2024 onwards

DEPARTMENT OF CIVIL ENGINEERING

Classification of Credits Points:

1 Hr Lecture (L) per week	1 Hr Tutorial (T) per week	1 Hr Laboratory (P) per week
1 credit	1 credit	0.5 credit

Semester 1			
Course Code	**Course Name**	**L-T-P**	**Credits**
CEL 2101	Structural Dynamics	3-0-0	3
CEL 2102	Bridge Engineering	3-0-0	3
CEL 2103	Advanced Reinforced Concrete Design	3-0-0	3
CEL 2104	Continuum Mechanics	3-0-0	3
CEL 21XX	Elective 1	3-0-0	3
CEP 2101	Structural Engineering Laboratory	0-0-3	1.5
CEP 2102	Seminar 1	0-0-2	1
Total Credits		**15-0-5**	**17.5**

Semester 2			
Course Code	**Course Name**	**L-T-P**	**Credits**
CEL 2201	Finite Element Methods	3-0-0	3
CEL 2202	Design of Earthquake Resistant Structures	3-0-0	3
CEL 2203	Advanced Concrete Technology	3-1-0	4
CEL 22XX	Elective 2	3-0-0	3
CEL 22XX	Elective 3	3-0-0	3
CEP 2201	Computer Modelling and Simulation of Structures	0-0-3	1.5
CEP 2202	Seminar 2	0-0-2	1
Total Credits		**15-1-5**	**18.5**

Semester 3			
Course Code	**Course Name**	**L-T-P**	**Credits**
CEP 2301	MTP 1	0-0-16	8
Total Credits		**0-0-16**	**8**

Semester 4			
Course Code	**Course Name**	**L-T-P**	**Credits**
CEP 2401	MTP 2	0-0-24	12
Total Credits		**0-0-24**	**12**

SEMESTER WISE CREDIT POINT(s)

Semester	1	2	3	4	Total
Credit	**17.5**	**18.5**	**8**	**12**	**56**

LIST OF ELECTIVES

Sl No.	Course Code	Course Name
Electives 1		
1	CEL 2105	Theory of Stability of Structures
2	CEL 2106	Numerical Methods in Structural Engineering
3	CEL 2107	Sustainable Engineering
4	CEL 2108	High Rise Structures
5	CEL 2109	Analysis and Design of Plates and Shells
6	CEL 2110	Random Vibration
Electives 2		
1	CEL 2204	Structural Health Monitoring and Control
2	CEL 2205	Design of Masonry Structures
3	CEL 2206	Performance-Based Seismic Design of Structures
4	CEL 2207	Fracture Mechanics
5	CEL 2208	Theory of Plasticity
6	CEL 2209	Non-Linear Analysis of Structures
Electives 3		
1	CEL 2210	Optimization Techniques
2	CEL 2211	Condition Assessment and Retrofitting of Structures
3	CEL 2212	Design of Pre-Stressed Concrete Structures
4	CEL 2213	Advanced Steel Design and Composite Structures
5	CEL 2214	Risk and Reliability Analysis of Structural Systems
6	CEL 2215	Fluid Structure Interaction

SYLLABUS OF FIRST SEMESTER

(CEL 2101) Structural Dynamics **(3-0-0)**

1. Course Description

This course introduces the basic concepts of dynamic loading and response of structure to such loads, and then uses these concepts to illustrate applications in practical structures. The course introduces dynamics of simple structures and develops fundamental knowledge of vibration analysis of multi degree of freedom structures and continuous structures.

2. Learning Outcome

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

- understand fundamental theory of dynamic equation of motion
- formulate equations of motion for systems excited by harmonic, impulse and arbitrary loadings
- analyze response of structure by time domain and frequency domain methods.

3. Broad Course Outline

- Dynamics of single DOF systems
- Earthquake response of SDOF systems
- Numerical evaluation of Dynamic response of SDOF systems
- Dynamics of multi DOF system
- Dynamics of continuous systems

4. Textbooks

a) M. Paz, "Structural dynamics", CBS Publishers 1987.
b) K. Chopra, "Dynamics of structures: Theory and applications to earthquake engineering", PHI Ltd., 1997.

5. References

a) R.W. Clough and J. Penzien, "Dynamics of Structures", Second Edition, McGraw Hill International Edition, 1993.
b) K. Rao, "Vibration analysis and foundation dynamics", Wheeler, 1998.

6. Sessional Plan

Sl. No	Topics	Hours (Tentative)
1	Equations of motion, Free vibration, damping, Forced vibrations under harmonic, impulse and general loadings, Response spectrum.	6
2	Time domain analysis: Frequency domain analysis: basic methodology.	5
3	Dynamic properties, modal damping, classical damping, modal superposition methods, Response history for earthquake excitation using modal analysis, Response spectrum analysis for peak response.	10
4	Basic concepts, mass-spring system, lumped mass systems, systems with distributed mass and elasticity, Rayleigh's method.	8
5	Equations of motion for axial and flexural vibration of a beam, free vibration analysis, froced vibration analysis.	7
Total Number of Hours		36

7. Evaluation Plan

Sl No	Type of Evaluation	Weightage
1	Mid semester examination	30
2	Internal evaluation	20
3	End semester examination	50
Total		100

(CEL 2102) Bridge Engineering **(3-0-0)**

1. Course Description

Bridge engineering focuses on certain features required for analysis and design of bridge such as structural configuration, loading standards and specifications (IRC, IRS and AASHTO guidelines). It mainly emphasizes on design of reinforced concrete bridges. Also, a brief introduction to steel and concrete bridges has been included. Different components of bridge structure are also included in this course.

2. Learning Outcome

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

- different loads acting on bridges
- components of bridge structures
- design codes and standards for bridges
- analyze and design of RCC bridges.
- understand the basic knowledge on design and analysis of steel bridges.

3. Broad Course Outline

- History of Bridges Construction and Types of Bridges
- Bridge Classification
- Superstructure and Substructure Design of Bridges
- Standards and Codes for Bridge Design
- Loads Acting on a Bridges

4. Textbooks

a) R.M. Barker and J.A. Puckett, "Design of Highway Bridges: An LRFD Approach", 4th Edition, Wiley Publications, 2021.
b) M.G. Aswani, V.N. Vazirani and M.M. Ratwani, "Design of Concrete Bridges", Khanna Publishers, 1995.
c) R.N. Krishna, "Prestressed Concrete Bridges", CBS Publishers, 2016.

5. References

a) IRC:5-1998, "Standard Specifications and code of practice for road bridges".
b) IRC:6 –2000, "Standard specifications and code of practice for road bridges".
c) IRC:21-2000, "Standard specifications and code of practice of road bridges".
d) IRC:112-2011, "Code of practice for concrete road bridges".

6. Sessional Plan

Sl. No	Topics	Hours (Tentative)
1	Historical evolution of different bridge types: Stone masonry bridges, timber bridges, iron bridges, steel arch and truss bridges, reinforced concrete bridges, box girder bridges, prestressed concrete bridges, cable stayed bridges, suspension bridges Bridge classification based on different criteria: function, material of construction, connections and inter-span relations, bridge inspection and maintenance.	10
2	Superstructure design: standard specifications and loads, dead loads, standard live loads from IRC Bridge code, impact effects, temperature effects, shrinkage effects, deformation stresses Superstructure design examples: reinforced concrete slab bridge design, steel girder bridge design, prestressed concrete box-girder bridge design Superstructure design through software applications Types of bridge superstructure elements: bearings and joints, piers, abutments, foundations	16
3	Substructure design: standard specifications and loads, hydrologic forces, wind loads, seismic forces, barge/ship impact forces, earth pressure Substructure design examples: pier design, abutment design	10
Total Number of Hours		36

7. Evaluation Plan

Sl No	Type of Evaluation	Weightage
1	Mid semester examination	30
2	Internal evaluation	20
3	End semester examination	50
Total		100

(CEL 2103) Advanced Reinforced Concrete Design (3-0-0)

1. Course Description

Advanced Reinforced concrete design will help the students to grasp the basic concept of concrete structural design. This course will also enable the students to carry out design of engineering structures in accordance to Indian standard code. Designing of structures other than buildings such as water tanks and others special structures are presented in this course. This course also highlight the various steps in carrying out the analysis of frame structures

2. Learning Outcome

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

- analyze and design continuous and deep beams
- analyze and design of multi-storey frame structures
- design of water tanks for different shapes and conditions
- design of special engineering structures such as silo, culverts, etc.
- design different types of foundation/footing for a structure

3. Broad Course Outline

- Continuous and Deep Beams Design
- Multi-storey Frame Analysis
- Water Tank Design
- Special Structures Design
- Advanced Foundation Design

4. Textbooks

a) S.U. Pillai and D. Menon, "Reinforced Concrete Design", 3rd Edition, Tata McGraw-Hill, 2017.
b) N.K. Raju, "Structural Design and Drawing: Reinforced Concrete and Steel", Universities Press (India) Pvt. Ltd., 2005.

5. References

a) S.S. Bhavikatti, "Advanced RCC Design", New Age Publishers, 2006.
b) T. Paulay and M.J.N Priestley, "Seismic Design of Reinforced Concrete and Masonry Buildings", John Wiley & Sons Inc., 1992.
c) IS:456-2000, "Plain and Reinforced Concrete-Code of Practice".
d) IS:13920-2016, "Ductile Detailing of Reinforced Concrete Structures".
e) SP-16, "Design Aid for IS:456-2000".

