Appendix-

DEPARTMENT OF CIVIL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

Program Code: **20** **M. Tech. (Structural Engineering)**
Department: **CE** **Civil Engineering**
Year: **I**

Teaching Scheme					Contact Hours/Week			Exam Duration		Relative Weight (%)				
S. No.	Subject Code	Course Title	Subject Area	Credits	L	T	P	Theory	Practical	CWS	PRS	MTE	ETE	PRE
Semester- I (Autumn)														
1.	CEN-541	Matrix Structural Analysis	PCC	4	3	-	2	3	-	15	25	20	40	-
2.	CEN-542	Continuum Mechanics	PCC	4	3	1	-	3	-	25	-	25	50	-
3.	CEN-543	Advanced Concrete Design	PCC	4	3	-	2	3	-	15	25	20	40	-
4.	CEN-544	Structural Dynamics	PCC	4	3	1	-	3	-	25	-	25	50	-
5.		Programme Elective-1	PEC	4	-	-	-	-	-	-	-	-	-	-
		Total		20										
Semester-II (Spring)														
1.	CEN-545	Finite Element Analysis	PCC	4	3	-	2	3	-	15	25	20	40	-
2.	CEN-700	Seminar	SEM	2	0	0	2	-	-	-	-	-	100	-
3.		Programme Elective-II	PEC	4	-	-	-	-	-	-	-	-	-	-
4.		Programme Elective-III	PEC	4	-	-	-	-	-	-	-	-	-	-
5.		Programme Elective-IV	PEC	4	-	-	-	-	-	-	-	-	-	-
		Total		18										

DEPARTMENT OF CIVIL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

Program Code: **20** **M. Tech. (Structural Engineering)**
Department: **CE** **Civil Engineering**
Year: **II**

Teaching Scheme					Contact Hours/Week			Exam Duration		Relative Weight (%)				
S. No.	**Subject Code**	**Course Title**	**Subject Area**	**Credits**	**L**	**T**	**P**	**Theory**	**Practical**	**CWS**	**PRS**	**MTE**	**ETE**	**PRE**
Semester- I (Autumn)														
1.	CEN-701A	Dissertation Stage–I (to be continued next semester)	DIS	12	-	-	-	-	-	-	-	-	100	-
		Total		12										
Note: Students can take 1 or 2 audit courses as advised by the supervisor, if required.														
Semester-II (Spring)														
1.	CEN-701B	Dissertation Stage–II (contd. From III semester)	DIS	18	-	-	-	-	-	-	-	-	100	-
		Total		18										

Summary				
Semester	1	2	3	4
Semester-wise Total Credits	**20**	**18**	**12**	**18**
Total Credits	**68**			

Program Elective Courses (Structural Engineering)

Teaching Scheme					Contact Hours/Week			Exam Duration		Relative Weight (%)				
S. No.	Subject Code	Course Title	Subject Area	Credits	L	T	P	Theory	Practical	CWS	PRS	MTE	ETE	PRE
1.	CEN-521	Advanced Numerical Analysis (Autumn)	PEC	4	3	-	2	3	-	15	25	20	40	-
2.	CEN-641	Behaviour & Design of Steel Structures (Autumn)	PEC	4	3	-	2	3	-	15	25	20	40	-
3.	CEN-642	Analysis and Design of Bridges	PEC	4	3	-	2	3	-	15	25	20	40	-
4.	CEN-643	Analysis and Design of High rise Buildings	PEC	4	3	-	2	3	-	15	25	20	40	-
5.	CEN-644	Analysis and Design of Plates and Shells	PEC	4	3	-	2	3	-	15	25	20	40	-
6.	CEN-645	Mechanics of Composites	PEC	4	3	1	-	3	-	25	-	25	50	-
7.	CEN-646	Engineering Design Optimization and Reliability	PEC	4	3	-	2	3	-	15	25	20	40	-
8.	CEN-647	Condition Assessment and Retrofitting of Structures	PEC	4	3	-	2	3	-	15	25	20	40	-
9.	CEN-648	Concrete Technology	PEC	4	3	-	2	3	-	15	25	20	40	-
10.	CEN-649	Fracture Mechanics in Quasi-Brittle Materials	PEC	4	3	1	-	3	-	25	-	25	50	-
11.	CEN-650	Design of Bridge Sub-structure	PEC	4	3	-	2	3	-	15	25	20	40	-
12.	CEN-651	Wind Engineering	PEC	4	3	-	2	3	-	15	25	20	40	-