6. Sessional Plan

Sl. No	Topics	Hours (Tentative)
1	Continuous Beams and Deep Beams: pattern-loading use of co-efficient from IS:456, Design consideration including redistribution of moments, design for flexure and shear.	5
2	Multi storey structures: Introduction to space frame and plane frames, substitute frame method, Design of portal frame for analyzed data.	8
3	Water retaining structures general requirements as per IS 3370, Design of water tanks on ground; circular and rectangular tanks-fixed base and with different end conditions.	9
4	Design of Retaining Wall, Silo, Culverts, Chimney.	6
5	Design of Strap footing; Strip footing; Mat/Raft foundation, Pile foundation	8
	Total Number of Hours	36

7. Evaluation Plan

Sl No	Type of Evaluation	Weightage
1	Mid semester examination	30
2	Internal evaluation	20
3	End semester examination	50
	Total	100

(CEL 2104) Continuum Mechanics (3-0-0)

1. Course Description

Continuum mechanics is a branch of mechanics that deals with the behaviour of material modelled as a continuous mass rather than as discrete particles. The understanding of continuum mechanics constitutes the basis of several other courses in engineering science such as elasticity, plasticity, viscoelasticity, and fluid mechanics. This course provides an introductory-level discussion on continuum mechanics.

2. Learning Outcome

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

- understand the concept of deformation in an elastic medium
- understand the concept of stress in an elastic medium
- understand the concept of balance laws
- understand the concept of constitutive equations
- understand the concept of thermodynamics
- understand the concept of material nonlinearity

3. Broad Course Outline

- Mathematical preliminaries
- Kinematics of Deformation
- Balance Laws
- Continuum Thermodynamics
- Constitutive Equations
- Material nonlinearity and path dependence

4. Textbooks

a) Jog, C. S., Continuum Mechanics: Foundations and Applications of Mechanics, Volume-I, Third edition, Cambridge-IISc Series, Cambridge university press, 2015.

b) Mase, G.T., Smelser, R.E. and Mase, G.E., 2009. Continuum mechanics for engineers. CRC press.

5. References

a) Gurtin, M., Fried, E. and Anand, L., The Mechanics and Thermodynamics of Continua, Cambridge University Press, 2013.

b) Malvern, L. E., Introduction to the Mechanics of A Continuous Medium, Prentice-Hall Inc., Englewood Cliffs, New Jersey, 1969

c) Tadmor, E. B., Miller, R. E., and Elliot, R. S., Continuum Mechanics and Thermodynamics: From Fundamental Concepts to Governing Equations, Cambridge University Press, 2012.

d) Lai, W. M., Rubin, D., and Krempl, E., Introduction to Continuum Mechanics, Butterworth-Heinemann, 4th edition, 2015

6. Sessional Plan

Sl. No.	Topic	Hours (Tentative)
1.	Mathematical preliminaries: Introduction to Tensors: Vectors and second-order tensors; Tensor operation; Properties of tensors; Invariants, eigenvalues and eigenvectors of second-order tensors; Tensor fields; Differentiation of tensors; Divergence, Stokes and Localization theorems.;	3
2.	Kinematics of Deformation: Continuum hypothesis; Deformation mapping; Material (Lagrangian) and Spatial (Eulerian) field descriptions; Length, area and volume elements in deformed configuration; Material and spatial time derivatives - velocity and acceleration; Linearized kinematics;	9

3.	Balance Laws: Conservation of mass; Balance of linear and angular momentum - Cauchy stress tensor, state of stress; Spatial and material forms of balance laws - concept of first and second Piola-Kirchoff stress tensors; Conservation of energy;	9
4.	Continuum Thermodynamics: Basic laws of thermodynamics; Energy equation; Entropy; Clausius-Duhem inequality.	9
	Constitutive Equations: Material frame-indifference; Objective stress and stress-rates; Material symmetry; Constitutive relations for Hyperelastic Solids, Generalized Hooke's law;	
5.	Material nonlinearity and path dependence: nonlinear elasticity and viscoelasticity	6
	Total number of hours	36

7. Evaluation Plan

Sl No	Type of Evaluation	Weightage
1	Mid semester examination	30
2	Internal evaluation	20
3	End semester examination	50
Total		100

(CEP 2101) Structural Engineering Laboratory (0-0-3)

1. Course Description

This course will conduct quality control tests on concrete making materials. This course will also present conduct quality control tests on fresh & hardened concrete for different design of concrete mixes. In this course, Non-destructive tests on concrete is also included for safety assessment of existing engineering structures.

2. Learning Outcome

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

- evaluate different modulus of concrete
- carry out different mix design in concrete
- perform non-destructive testing on existing concrete structures

3. List of Experiments

- Evaluation of Young's Modulus of Concrete
- Evaluation of modulus of rupture through prism test and split tensile test.
- High Strength Concrete Mix Design & casting elements for strength studies
- Self-Compacting Concrete Mix Design & casting elements for strength studies
- Geopolymer Concrete Mix Design & casting elements for strength studies
- Non-Destructive testing of concrete

4. Textbooks

a) A.M. Neville, "Properties of Concrete", 5th Edition, Pearson Education India, 2012.
b) N.K. Raju, "Design of Concrete Mixes", 5th Edition, CBS Publishers and Distributor, 2018.
c) A.I. Laskar, "Concrete Technology Practices", Alpha Science International Ltd, 2015.

5. References

a) H.B. Egerton, "Non-Destructive Testing: Views, Reviews, Previews", Oxford University Press, 1969.
b) IS:10262-2009, "Guidelines for concrete mix design proportioning".
c) IS:13311(1)-1992, "Method of Non-destructive testing of concrete, Part 1: Ultrasonic pulse velocity".
d) IS:13311(2)-1992, "Method of Non-destructive testing of concrete-methods of test, Part 2: Rebound hammer".
e) IS:516-1959, "Method of Tests for Strength of Concrete".

SYLLABUS OF SECOND SEMESTER

(CEL 2201) Finite Element Methods (3-1-0)

1. Course Description

The finite element method is a powerful tool for numerical solution of wide range of engineering problems. The course introduces the concept of finite element modelling approach for various problems encountered in civil, mechanical and aerospace applications.

2. Learning Outcome

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

- understand concepts of variational methods and weighted residual methods in finite element method
- understand and use various shape functions in finite element formulation
- understand global, local and natural coordinates
- understand formulation of two-dimensional and three-dimensional problems
- apply finite element method solutions to structural problems

3. Broad Course Outline

- Fundamental concepts
- One-dimensional problems
- Two-dimensional problems
- Three-dimensional problems
- Application to structures
- Formulations for plates

4. Textbooks

a) R.D. Cook, D.S. Malkus and M.E. Plesha, "Concepts and Applications of Finite Element Analysis", John Wiley & Sons, 2002.
b) J.N. Reddy, "An Introduction to the Finite Element Method", Tata McGraw Hill, 2003.
c) S.S. Rao, "Finite Element Method in Engineering", Butterworth Heinemann, 1999.

5. References

a) O.C. Zienkiewicz, “The Finite Element Method”, Tata McGraw-Hill, 1977.
b) K.J. Bathe, “Finite Element Procedures”, Prentice Hall, 1995.
c) Y.M. Desai, T.I. Eldho and A.H. Shah, “Finite Element Method with Applications in Engineering”, Pearson, 2011.

6. Sessional Plan

Sl. No	Topics	Hours (Tentative)
1	Principles of discretisation; Element stiffness mass formulation based on direct, variational and weighted residual techniques and displacements, hybrid stress and mixed approaches, shape functions and numerical integrations, convergence.	9
2	Displacement formulations for rectangular, triangular and isoparametric elements for two dimensional and axisymmetric stress analysis; Thin and Thick plates and shells, Semi-analytical formulations	12
3	Three dimensional elements and degenerated forms; Stiffener elements and modifications such as use of different coordinate systems, use of nonconforming modes and penalty functions	11
4	Application to layered composite plate/shells, bridge, roof, nuclear and offshore structures	9
5	Hybrid stress and mixed formulations for plates	7
Total Number of Hours		48

7. Evaluation Plan

Sl No	Type of Evaluation	Weightage
1	Mid semester examination	30
2	Internal evaluation	20
3	End semester examination	50
Total		100

(CEL 2202) Design of Earthquake Resistant Structures (3-0-0)

1. Course Description

Design of earthquake resistant structures introduces the importance of incorporating seismic design in design of structures. Various concepts related to ground motion and its related hazards are introduced at the beginning of the course. It also focuses on how seismic load on buildings can be estimated for ductility considerations required for design of RC structures. Later, the course details the design of earthquake resistant structures and ductile detailing as per IS:13920-2016.

2. Learning Outcome

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

- understand the concepts of ground motion.
- understand concepts of structural dynamics and its importance in earthquake engineering.
- understand the importance of ductility and its implementation in earthquake resistant structures.
- design the earthquake resistant buildings

3. Broad Course Outline

- Introduction to Engineering Seismology
- Characteristics of strong ground motions
- Estimation of Seismic load in buildings.
- Earthquake resistant design and ductile detailing

4. Textbooks

a) P. Agarwal and M. Shrikhande, "Earthquake Resistant Design of structures", Prentice Hall of India Pvt. Ltd, 2006.
b) R. Park and T. Paulay, "Reinforced Concrete Structures", Wiley India, 2009.
c) T. Paulay and M.J.N Priestley, "Seismic Design of Reinforced Concrete and Masonry Buildings", Wiley, 1992.