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-541** Course Title : **Matrix Structural Analysis**
2. Contact Hours : **L: 3** **T : 0** **P: 2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **04** 6. Semester: **Autumn** 7. Subject Area : **PCC**
8. Pre-requisite: **Nil**
9. Objective: To equip students with different methods of linear and non-linear analysis using matrix approach and expose them to write small utility programs and use of commercial packages for computer aided analysis of common 2D and 3D structures

10. Details of Course:

S. No.	Contents	Contact Hours
1	Basic methods of analysis, different indeterminacies, stiffness and flexibility approach	04
2	Flexibility method using member approach	06
3	Stiffness matrix for prismatic, non-prismatic and curved members, shear deformations	08
4	Linear analysis of different 2D and 3D structures	08
5	Techniques for enhancing computing power: solution algorithm, substructuring	04
6	Non linear analysis: types and different techniques, convergence criteria	08
7	Development of codes and introduction to different software packages	04
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publisher	Year of Publication/ Reprint
1	William Weaver Jr & James M Gere, “Matrix Analysis of Framed Structures”, 2nd Ed., CBS Publishers, New Delhi	1986
2	Madhu B Kanchi, “Matrix Methods of Structural Analysis”, 2nd Ed., Wiley Eastern Ltd.	1993
3	Majeed K I, “Non Linear Structure Analysis”, Butterworth Ltd. London.	1973

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-542** Course Title : **Continuum Mechanics**
2. Contact Hours : **L: 3** **T : 1** **P: 0**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS :25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits : **04** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**

9. Objective of Course : To impart to students the basic knowledge in theory of vibrations and behaviour of soils under dynamic loads so that foundations for various types of machines could be designed.

10. Details of Course :

S. No.	Contents	Contact Hours
1.	Vector and Tensors Algebra, Lineariziation and Directional Derivatives, Stress and Equilibrium, Analysis for Stresses, Translational and Rotational Equilibrium, Principal Stresses and Principal Planes in 3D, Stress Invariants, Cauchy and Kirchhoff Stress Tensor, Deviatoric and Volumetric Components, Work Conjugancy, Octahedral and von-Mises stresses.	
2.	Kinematics, Linearized Kinematics, Strain Quadric of Cauchy, Principal Strains, Invariants, Equations of Compatibility, Finite Deformation, Material (Lagrangian) and Spatial (Eulerian) Descriptions, Deformation Gradient, Polar Decomposition, Volume change, Distortional Component of Deformation Gradient, Area Change.	
3.	Equations of Elasticity,Hooke's Law, Generalized Hooke's Law, Anisotropic, Orthotropic and Isotropic Elasticity Tensor, Plane Stress and Strain Problems, Airy Stress Functions for Two-Dimensional Problems, Airy Stress Function in Polar Coordinates, Isotropic Hyper elasticity, Three-Dimensional Elasticity.	
4.	Elasto-Plastic Behavior of Material, Elasto-Plastic Formulations, Material Yield Criteria- von Mises, Tresca, Mohr-coulomb, Ducker-Pager, Isotropic and Kinematic Hardening, Normality Principle, Plastic Flow Rule, Plastic Potential, Elasto-Plastic Stress-Strain Relations, Prandtl-Rauss Equations, Levy-Mises Relations, Hardening Modulus, Generalized Elasto-Plastic Stress-Strain Relations	
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Finite element analysis in Geotechnical Engineering theory, By David M Potts and Lidija Zdravkovic, Thomas Telford	1999
2.	Mechanics of Materials and Interfaces: The Disturbed State Concept, By C S Desai, CRC Press LLC	2000
3.	Mechanics of Geomaterial Interfaces, By A.P.S. Selvadurai, M.J. Boulon, Elsevier	1995

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-543** Course Title : **Advanced Concrete Design**
2. Contact Hours : **L: 3** **T : 0** **P: 2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **04** 6. Semester: **Autumn** 7. Subject Area : **PCC**
8. Pre-requisite: **Nil**
9. Objective: To give a consistent and sound theoretical background to the force and stress distributions in reinforced and pre-stressed concrete. To introduce the concepts of yield line analysis, strut-tie models and other state of art analysis techniques and to connect these with the extant design ideologies in the building codes. To study advanced concepts of creep/rheology & crack widths in reinforced and prestressed concrete and creating numerical models of these. To develop a clear theoretical understanding of the underlying reasons behind codal details as ductile detailing, reinforcement placement etc.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Plastic Section Theory for Reinforced Concrete including interaction of flexure-Shear-Axial effects	5
2.	Upper bound and lower bound plastic theorems	2
3.	Application of plastic analysis to frames – instantaneous centre of rotations	4
4.	Introduction to Pushover Analysis	3
5.	Introduction to Strut-Tie Models	2
6.	Strut-Tie Models for Deep Beams, Beam-Column Joints& Shear walls	5
7.	Introduction to Yield line analysis and application for slabs, raft foundations etc.	4
8.	Introduction to Pre-stressed concrete and behaviour for simple elements	8
9.	Modelling of creep/shrinkage and long term effects for RCC and prestressed concrete	5
10.	Calculation of crack widths and crack control designs	4
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Reinforced Concrete: Mechanics and Design, 6th Ed., McGregor & White	2011
2.	Reinforced Concrete: A Fundamental Approach, 6th Ed., Edward Nawy	2008
3.	Design of Prestressed Concrete, 2nd Ed., Arthur H. Nilson	1987
4.	Darwin & Dolan, “Design of Concrete Structures”, 14th Ed., Nilson,	2009
5.	Prestressed Concrete: A Fundamental Approach, 5th Ed., Edward Nawy	2005
6.	J Schlaich, K Schaefer, and M. Jennewin, “Toward a Consistent Design of Structural Concrete”, PCI Journal V. 32, No. 2, pp. 72-150.	1987
7.	Kennedy & Goodchild, “Practical Yield Line Design”, The Concrete Centre, TCC/03/3.	2004