5. References

a) A.K.Chopra, "Dynamics of structures", Prentice Hall, 1995.
b) IS:1893(1)-2016, "Criteria for Earthquake Resistant – Design of structures".
c) IS:4326-1993, "Earthquake Resistant Design and Construction of Building".
d) IS:13920-2016, "Ductile detailing of concrete structures subjected to seismic force".
e) IS:15988-2013, "Seismic Evaluation and Strengthening of Existing Reinforced Concrete Buildings".

6. Sessional Plan

Sl. No	Topics	Hours (Tentative)
1	Structure of earth, faults, plate tectonics, seismic waves, intensity scale, magnitude scale, Richter magnitude, Seismic Moment and Moment Magnitude.	7
2	Strong Motion, Accelerographs, Accelerograms, Characteristics, Side effects, Definitions, Seismic Hazards, Seismic Vulnerability, Seismic Risks.	8
3	Provisions of IS 1893, 2016: Design Response Spectrum; Irregularities in buildings; Equivalent static method, Response Spectrum Method.	10
4	Introduction to Earthquake Resistant Design: Role of Ductility, Beam Column connection design, Joint shear, Strong column weak beam criterions; Ductile Detailing and Shear wall design as per IS 13920, 2016, Introduction to Seismic Evaluation and retrofitting of buildings: Provisions of IS 15988, 2013.	11
Total Number of Hours		36

7. Evaluation Plan

Sl No	Type of Evaluation	Weightage
1	Mid semester examination	30
2	Internal evaluation	20
3	End semester examination	50
Total		100

(CEL 2203) Advanced Concrete Technology (3-0-0)

1. Course Description

In this course, the students will be introduce to various admixtures/ingredients of concrete. Various types of concrete which are used in advanced RC construction are also introduced. Durability and resistance of concrete against fire and other environmental factor are also described. Under water concreting and use of waste materials in concrete structures will also be introduce to the students.

2. Learning Outcome

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

- understand the advanced concrete terminology.
- understand the mixed design of concrete, high strength of concrete requirements for advanced concrete.
- understand the use of plasticizers, effect of water cement ratio and super plasticizers used in the construction works.
- understand the process of under water concreting.
- understand how to subsititute daily waste for concrete materials.

3. Broad Course Outline

- Admixtures of concrete
- Types of Advanced concrete
- Durability of concrete
- Usage of waste materials
- Under water concreting

4. Textbooks

a) S. Popovics, "Concrete Materials, Properties, Specification and Testing", Standard Publishers, 2002.
b) S.B. Singh, "Analysis and Design of FRP Reinforced Concrete Structures", McGraw Hill, 2015.
c) A.M. Neville, "Properties of Concrete", 5th Edition, Pearson Education India, 2012.

5. References

a) S. Chandra, "Waste Materials in Concrete Manufacturing", Elsevier, 1996.
b) P.K. Metha and P.J. Monterio, "Concrete: Microstructures, Properties and Materials", McGraw Hill, 2017.
c) P. Hewlett and M. Liska, "Lea's Chemistry of cement and concrete", 5th Edition, Butterworth-Heinemann, 2019.
d) F. De Larrard, "Concrete Mixture proportioning – A scientific Approach", CRC Press, 2019.
e) IS:10262-2019, "Guidelines to Concrete mix design"

6. Sessional Plan

Sl. No	Topics	Hours (Tentative)
1	Standards, specifications, Ingredients, Cement and its types, Coarse Aggregate– Fine Aggregate. Chemical admixtures, Mineral admixtures, Polymer concrete Mix design - Mix Design by IS:10262-2019 and other methods of mix design. Concrete Microstructure	5
2	Normal Vibrated Concrete, High volume fly ash concrete, High strength concrete, Reactive powder concrete & Oil well concrete, Ready mix concrete, pervious concrete. Fiber Reinforced Concrete, FRP in concrete, Self compacting concrete, Bacterial Concrete, Self curing concrete. Geopolymer Concrete.	10

3	Deterioration of concrete, Factors effecting the durability, Sulphate attack, Acid attack. Alkali Aggregate reaction, Carbonation, Abrasion, Freezing and Thawing, Corrosion of Rebar, Rapid Chloride penetration test	8
4	Waste from industry, Recycled aggregates, Sustainability, Green concrete, Eco-Friendly Concrete	5
5	Tremie Method, Concrete in Cold weather, Concrete in Hot weather.	5
Total Number of Hours		36

7. Evaluation Plan

Sl No	Type of Evaluation	Weightage
1	Mid semester examination	30
2	Internal evaluation	20
3	End semester examination	50
Total		100

(CEP 2201) Computer Modelling and Simulation of Structures (0-0-3)

1. Course Description

In this course, the students will be introduce to computational analysis of various structural engineering practices. Different structural engineering software which are relevant to real world practices will be taught to the students. This course will dealt with analysis and design of buildings as well as other types of engineering structures.

2. Learning Outcome

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

- learn various structural engineering software.
- analysis of framed structure/buildings
- design of bridges
- design of special engineering structures

3. Broad Course Outline

- Introduction to various structural engineering computational software (MATLAB, ABACUS, SAP, etc.)
- Complete design and structural detailing for standard structures like framed structures for residential, industrial, public utility and recreational purposes;
- Design and analysis of trusses, bridges
- Design and analysis of storage vessels
- Design and analysis of underground structures etc. in concrete, steel and other materials.

4. Textbooks

a) F. Mark, "Handbook of Concrete Engineering", V.N.R.Co., 1974.
b) Relevant handbook for structural engineering.

5. References

a) Relevant I.S. Codes of practices for structural engineering design.
b) Tutorial videos and books relevant to structural engineering software.

LIST OF ELECTIVES

ELECTIVES-1

(CEL 2105) Theory of Stability of Structures (3-0-0)

1. Course Description

In this course, the students will be introduce to structure stability and instability analysis. The stability conditions of columns, beams, plates and frame are included in this course. The students will be introduces to methods used for determining the stability of structures. Buckling analysis of a column for a structures is also included.

2. Learning Outcome

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

- understand the concepts of structural stability .
- determine the stability of beams and frame.
- understand the stability of beams-columns joint.
- determine the stability of plate.
- analyze different buckling condition.

3. Broad Course Outline

- Elastic Stability
- Discrete System
- Stability of Different Structural Components
- Approximate Methods for Stability Determination
- Different Buckling Conditions

4. Textbooks

a) W.F. Chen and E.M. Lui, “Structural Stability: Theory and Implementation”, Prentice-Hall, 1987.
b) T.V. Galambos and A.E. Surovek, “Structural Stability of Steel: Concepts and applications for structural engineers”, Wiley, 2008.

5. References

a) S.P. Timoshenko and J.M. Gere, “Theory of Elastic Stability”, McGraw-Hill, 1961.
b) J.M.T. Thompson and G.W. Hunt, “A general theory of elastic stability”, Wiley, 1973.
c) Z.P. Bazant and L. Cedolin, “Stability of structures”, Dover, 1991.

6. Sessional Plan

Sl. No	Topics	Hours (Tentative)
1	Basic Concepts: Concept of stability, Structural instability and bifurcation, Basic approaches to stability analysis.	4

2	Law of minimum potential energy, Concept of dynamics and energy criteria; Stability of single and multi-degrees of freedom systems, large deflection analysis.	5
3	Governing differential equation and boundary conditions; End-restrained columns; Effect of imperfection; Eccentrically loaded columns; Large deflection solution of elastic columns. Behavior of beam-columns; continuous columns and beam-columns, single-storey frames, frames with sway and no-sway, buckling analysis using stiffness and flexibility method.	8
4	Solution of boundary value problems; Rayleigh-Ritz Method; Method of weighted residuals; Eigenvalue problems; Numerical solution of elastically supported columns.	6
5	Governing differential equation for rectangular plates, Thin plates with all edges simply supported, plates with other boundary conditions, Plates under uniform and sinusoidal loading conditions; buckling under in-plane shear, post buckling analysis.	7
6	Buckling snap through and post-buckling; Inelastic buckling; Torsional buckling, torsional-flexural buckling, lateral-torsional buckling of symmetric cross-sections.	6
Total Number of Hours		36

7. Evaluation Plan

Sl No	Type of Evaluation	Weightage
1	Mid semester examination	30
2	Internal evaluation	20
3	End semester examination	50
Total		100

(CEL 2106) Numerical Methods in Structural Engineering (3-0-0)

1. Course Description

This course will introduce the students to various numerical methods for solving structural problems in Civil Engineering. Different methods of linear system and non-linear system solution are included in this course. Techniques for Eigen values estimation are also presented in this course. Numerical analysis, along with several boundary problem solutions are also included for the students future research in structural engineering.

2. Learning Outcome

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

- formulate structural problems using numerical methods applied to real world problems.
- carry out numerical simulations of many structural engineering problems.
- relate different aspects of the structural engineering aspects in order to have a global picture of the behaviour of a given problem.
- develop program for solve particular problems in structural systems.

3. Broad Course Outline

- Linear Systems in Numerical Methods
- Non-Linear Systems in Numerical Methods
- Eigen Values and Eigen Vectors
- Numerical Integration and Numerical Differentiation
- Partial Differential Equations
- Boundary Value Problems

4. Textbooks

a) J.H. Wilkinson, "The Algebraic Eigenvalue Problem", Oxford University Press, 1965.
b) K.E. Atkinson, "An Introduction to Numerical Analysis", Wiley, 1989.
c) G.E. Golub and C.F. Van Loan, "Matrix Computations", Johns Hopkins University Press, 1989.