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-544** Course Title : **Structural Dynamics**
2. Contact Hours : **L: 3** **T : 1** **P: 0**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits : **04** 6. Semester: **Autumn** 7. Subject Area : **PCC**
8. Pre-requisite: **Nil**
9. Objective: To understand the response of structures to earthquakes requires study of structural dynamics. Therefore, Single Dynamic Degree of Freedom Systems are first introduced, then two and three DOF system are covered. Finally the earthquake effects on structures are covered.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Overview of Structural Dynamics, Single Degree of Freedom Systems – Analysis of Free Vibrations – undamped and damped systems, estimation of damping by logarithmic decrement method.	3
2.	Formulation of equation of motion for generalized SDOF dynamic problems using virtual work method.	3
3.	Response of SDOFS systems to Harmonic, Periodic, Impulse Loads	3
4.	Formulation of equation of motion for two/three DOF systems. Finding mode shapes and frequencies by solving the determinantal equation, and iterative techniques. Use of sweeping matrices for obtaining higher modes. Proof of Convergence. Modal superposition and Response Spectrum Methods.	12
5.	Response of single and multiple DOFS systems to Earthquake Loading using Time-Stepping Methods based on Forward Cauchy Euler, Backward Cauchy Euler and Trapezoidal Rule. Accuracy, stability and algorithmic dampingin step-by-step methods.	6
6.	Earthquake response analysis of Multi-DOF systems subjected to earthquake ground motion. Concept of modal mass and mode participation factors, etc.	6
7.	Newark & Hall's linear and inelastic response spectra for earthquakes	6
6.	Introduction to IS code provisions regarding earthquake.	3
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Ray W. Clough & Penzien, "Dynamics of Structures", Mc Graw Hill.	1993
2.	Anil Chopra, "Dynamics of Structures ", Mc Graw Hill.	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-545** Course Title : **Finite Element Analysis**
2. Contact Hours : **L: 3** **T : 0** **P: 2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weightage : **CWS : 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **04** 6. Semester: **Spring** 7. Subject Area : **PCC**
8. Pre-requisite: **Nil**
9. Objective: To introduce the concept of domain discretisation and a variational framework of the equations of mechanics. Application of these methodologies to a wide range of engineering problems and connection with the laws of continua.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Basic Concepts, Discretization; Displacement, Force and Hybrid Models	02
2.	Interpolation Functions for General Element Formulations: Compatibility and Completeness, Polynomial Forms: One Dimensional Elements, Geometric Isotropy, Triangular Elements, Rectangular Elements, Three Dimensional Elements, Isoperimetric Formulations, Axisymmetric Elements; Numerical Integration.	08
3.	Applications in Solid Mechanics: Plane Stress/Strain: FE Formulation: CST, LST; Stiffness Matrix, Load Matrix Formation Rectangular Element Isoparametric Formulation: Plate Elements and Shell Elements, Three Dimensional Elements FE Formulation: Axisymmetric Stress Analysis, Torsion, Interface Elements, Infinite Elements	08
4.	Application in Structural Dynamics and Vibrations: Mass (Consistent and Diagonal) and Damping Matrices; Modal Analysis, Time History Analysis, Explicit Direct Integration/ Implicit Direct Integration and Mixed Methods.	06
5.	Introduction to Nonlinear Problems: Geometric and Material (Elasto-plastic), Solution Methods: Newton Ralphson Method, Modified Newton-Ralphson Method, Arc Method, A Problem of Geometric Nonlinearity.	08
6.	Stationary Principles, Rayleigh Ritz Method and Interpolation; Weighted Residual Methods and Variational Methods, Numerical Errors and Convergence	06
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	David Hutton, “Fundamentals of Finite Element Analysis”, Tata McGraw Hill	2005
2.	R. D. Cook, Malkus and Plesha, “Concepts and Applications of Finite Element Analysis”, 3rd Ed., John Wiley.	1989
3.	T. J. R. Hughes, “The Finite Element Method : Linear Static and Dynamic Analysis”, Prentice Hall.	1987
4.	Klaus Juergen Bathe, “Finite Element Procedures”, Prentice Hall of India.	2003
5.	O. C. Zienkiewicz., R. L. Taylor & J. Z. Zhu., “The Finite Element Method Its Basis & Fundamentals”, Elsivier Publications.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-641** Course Title : **Behaviour and Design of Steel Structures**
2. Contact Hours : **L: 3** **T : 0** **P: 2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **04** 6. Semester: **Autumn** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**

9. Objective: To introduce basic concepts of stability of structures and illustrate it's application in thin walled structures along with advanced topics in analysis and design of steel structures