5. References

a) J.B. Scarborough, "Numerical Mathematical Analysis", 6th Edition, Oxford & IBH Publishing, 2020.
b) K.K. Jain, S.R.K Iyengar and R.K. Jain, "Numerical Methods - Problem and Solutions", Wiley India, 2001.
c) R.W. Hamming, "Numerical Methods for Scientist and Engineers", McGraw Hill, 1998.
d) J.H. Mathews and K.D. Fink, "Numerical Methods using MATLAB", Pearson, 2004.

6. Sessional Plan

Sl. No	Topics	Hours (Tentative)
1	Introduction to Numerical Methods, error in numerical solutions. Mathematical foundations of structural theory.	3
2	Order of accuracy Direct Solution of Linear systems- Gauss elimination, Gauss Jordan elimination, Pivoting, inaccuracies due to pivoting, Factorization, Cholesky decomposition, Diagonal dominance, condition number, ill conditioned matrices, singularity and singular value decomposition. Banded matrices, storage schemes for banded matrices, skyline solver. Iterative solution of Linear systems- Jacobi iteration, Gauss Seidel iteration, Convergence criteria.	7
3	Non Linear Systems, Direct Solution of Non Linear systems- Newton Raphson iterations to find roots of a 1D nonlinear equation, Newton Iterations, Quasi Newton iterations.	5
4	Properties of Eigenvalues and Eigenvectors, Diagonalization and Numerical techniques to compute eigenvalues - Vector Iteration, QR algorithm, Jacobi Method.	6
5	Numerical Integration: Introduction, Newton–Cotes formulas, Adaptive Integration, Gaussian quadrature. Numerical differentiation: Equally Spaced Data, Taylor Series Approach, Difference Formula, Error Estimation.	6
6	Elliptic, Parabolic and Hyperbolic Partial Differential Equations (PDEs)	4
7	Numerical Solution of Boundary Value Problems - Finite Difference Method, Explicit and Implicit Approaches; Method of Weighted Residuals, Galerkin's Method.	5
Total Number of Hours		36

7. Evaluation Plan

Sl No	Type of Evaluation	Weightage
1	Mid semester examination	30
2	Internal evaluation	20
3	End semester examination	50
Total		100

(CEL 2107) Sustainable Engineering **(3-0-0)**

1. Course Description

The Sustainable Construction and Design course discusses in detail the sustainable practices in structural engineering and construction industry. With the construction and use of our built environment responsible for 39% of global greenhouse gas emissions, there is a need for sustainable practices to reduce the environmental impacts. To address these challenges, the construction industry has endorsed sustainable construction methods to ensure that construction projects minimize their environmental impacts while supporting the economic wellbeing and social welfare of the communities in which they are developed. In this course, you'll delve into environmental, economic, and social sustainability, understanding what it is and how it relates to the construction industry. With this knowledge, you'll be able to explore the environmental implications of built assets as well as potential solutions such as sustainable materials, building design and construction practices. You'll unpack the barriers to economic, and social sustainability before learning how to navigate these challenges with tools and techniques. By the end of the course, the students will have the knowledge and skills to implement sustainability in the structural engineering to help build a better future.

2. Learning Outcome

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

- define sustainable development (economic, environmental, and social), circular economy, and their relationship with structural engineering
- learn about innovative circular design principles such as design for adaptability, design for disassembly, design for longevity, design for service, and design for material recovery
- learn about reversible designs allowing disassembly and reassembly, designing for deconstruction, reuse, renovation, retrofitting, refurbishment, and repurpose
- examine the properties of common construction materials and understand the transition toward sustainable materials, along with their behaviours under different environments, short- or long-term
- learn about construction and demolition waste management and material upcycling technologies
- learn about the role of renewable energy in construction industry, and design concepts of green building, energy use efficiency, and carbon neutrality
- learn how to assess the environmental impacts of materials, and construction projects using life cycle analysis

3. Broad Course Outline

- The concept of sustainability (Sustainability and Building Industry)
- Sustainable Design in Practice
- Sustainable Construction Materials

- Construction and Demolition waste management and material upcycling technologies.
- Renewable energy in construction industry, and design concepts of green building, energy use efficiency, and carbon neutrality
- Life Cycle Assessment
- Economics and Social aspects of Sustainability

4. Textbooks

a) The Philosophy of Sustainable Design by Jason F. McLennan, Ecotone Publishing Co., 2004.
b) Green Building Fundamentals by Mike Montoya, Pearson, 2nd edition, 2010.
c) Sustainable Construction - Green Building Design and Delivery by Charles J. Kibert, John Wiley & Sons, 2nd edition, 2008.

5. References

a) Sustainable Construction and Design by Regina Leffers, Prentice Hall, 2009.
b) Sustainable Construction and Building Materials by Bibhuti Bhusan Das, Narayanan Neithalath, 2018
c) Energy Efficient Buildings In India by Mili Majumdar The Energy Research Institute.
d) Energy-Efficient Building Systems Lal Jayamaha McGraw Hill Publication.

6. Sessional Plan

Sl. No	Topics	Hours (Tentative)
1	Unsustainable practices in construction industry, environmental impacts, Definitions of sustainable development (economic, environmental, and social), circular economy and its relationship with structural engineering.	4
2	Innovative circular design principles, design for adaptability, design for disassembly, design for longevity, design for service, and design for material recovery; Reversible designs allowing disassembly and reassembly, designing for deconstruction, reuse, renovation, retrofitting, refurbishment, and repurpose.	6
3	Properties of common construction materials, Sustainable materials – Rammed earth, Bamboo & Timber, Bioplastics & biocomposites, Composite Roofing Shingles, Smart glass, Mycelium, Precast concrete & green concrete, 3D Printed materials, etc., Short- or long-term behaviours under different environments and cost economics.	7
4	Construction and Demolition (C&D) waste definitions; Composition & Characteristics; C&D waste Management Rules, 2016; Collection, Transportation and Disposal; Processing, Material Recovery, Recycling – challenges and competence with conventional building materials, and Upcycling Techniques.	8
5	Conservation & energy efficiency concepts; Solar energy fundamentals & practices in building design; optimal orientation of building, shadow analysis; Heating and ventilation design- Human thermal comfort, climatological factors, material specifications; Concept of cost/benefit of energy conservation & carbon footprint estimation. Energy efficient lighting system design; Green buildings; Carbon Neutrality.	7

6	Life cycle assessment – Basic Overview, Life cycle inventory (LCI), life cycle impact assessment (LCIA), Concepts of economic sustainability, and social sustainability.	4
	Total Number of Hours	36

7. Evaluation Plan

Sl No	Type of Evaluation	Weightage
1	Mid semester examination	30
2	Internal evaluation	20
3	End semester examination	50
Total		100

(CEL 2108) High Rise Structures (3-0-0)

1. Course Description

Analysis, design and stability of tall buildings are covered in this course. At the end of this course, the student will have an understanding of the behaviour of tall buildings subjected to different loading especially lateral loading such as wind and earthquake.

2. Learning Outcome

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

- understand the anatomy of high rise structures
- understand different loading on high rise structures
- understand the analysis of high rise structures under different loading conditions
- understand the stability of high rise structures

3. Broad Course Outline

- Structural system and important analysis aspects of tall buildings
- Gravity load-resisting system
- Lateral load resisting system
- High rise structures subjected to wind load
- High rise structures subjected to earthquake load
- Stability of high rise structure

4. Textbooks

a) Bungale S. Taranath (2021), Structural Analysis and Design of Tall Buildings: Steel and Composite Construction
b) Bryan Stafford Smith and Alex Coull (2011), Tall Building Structures: Analysis and Design.

5. References

a) Bungale S. Taranath (2019), Wind and Earthquake Resistant Buildings: Structural Analysis and Design
b) S. K. Duggal (2013), Earthquake-Resistant Design of Structures
c) Bungale S. Taranath (2010), Reinforced Concrete Design of Tall Buildings
d) Johann Eisele and Ellen Kloft; (2003), High-Rise Manual: Typology and Design, Construction and Technology
e) Gaylord, Edwin (1980), Tall Building Criteria & Loading

6. Sessional Plan

Sl. No.	Topic	Hours (Tentative)
1	Structural system of tall buildings Important structural analysis and design aspects of tall buildings, Progressive Collapse, Pounding, P-Δ Effect, Buckling of a Tall Building, Ductility, Redundancy, Hysteresis, Loads and load combinations	6
2	Gravity Load-Resisting Systems: Design Strategy, Floor Systems, Yield-Line Method, Deep beams	3
3	Lateral Load-Resisting Systems: Flat Slab-Frame System, Moment-Resistant Frames, Shear Walls, infilled frames, coupled frames, Shear Wall–Frame Interaction, Frame Tube System, Exterior Diagonal Tube, Bundled Tube,	6
4	Analysis method of 2D frame under lateral load: Cantilever and Portal frame method, Irregular building, Necessity of 3D analysis, Lateral Load Design Philosophy	3
5	High rise structures subjected to wind load: Wind forces, Design Considerations, Codal aspects, Gust Factor, Building drift and Separation, Principles of Cyclone Resistant Design	6
6	High rise structures subjected to earthquake load: Seismic Design Concept, Influence of Soil, Load path, Seismic coefficient method, Response-Spectrum Method, Principles of earthquake resistant design, Soft storey, Diaphragms, Foundations: Footings, Mats, and Piles	6
7	Stability of High Rise Structures: Buckling of Frame, Shear mode, Flexural mode, Combined shear and flexural modes, Bucking of wall-frame, Translational and torsional instability	6
	Total number of hours	36

7. Evaluation Plan

Sl No	Type of Evaluation	Weightage
1	Mid semester examination	30
2	Internal evaluation	20
3	End semester examination	50
Total		100

(CEL 2109) Analysis and Design of Plates and Shells (3-0-0)

1. Course Description

Plates and shells are used in many engineering applications such as pressure vessels, aircraft, bridge decks, dome roofs, missiles, and the vehicle body, etc. This course will enable students to understand the various theories of plates and shells and their application to various structures.

2. Learning Outcome

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

- understand the theoretical basis of analysis of plates and shells
- understand the vibration analysis of plates and shells
- understand the buckling analysis of plates and shells

3. Broad Course Outline

- Theory of plates

- Theory of shells
- Buckling of plates
- Buckling of shells
- Vibration of plates and shells
- Folded plates and roof structures
- General shell theory in light of differential geometry
- Approximate solutions of general shells

4. Textbooks

a) S. Timoshenko and S. K. Woinowsky, "Theory of Plates and Shells", McGraw-Hill International, 2007
b) J. N. Reddy, "Theory and Analysis of Elastic Plates and Shells", CRC Press, 2006.

5. References

a) P. L. Gould, "Analysis of Shells and Plates", Springer-Verlag, 1988.
b) Szilard, R. 1974. Theory and Analysis of Plates-Classical and Numerical Methods. Englewood Cliffs, NJ: Prentice-Hall.
c) Naghdi PM (1972) The theory of plates and shells. In: Flilgge S (ed) Handbuch der Physik. Springer, Berlin VI, A2: 425-646
d) C. L.Dym., "Introduction to the Theory of Shells", Hempshire Publishing Corp., 1990.
e) A. Ugural, "Stresses in Plates and Shells", McGraw Hill, 1999.
f) E. Ventsel and T. Krauthammer, "Thin Plates and Shells", Marcel Dekker, Inc., 2001.

6. Sessional Plan

Sl. No.	Topic	Hours (Tentative)
1	Kinematics of plates, Variational formulations of plate problems, Governing equations, boundary conditions and initial conditions, Thermal stresses in plates; Bending of rectangular plates, Navier's solutions, Levy's solutions; Bending of circular plates; Vibration of plates, Approximate limit design of plates: Yield line theory	12
2	Kinematics of shells, Approximate theories of shells (Donnel's theory, Love's theory, Sander's theory etc.), Analytical solutions of singly-curve and doubly-curve shells, Thermal stresses in shells; Membrane theory of shells of revolution; Bending of shells of revolution, Vibration of shells	9
3.	Buckling of plates and Post buckling behavior of plates;	3
4	Buckling of cylindrical shells;	3
5	Folded plates and roof structures	3
6	The modern theory of shells: general shell theory in light of differential geometry	3
7	Approximate solutions of general shells	3
	Total number of hours	36

7. Evaluation Plan

Sl No	**Type of Evaluation**	**Weightage**
1	Mid semester examination	30

2	Internal evaluation	20
3	End semester examination	50
Total		100

(CEL 2110) Random Vibration **(3-0-0)**

1. Course Description

Variability and uncertainties are present in all engineering systems. Through this course, the students will learn to apply tools from probabilistic modelling to analyse dynamic systems while accounting for variability and uncertainties that are inevitably present in real engineering systems.

2. Learning Outcome

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

- understand the concept of Stochastic processes and stochastic calculus
- understand the concept of stationary random processes
- understand the concept of Failure due to random vibration in structural systems.
- understand the concept of measurement and processing of random data

3. Broad Course Outline

- Introduction and review of probability theory
- Stochastic processes, stochastic calculus
- single and multi-degree of freedom system
- Continuous system
- Failure due to random vibration in structural systems.
- measurement and processing of random data

4. Textbooks

a) D. E. Newland, An Introduction to Random Vibrations and Spectral Analysis, Second Ed., Longman Inc., NewYork, 1984
b) N. C. Nigam, Introduction to Random Vibrations, MIT Press, Cambridge, 1983
c) A Papoulis, 1991, Probability, random variables and stochastic processes, 3rd Edition, McGrawHill, New York

5. References

a) H. Benaroya, S. M. Han and M. Nagurka, Probabilistic Models for Dynamical Systems, 2nd ed., CRC Press,
b) Loren D. Lutes and Shahram Sarkani (2004) Random Vibrations: Analysis of Structural and Mechanical Systems, Elsevier Butterworth-Heineman

6. Sessional Plan

Sl. No.	Topic	Hours (Tentative)
1.	Introduction and review of probability theory	3
2.	Stochastic processes, correlation functions, Gaussian processes, stochastic calculus.	9
3.	Excitation response relations for stationary random processes- single and	12

	multi-degree of freedom system with linear and non-linear characteristics, continuous systems.	
4.	Failure due to random vibration in structural systems.	6
5.	A brief discussion on measurement and processing of random data	6
	Total number of hours	36

7. Evaluation Plan

Sl No	Type of Evaluation	Weightage
1	Mid semester examination	30
2	Internal evaluation	20
3	End semester examination	50
Total		100

ELECTIVES-2

(CEL 2204) Structural Health Monitoring **(3-0-0)**

1. Course Description

Structural health monitoring of an existing structure is introduce in this course. Different methods to determine the damage of an existing structures is included in this course. Various techniques involved in Non Destructive Test (NDT) for damage detection are also introduced.

2. Learning Outcome

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

- understand the concepts of structural health monitoring.
- understand several damage detection techniques.
- understand modal testing in damage detection.
- understand machine learning in structural health monitoring.
- understand types and materials involved in different NDT.

3. Broad Course Outline

- Structural Health Monitoring Concepts
- Sensing Technology for Structural Health Monitoring
- Damage Detection Techniques
- Machine Learning Techniques
- Non Destructive Test (NDT)

4. Textbooks

a) D. Balageas, C.P. Fritzen and A. Güemes, “Structural Health Monitoring”, Wiley, 2006.
b) H.P. Chen and Y.Q. Ni, “Structural Health Monitoring of Large Civil Engineering Structures”, Wiley, 2018.
c) C.R. Farrar and K. Worden, “Structural Health Monitoring: A Machine Learning Perspective”, Wiley, 2012.

5. References

a) J.H. Bungey and S.G. Millard, "Testing of concrete in structures. Blackie Academic & Professional", Chapman & Hall, 1996.
b) H.B. Egerton, "Non-Destructive Testing: Views, Reviews, Previews", Oxford University Press, 1969.
c) V.M. Malhotra and N.J. Carino, "Handbook on Nondestructive Testing of Concrete", 2nd Edition, CRC press, 2007.

6. Sessional Plan

Sl. No	Topics	Hours (Tentative)
1	Introduction to Structural Health Monitoring, Historical Overview, Introduction to Various Structural Damage Detection Techniques, Various Sensing Technologies for Structural Health Monitoring	7
2	Data Acquisition, Communication and Data Management, Vibration-Based Damage Detection Techniques, Principles of Modal Testing, Damage Detection Using Finite Element Model Updating, Structural Health Monitoring Using Machine Learning Techniques, Structural Health Monitoring For Large Structures	15
3	Types of materials, tests and the variables involved, destructive and non-destructive testing correlation of properties obtained by NDT with the basic structure of matter and other properties; NDT of different materials by various techniques such as radiographic, sonic and ultrasonic, electrical and magnetic, soleoroscopic, microwave, eddy current penetrant, thermal optical, holographic etc., practical applications and advances in NDT.	14
Total Number of Hours		36

7. Evaluation Plan

Sl No	Type of Evaluation	Weightage
1	Mid semester examination	30
2	Internal evaluation	20
3	End semester examination	50
Total		100

(CEL 2205) Design of Masonry Structures (3-0-0)

1. Course Description

In this course, the students will be introduce to masonry structures, its construction materials and design approaches. Loads acting on masonry structures and various analysis are included. This course also contained the design of different types of masonry structures.

2. Learning Outcome

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

- understand materials required for masonry structures.
- understand the design approach of masonry structures.
- conceptualize the loads acting on masonry structures.
- analyze the masonry structure components.

- design of different types of masonry structures

3. Broad Course Outline

- Masonry Structures
- Materials for Masonry Structures
- Loads on Masonry Structures
- Analysis of Masonry Structures
- Masonry Structures Design

4. Textbooks

a) R.G. Drysdale, A.H. Hamid and L.R. Baker, "Masonry Structure: Behaviour Design", Prentice Hall, 1994.
b) A.W. Hendry, "Structural Masonry", 2nd Edition, Palgrave Macmillan, 1998.
c) A.W. Hendry, B.P. Sinha and S.R. Davis, "Design of Masonry Structures", CRC Press, 2017.

5. References

a) T. Paulay and M.J.N. Priestley, "Seismic Design of Reinforced Concrete and Masonry Building", Wiley, 1992.
b) N. Taly, "Design of Reinforced Masonry Structures", 2nd Edition, McGraw Hill, 2010.
c) M. Wakabayshi, "Design of Earthquake resistant Buildings", McGraw Hill, 1986.
d) IS:13935-2009, "Seismic Evaluation, Repair and Strengthening of Masonry Buildings".

6. Sessional Plan

Sl. No	Topics	Hours (Tentative)
1	Introduction to Masonry Structures Design and Historical Background, Masonry Materials, Masonry Design Approaches	5
2	Overview of Load Conditions, Compression Behaviour of Masonry, Masonry Wall Configurations, Distribution of Lateral Forces, Flexural Strength of Reinforced Masonry Members, In-plane and out-of-plane Loading, Interactions	9
3	Elastic and inelastic analysis, Modelling Techniques, Static Push-over Analysis and use of Capacity Design Spectra	11
4	Structural Wall, Columns and Pilasters; Retaining Wall, Pier and Foundation, Shear Strength and Ductility of Reinforced Masonry Members, Pre-stressed Masonry, Stability of Walls, Coupling of Masonry Walls, openings, Columns, Beams	11
Total Number of Hours		36

7. Evaluation Plan

Sl No	Type of Evaluation	Weightage
1	Mid semester examination	30
2	Internal evaluation	20
3	End semester examination	50
Total		100

(CEL 2206) Performance Based Seismic Design of Structures (3-0-0)

1. Course Description

This course will help the students to learn the development in the domain of performance based design. Students will be able to understand the concepts of performance levels and will learn the application of performance based design.

2. Learning Outcome

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

- get familiarized with limitation of force-based codal method of design and the need for cement based design.
- learn design with target criteria under given hazard level.
- learn design incorporating drift and performance level for frame buildings, frame-wall buildings and other structures.
- get motivation for higher studies in displacement-based design and get impetus for lifelong learning.

3. Broad Course Outline

- Limitation of Force-Based Methods
- Ground Motion Relation to Structures
- Performance Levels and Objectives
- Displacement Based Design
- Base Isolation

4. Textbooks

a) M.J.N. Priestley, G.M. Calvi and M.J. Kowalasky, "Displacement-Based Seismic Design of Structures", IUSS Press, 2007
b) T.J. Sullivan, M.J.N. Priestley and G.M. Calvi, "Seismic Design of Frame-Wall Buildings", ROSE-2006/02 Reports.
c) T. Paulay and M.J.N. Priestley, "Seismic Design of Reinforced Concrete and Masonry Structures", Wiley, 1992

5. References

a) R. Park and T. Pauley, "Reinforced Concrete Structures", Wiley, 2009.
b) FEMA:356, "Pre-standard and Commentary for the Seismic rehabilitation of Buildings".
c) AC-41-17, "Seismic Evaluation and Retrofit of Existing Buildings".
d) ATC-40, "Seismic Evaluation and Retrofit of Concrete Buildings".

6. Sessional Plan

Sl. No	Topics	Hours (Tentative)
1	Force-based method of design vs. Performance-based method of design, Historical development. Limitations of Force-based method of design. Limitations of IS 1893 (Part 1)-2016. Moment-curvature relationship. Strength-Stiffness relationship. Types of strengths: Expected strength, characteristic strength, and extreme strength.	7

2	Definition of Maximum Credible Earthquake (MCE) and Design Basis Earthquake (DBE). Spectrum Compatible Ground Motions. Review of Response Spectrum Method of Design. Displacement Spectra.	8
3	Performance levels: Immediate Occupancy Level, Life Safety Level, Collapse Prevention Level. The concept of Operational Level Buildings. Multi-objective design. Drift in buildings and design for drift. Design for desired performance objectives.	11
4	The concept of Capacity Design. Capacity design applied to buildings and other structures. Displacement-based design philosophy. Direct Displacement-based design methods. Unified Performance-based design method. Application to Frame Buildings, Frame-Shear wall buildings and other structures. Effect of infill. Base Isolation and added damping.	10
Total Number of Hours		36

7. Evaluation Plan

Sl No	Type of Evaluation	Weightage
1	Mid semester examination	30
2	Internal evaluation	20
3	End semester examination	50
Total		100

(CEL 2207) Fracture Mechanics **(3-0-0)**

1. Course Description

The presence of flaws in solids can affect their strength and the load-carrying capacity of structures. However, the conventional methods of analysis and design of structures based on strength of material and elasticity (and plasticity) do not consider the effect of these flaws. In this course, the students will be introduced to the concept of fracture in solids. This course intends to provide a theoretical background of the mechanics of fracture and its applications in structural engineering problems. The students will learn how and under what circumstances a pre-existing flaw (or a crack) in a material may propagate and eventually cause failure.

2. Learning Outcome

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

- understand the concept of linear elastic fracture mechanics
- understand the concept of stress intensity factor & fracture toughness
- understand the concept of mixed-mode fracture
- understand the concept of crack tip plasticity
- understand the concept of elastic-plastic fracture mechanics
- understand the concept of fatigue crack growth
- understand the concept of numerical modelling of cracks in solids

3. Broad Course Outline

- Introduction and historical perspective of Fracture Mechanics
- Linear Elastic Fracture Mechanics
- Elastic-Plastic Fracture Mechanics

- Fatigue crack growth
- Numerical modelling of crack in solids using FEM

4. Textbooks

a) T. L. Anderson, Fracture Mechanics: Fundamentals and Applications, CRC press, 3rd Ed., 2005
b) Prashant Kumar, Element of Fracture Mechanics, Tata McGraw Hill

5. References

a) David Broek, Engineering Fracture Mechanics, Martinus Nijhoff publishers, 1982.

6. Sessional Plan

Sl. No.	Topic	Hours (Tentative)
1.	Overview of Fracture Mechanics, Historical perspective, Brief review of linear elasticity	3
2.	An atomic view of fracture, Stress concentration, Griffith's energy balance approach, Energy release rate	6
3.	Brittle and ductile failure, Fracture process zone, Plane stress vs. plane strain fracture, Resistance curve, Critical energy release rate	6
4.	Stress intensity factor (SIF), Relation between energy release rate and SIF, Methods for determining SIF, SIF of more complex cases, Fracture toughness	3
5.	Mixed mode fracture, Different criteria for crack initiation and propagation in mixed mode	3
6.	Inelastic deformation at crack tip, Concept of effective crack: Irwin's and Dugdale approach	3
7.	Crack tip opening displacement, J-integral	3
8.	Introduction to fatigue, Paris law, Crack closure, Variable amplitude loading and retardation	6
9.	Brief introduction to modelling cracks in solids using FEM	3
	Total number of hours	36

7. Evaluation Plan

Sl No	Type of Evaluation	Weightage
1	Mid semester examination	30
2	Internal evaluation	20
3	End semester examination	50
Total		100

(CEL 2208) Theory of Plasticity **(3-0-0)**

1. Course Description

This course will enable students to understand, use and build constitutive models for materials that may deform plastically. The application of plasticity theory to boundary value problems and computational aspects of plasticity will also be covered at the introductory level.

2. Learning Outcome

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

- understand the theoretical basis of plasticity
- understand the elastic-plastic boundary value problems
- understand the computational aspect with emphasis on FEM for plasticity problems

3. Broad Course Outline

- A brief review of elasticity
- Constitutive relations
- Phenomenological Plasticity Theory
- Elastic-plastic boundary value problems
- Introduction to computational plasticity

4. Textbooks

a) Lubliner J. Plasticity Theory. University of California at Berkeley, 2006.

5. References

a) Chakrbarty J. Applied Plasticity. Dordrecht: Springer, 2010. 771 p
b) Kachanov L.M. Foundations of Theory of Plasticity. Amsterdam: North-Holland, 1971.
c) Simo, J.C. and Hughes, T.J., 2006. Computational inelasticity (Vol. 7). Springer Science & Business Media.
d) Calladine, C.R., 1985. Plasticity for engineers. E. Horwood.

6. Sessional Plan

Sl. No.	Topic	Hours (Tentative)
1.	A brief review of the fundamentals of elasticity: Concepts of stress and strain, different measures, transformation, stress invariants, strain rate, stress objectivity, Generalized Hooke's law, anisotropy, visco-elasticity etc.	3
2	Plastic deformation, the role of microstructure and thermodynamics in plastic deformation, a physical overview of crystal plasticity, plasticity of soils, rock, concrete etc.	3
3.	Constitutive relations: Plastic strain, incremental strain, Yield surface for rate-independent materials, normality rules and related invariance, Flow Potential for Rate-Dependent Materials, Ilyushin's Postulate, Drucker's Postulate	9
4.	Phenomenological Plasticity Theory: Formulation in Strain Space, Formulation in Stress Space, Hardening Models in Stress Space, Yield Surface in Strain Space/Stress Space, Pressure-Dependent Plasticity, Non-associative Plasticity, Rate-Dependent Plasticity	12
5.	Elasto-plastic boundary value problems: Tension and torsion of tubes and rods, pressurized thin and thick spherical shells etc.	3
6.	Introduction to computational plasticity: Integration of plasticity models; return mapping; principle of virtual work; overview of finite elements for plasticity	6
	Total number of hours	36

7. Evaluation Plan

Sl No	Type of Evaluation	Weightage
1	Mid semester examination	30
2	Internal evaluation	20
3	End semester examination	50
Total		100

(CEL 2209) Non-Linear Analysis of Structures (3-0-0)

1. Course Description

In many engineering problems, the equations representing a structural system are non-linear. This non-linear effect may be ascribed to geometrical nonlinearity (such as large deformation), material nonlinearity (such as inelastic behaviour), and contact. In such situations, the methods constituted based on linearity assumptions cannot be applicable. This course intends to provide an understanding of various sources of nonlinearity and study the methods for analysing the non-linear behaviour of structural systems considering the effect of material and geometric nonlinearity.

2. Learning Outcome

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

- understand the various sources of nonlinearity in structural systems
- understand the concept of nonlinear elasticity
- understand the concept of visco-elasticity
- understand the concept of plasticity
- understand the concept of solution strategies for structures undergoing nonlinear behaviour
- understand the concept of nonlinear oscillations and dynamic stability

3. Broad Course Outline

- Introduction to various factors affecting the nonlinear behaviour of structures
- Mathematical preliminaries
- Review of fundamental concepts of continuum mechanics
- Material nonlinearity
- Geometric nonlinearity
- Solution strategies
- Nonlinear oscillations and dynamic stability

4. Textbooks

a) Sathyamoorthy, M. (1998). Nonlinear Analysis of Structures. Boca Raton, FL: CRC Press
b) Prashant Kumar, Element of Fracture Mechanics, Tata McGraw Hill

5. References

a) Crisfield, M. A. (1991). Non-Linear Finite Element Analysis of Solids and Structures. Chichester, England: John Wiley & Sons, Inc
b) Timoshenko, S., & Gere, J. M. (1961). Theory of Elastic Stability. Mineola, NY: Dover Publications
c) Bathe, K.-J. (2005). Inelastic Analysis of Solids and Structures. Berlin, Germany: Springer.

d) Belytschko, T., Liu, W.K., Moran, B. and Elkhodary, K., 2014. Nonlinear finite elements for continua and structures. John wiley & sons.

6. Sessional Plan

Sl. No.	Topic	Hours (Tentative)
1.	Factors affecting the nonlinear behaviour of structures – geometrical effects, material effects, instability phenomena (snap-through, bifurcation, post-buckling behaviour)	2
2.	Linear spaces and spectral theory, eigenvalue problems and bifurcation. Tensor and Vector Analysis, Tensor Calculus	3
3.	Review of fundamental concepts of continuum mechanics: Kinematics: Material and spatial coordinates, deformation gradient, polar decomposition, velocity and material time derivatives, rate of deformation, spin tensor, Deformation and Strain, different measures of strains Stress: different measures of stress Conservation laws: mass, momentum and energy	6
4	Nonlinear elastic behaviour, Elasto-plastic material behaviour, Time-dependent rheological behaviour (visco-elasticity), Linearization and Solution methods, Finite Element discretization, Newton's type methods	12
5.	Large deformation and post-buckling behaviour of elastic arches, beams, plates and columns	9
6	Introduction to Nonlinear oscillations and dynamic stability, critical points	4
	Total number of hours	36

7. Evaluation Plan

Sl No	Type of Evaluation	Weightage
1	Mid semester examination	30
2	Internal evaluation	20
3	End semester examination	50
Total		100

ELECTIVES-3

(CEL 2210) Optimization Techniques (3-0-0)

1. Course Description

In this course, the students will be introduce to simple linear programming and methods involved in linear programming. The integer programming relevant to various civil engineering examples are also included. The complex non linear programming and various methods such as quadratic programming will also be introduced to the students.

2. Learning Outcome

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

- understand the concept of linear programming.
- understand the concept and application of integer programming
- understand the concept and application of non-linear programming.
- solve real world examples using engineering optimization techniques

3. Broad Course Outline

- Simplex Method
- Duality Theorems
- Branch and Bound Algorithm
- Non Linear Programming
- Multi-objective Optimization

4. Textbooks

a) S.S. Rao, “Engineering Optimization: Theory and Practice”, Wiley, 2009.
b) F.H. Hillier and G. J. Liberman, “Introduction to Operations Research”, McGraw-Hill, 2010.
c) W.L. Winston, “Operations Research: Applications and Algorithm”, 4th Edition, Cengage Learning, 1994.

5. References

a) A. Ravindran, D.T. Phillips and J.J. Solberg, “Operations Research: Principles and Practice”, Wiley, 1987.
b) K. Deb, “Optimization for Engineering Design”, Prentice Hall, 2013.
c) M.C. Joshi and K.M. Moudgalay, “Optimization: Theory and Practice”, Narosa, 2004.
d) K. Deb, “Multi-objective Optimization using evolutionary algorithms”, Wiley, 2009.

6. Sessional Plan

Sl. No	Topics	Hours (Tentative)
1	Formulating linear programs, Graphical solution of linear programs. Special cases of linear program, The Simplex Method: Converting a problem to standard form. The theory of the simplex method, The simplex algorithm, Special situations in the simplex algorithm, Obtaining initial feasible solution, Duality and sensitivity analysis: Sensitivity analysis, Shadow prices, Dual of a normal linear program Duality theorems, Dual simplex method.	12
2	Formulating integer programming problems. The branch-and-bound algorithm for pure integer programs. The branch-and-bound algorithm for mixed integer programs.	9
3	Introduction to non-linear programming (NLP), Convex and concave functions, NLP with one variable, Line search algorithms. Multivariable unconstrained problems, constrained problems, Lagrange Multiplier, The Karush-Kuhn-Tucker (KKT) conditions. The method of steepest ascent, Convex combination method, penalty function methods, Quadratic programming, Dynamic programming Evolutionary algorithms such as Genetic Algorithm. Concepts of multi-objective optimization, Markov Process, Queuing Models	15
Total Number of Hours		36

7. Evaluation Plan

Sl No	Type of Evaluation	Weightage
1	Mid semester examination	30
2	Internal evaluation	20
3	End semester examination	50

Total	100

(CEL 2211) Condition Assessment and Retrofitting of Structures (3-0-0)

1. Course Description

This course will help the students to assess the condition of existing buildings. Various methods of testing and techniques for evaluation of buildings will be introduced to the students. In this course, the different methods of repairing and retrofitting the existing buildings are also included.

2. Learning Outcome

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

- understand various factors contributing to deterioration of concrete buildings
- learn the different methods of evaluating concrete buildings
- learn different materials used for retrofitting
- understand retrofitting techniques
- use different codes and guidelines available for retrofitting of buildings

3. Broad Course Outline

- Concrete Buildings Deterioration
- Evaluation of the Existing Buildings Condition
- Retrofitting Techniques
- Strengthening Techniques
- Guidelines for Retrofitting and Strengthening

4. Textbooks

a) P.H. Emmons, “Concrete Repair and Maintenance”, RSMeans, 2002
b) S. Bungey, G. Lillard and M.G. Grantham, “Testing of Concrete in Structures”, Taylor and Francis, 2001
c) H. Bohni, “Corrosion in Concrete Structures”, CRC Press, 2005.
d) V.M. Malhotra, and N.J. Carino, “Handbook on Nondestructive Testing of Concrete”, 2nd Edition, CRC press, 2007.

5. References

a) Central Public works Department-Government of India, “Handbook on Repair and Rehabilitation of RCC buildings”, 2002.
b) FEMA:356, “Pre-standard and Commentary for the Seismic rehabilitation of Buildings”.
c) FEMA:P-58-1, “Seismic Performance Assessment of Buildings (Volume-1)”.
d) AC-41-17,” Seismic Evaluation and Retrofit of Existing Buildings”.
e) IS:15988-2013, “Seismic Evaluation and Strengthening of Existing Reinforced Concrete Buildings”.

6. Sessional Plan

Sl. No	Topics	Hours (Tentative)
1	Embedded Metal Corrosion, Disintegration Mechanisms, Moisture Effects, Thermal Effects, Structural Effects, Faulty Construction	4
2	Visual Investigation, Destructive Testing Systems, Non-Destructive Testing Techniques, Semi-Destructive Testing Techniques, Chemical Testing, Performance Evaluation of buildings using non-linear analyses	9

3	Surface Repair & Retrofitting Techniques: Strategy & Design, Selection of Repair Materials, Surface Preparation, Bonding repair Materials to Existing concrete, Placement Methods, Epoxy Bonded Replacement Concrete, Preplaced Aggregate Concrete, Shotcrete/Gunite, Grouting, Injection Grouting, Micro concrete	12
4	Strengthening Techniques, Beam Shear Capacity. Strengthening, Shear Transfer Strengthening between Members, Column Strengthening, Flexural Strengthening, and Crack Stabilization. Guidelines for Seismic Rehabilitation of Existing Buildings, Seismic Vulnerability and Strategies for Seismic Retrofit.	11
Total Number of Hours		36

7. Evaluation Plan

Sl No	Type of Evaluation	Weightage
1	Mid semester examination	30
2	Internal evaluation	20
3	End semester examination	50
Total		100

(CEL 2212) Design of Pre-stressed Concrete Structures (3-0-0)

1. Course Description

In this course, analysis and design of prestressed concrete members and connections will be performed. This course will enable the students to identify and interpret the appropriate relevant industry design codes. They will be familiar with professional and contemporary issues in the design and fabrication of prestressed concrete members

2. Learning Outcome

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

- understand the general mechanical behavior of prestressed concrete.
- to analyze prestress concrete and bending stress.
- to analyze and design for flexural and shear in prestressed concrete.
- to analyze transfer of load in prestressed concrete as well as prestress losses.
- to identify and apply the applicable industry design codes relevant to the design of prestressed concrete members.
- design of prestressed concrete pipes and tanks.
- design of prestressed concrete poles, sleepers and other concrete section.

3. Broad Course Outline

- Concept of Prestressing
- Prestressing System
- Flexural and Shear Strength
- Anchorage Zone
- Design of Prestressed Concrete Pipes
- Design of Sleepers for Railways
- Design of Pavements for Bridges and Roads

4. Textbooks

a) T.Y. Lin and N.H. Burns, “Design of Prestressed Concrete Structures”, Wiley, 1981.
b) N.K. Raju, “Design of Pre-stressed Concrete Structures”, 6th Edition, McGraw Hill, 2018.
c) S.S. Bhavikatti, “Design of Pre-stressed Concrete Structures”, Medtech, 2019.

5. References

a) A.E. Naaman, “Prestressed Concrete Analysis and Design: Fundamentals”, 2nd Edition, Technopress, 2004.
b) Y. Guyan, “Limit State Design of Prestressed Concrete”, Applied Science Publishers, 1972.
c) IS:1343-1980(-1990), “Code of Practice for Pre-stressed Concrete”.

6. Sessional Plan

Sl. No	Topics	Hours (Tentative)
1	Concept and Advantages of Pre-stressing, Materials for pre-stressed concrete, Different Pre-stressing System. Analysis of pre-stress and bending stresses, various losses of prestress, Deflection of pre-stressed concrete member. Statically indeterminate Pre-stressed Structures	10
2	Flexural and shear strength of pre-stressed concrete members, Shear torsion and axial forces. Transfer of pre-stress in pretensioned members. Anchorage zone stresses in post tensioned members. Limit state design for Pre-stressed concrete	13
3	Design of pre-stressed concrete sections, Design of pretension and post tensioned Flexural member, Pre-stressed concrete pipes and tanks. Pre-stressed concrete slabs and grid floors. Pre-stressed concrete poles, pipes, sleepers, pressure vessels and pavements. Pre-stressed concrete for Bridges.	13
Total Number of Hours		36

7. Evaluation Plan

Sl No	Type of Evaluation	Weightage
1	Mid semester examination	30
2	Internal evaluation	20
3	End semester examination	50
Total		100

(CEL 2213) Advanced Steel Design and Composite Structures (3-0-0)

1. Course Descriptipon

Steel and steel-concrete composites are widely used in structures buildings, bridges, stadiums, towers and offshore structures. The analysis and design of such structures require a thorough understanding of the behaviour of structural members and systems. This course is intended to provide an integrated and comprehensive introduction to the analysis and design of steel and composite structures.

2. Learning Outcome

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

- understand the concept of the design of steel members
- understand the concept of plastic analysis of beams and frames
- understand the concept of analysis and design of steel-concrete composite members

3. Broad Course Outline

- Introduction, limit state design philosophy, material properties
- Plastic analysis of steel beams and frames
- Analysis and design of steel members under axial loading and bending
- Design of steel connections
- Analysis and design of composite slab, beam, column and connections

4. Textbooks

a) Qing Quan Liang, Analysis and Design of Steel and Composite Structures, CRC Press, 2015

5. References

a) Jones, RM, Mechanics of Composite Materials, taylor and Francis, 1999.

b) Vasiliev, V.V. and Morozov, E.V., 2013. Advanced mechanics of composite materials and structural elements. Newnes.

6. Sessional Plan

Sl. No.	Topic	Hours (Tentative)
1.	Introduction, limit state design philosophy, material properties	3
2.	Local buckling of thin steel plate: steel plate under uniform edge compression, steel plate under in-plane bending, steel plate in shear, steel plate under bending and shear, steel plate in bearing, steel plate in concrete-filled steel tubular column, double skin composite panels	3
3.	Steel member under bending	3
4.	Steel member under axial loading and bending	3
5.	Steel connections	3
6.	Plastic analysis of steel beams and frames: concept of plastic hinge and plastic moment, plastic collapse mechanisms, section capacity under axial load and bending	6
7.	Composite slab: component of composite slab, behaviour of composite slab, shear connections, moment and shear capacity, design considerations	4
8	Composite beams: component of composite beam, behaviour of composite beam, shear connections, moment and shear capacity, design considerations,	4
9	Composite columns: analysis and design of short composite columns, analysis and design of slender composite column	4
10	Composite connections: single plate shear connections, Tee shear connections, beam-column connections, semi rigid connections	3
	Total number of hours	36

7. Evaluation Plan

Sl No	Type of Evaluation	Weightage
1	Mid semester examination	30
2	Internal evaluation	20
3	End semester examination	50
Total		100

(CEL 2214) Risk and Reliability Analysis of Structural Systems (3-0-0)

1. Course Description

Variability and uncertainties are present in all engineering systems. In structural engineering, these uncertainties originate from environmental loads such as wind and earthquakes, scatter in properties of building materials etc. This course offers a mathematical framework to quantify these uncertainties.

2. Learning Outcome

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

- understand the concept of random variables and probability distributions
- understand the concept of methods of structural reliability based on reliability indices
- understand the concept of first- and second-order reliability methods (FORM and SORM)
- understand the concept of Monte Carlo simulations including variance reduction techniques and RSM
- understand the concept of code calibration.
- understand the concept of reliability-based design.
- understand the concept of stochastic FEM

3. Broad Course Outline

- Review of random variables and probability distributions
- Formulation of reliability for structural components and systems.
- Exact solutions and simulation-based methods
- Basis for probabilistic design codes
- Time-variant and finite element reliability methods
- Introduction to stochastic FEM

4. Textbooks

a) Melchers, R.E. and Beck, A.T., 2018. Structural reliability analysis and prediction. John wiley & sons.
b) Hines, W.W., Montgomery, D.C. and Borror, D.M.G.C.M., 2008. Probability and statistics in engineering. John Wiley & Sons.

5. References

a) Alfredo, H.S.A. and Wilson, H., 1975. Probability concepts in engineering planning and design. John Wily and Sons.
b) Breneman, J.E., Sahay, C. and Lewis, E.E., 2022. Introduction to reliability engineering. John Wiley & Sons.
c) Haldar, A., and Mahadevan, S. (2000). Reliability assessment using stochastic finite element analysis. John Wiley and Sons, New York.
d) J R Benjamin and C A Cornell, 1970, Probability, statistics and decisions for civil engineers, John Wiley, New York.

6. Sessional Plan

Sl. No.	Topic	Hours (Tentative)
1	Introduction, motivation and overview; Variability and uncertainty in structural systems	1
2	Review of random variables and probability distributions	3
3	Formulation of reliability for structural components and systems.	3
4	Exact solutions, first- and second-order reliability methods. Reliability indices.	4
5	Simulation-based methods. Variance reduction techniques.	4
6	Implicit performance function and response surface modelling.	3
7	Basis for probabilistic design codes. Reliability sensitivity measures. Systems reliability.	6
8	Stochastic load models and load combination.	3
9	Time-variant and finite element reliability methods.	3
10	Introduction to stochastic FEM.	6
	Total number of hours	36

7. Evaluation Plan

Sl No	Type of Evaluation	Weightage
1	Mid semester examination	30
2	Internal evaluation	20
3	End semester examination	50
Total		100

(CEL 2215) Fluid Structure Interaction **(3-0-0)**

1. Course Description

Fluid-structure interaction is encountered in many engineering problems ranging from tall bridges, nuclear plate assemblies, offshore platform/ risers, subsea pipelines, paper printing to micro-aerial vehicle, parachutes, airbags, blood flow in arteries, heart valves, and many more. This course is intended to provide a theoretical background of the fluid-structure interaction with particular emphasis on a few engineering problems of practical interest.

2. Learning Outcome

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

- understand the concept of sloshing in a solid container
- understand the concept of hydro-elasticity
- understand the concept of Lagrangian and Eulerian formulations
- understand the concept of acoustics and shock waves
- understand the concept of vortex-induced vibrations

3. Broad Course Outline

- Introduction and application areas
- Review of basics of structural dynamics and fluid dynamics
- Sloshing of liquid in a solid container
- Hydro-elasticity

- Lagrangian and Eulerian formulaions
- Acoustic basics
- Shock waves interacting with solids
- Vortex-induced vibration

4. Textbooks

a) Jean-Francois Sigrist, 2015. Fluid-Structure Interaction: An Introduction to Finite Element Coupling. Wiley Publications.

5. References

a) Modarres-Sadeghi, Y., 2022. Introduction to Fluid-Structure Interactions. Springer Nature.

b) Bazilevs, Y., Takizawa, K. and Tezduyar, T.E., 2013. Computational fluid-structure interaction: methods and applications. John Wiley & Sons.

c) Païdoussis, M.P., Price, S.J. and De Langre, E., 2010. Fluid-structure interactions: cross-flow-induced instabilities. Cambridge University Press.

6. Sessional Plan

Sl. No.	Topic	Hours (Tentative)
1.	Introduction and application areas Review of structural dynamics of continuous systems	3
2.	Basics of fluid dynamics and wave equations;	3
3.	Sloshing: Sloshing of fluids in rigid containers; Sloshing of fluids in rigid containers subjected to harmonic loads; Sloshing of fluids in elastic containers interacting with fluid	6
4.	Coupled and Partitioned systems (local and global partitions), simple examples	3
5.	Hydro-elasticity: coupled system approach; partitioned approach;	5
6.	Lagrangian formulations, Total and Updated Lagrangian; Eulerian formulations; Arbitrary Lagrangian-Eulerian formulation;	5
7.	Elastic interacting solid fully submerged in fluid; Elastic interacting fluid partially submerged in fluid;	5
8.	Acoustic basics; Shock waves interacting with solid	3
9.	Vortex induced vibration	3
	Total number of hours	36

7. Evaluation Plan

Sl No	Type of Evaluation	Weightage
1	Mid semester examination	30
2	Internal evaluation	20
3	End semester examination	50
Total		100