10. Details of Course:

S. No.	Contents	Contact Hours
1	Concepts of Stability, Introduction to Buckling Behaviour of Columns	03
2	Stability ofBeam-Columns and Frames	03
3	Lateral Instability of Beams	03
4	Local Buckling and Post Buckling Behaviour of Plates	03
5	Behaviour and Design of Cold Formed Thin Walled Structures Subjected to Flexure and Compression	10
6	Plastic Analysis and Design of Steel Structures, LRFD approach	04
7	Advanced Topics in Bolted and Welded Connections	05
8	Behaviour of Steel Concrete Composite Construction and Introduction to Brittle Fracture and Fatigue.	03
9	Design of Steel Truss Bridges	08
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	S.P. Timoshenko and J.M. Gere, "Theory of Elastic Stability" McGraw-Hill.	1963
2	A.S. Arya and J.L. Ajmani, "Design of Steel Structures" Nem Chand & Bros.	2000
3.	N. Subramanian, "Design of Steel Structures", Oxford University Press.	2008
4.	M.L. Gambhir, "Stability Analysis and Design of Structures", Springer.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-642** Course Title : **Analysis and Design of Bridges**
2. Contact Hours : **L: 3** **T : 0** **P: 2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective: To introduce bridge deck behavior with the help of classical and numerical analysis approaches and impart knowledge needed for design of R.C. and pre-stressed concrete bridges.

10. Details of Course:

S. No.	Contents	Contact Hours
1	Structural Forms and Design Loads for Bridges	03
2	Effective Width Concept and Load Distribution in Multi-Beam Bridges	05
3	Grillage Analogy	03
4	Design of R.C. and Pre-Stressed Concrete Slab Bridges	06
5	Design of R.C. and Pre-Stressed Concrete Girder Bridges	09
6	Behaviour of Box-Girder Bridges, Introduction to Arch Bridges, Suspension and Cable Stayed Bridges	09
7	Different Types of Bearings and Design of Elastomeric Bearings	03
8	Introduction to Secondary Effects, Temperature, Shrinkage, Creep. Construction Techniques and Effects of Construction Sequence on Design.	04
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1	N. Rajagopalan, “Bridge Superstructure”, Narosa Publishing House.	2010
2.	D.J. Victor, “Essentials of Bridge Engineering” Oxford & IBH Publishing.	2001
3.	Code of Practice for Concrete Road Bridges - IRC:112-2011, Indian Road Congress.	2011
4.	Standard Specifications and code of Practice for Bridges, Section II- Loads and Stresses - IRC:6-2010, Indian Road Congress.	2010
5.	E.C. Hambly, “Bridge Deck Behaviour”, Chapman and Hall, London.	1976

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-643** Course Title : **Analysis and Design of High-Rise Buildings**
2. Contact Hours : **L: 3** **T : 0** **P: 2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective: To introduce the analysis and design of tall buildings subjected to different loading conditions and detailing of various components.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Structural systems for multi-storey buildings, gravity and lateral loads on buildings, analysis of multi-storey frames. Behaviour of framed tube, tube-in-tube systems, and bundled tube systems	6
2.	Importance of symmetry and regularity in plan, and regularity in elevation. Analysis for torsion in buildings	6
3.	Design of buildings with shear walls and coupled shear walls	6
4.	Design and detailing of various members and beam-column joints for ductility. The capacity design principle. Performance based design philosophy	6
5.	Design of floor slabs, raft and pile foundations	9
6.	Application of MS-Excel, ETABS and SAFE software	9
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	U.H.Varyani, "Structural Design of Multi-storeyed Buildings", 2nd Ed., South Asian Publishers, New Delhi.	2002
2.	V.L. Shah & S.R.Karve, "Illustrated Design of Reinforced Concrete Buildings", (GF+3storeyed), Structures Publications, Pune.	2013
3.	Design of Multi Storeyed Buildings, Vol. 1 & 2, CPWD Publications.	1976
4.	Bungale S. Taranath, "Structural Analysis and Design of Tall Buildings", Mc-Graw Hill.	1988
5.	Bryan S. Smith and Alex Coull, "Tall Building Structures", Wiley India.	1991
6.	Wolfgang Schueller, "High Rise Building Structures", Wiley.	1986

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-644** Course Title : **Analysis and Design of Plates and Shells**
2. Contact Hours : **L: 3** **T : 0** **P: 2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective: To analyze and design of plate and shell structures
10. Details of Course:

S. No.	Contents	Contact Hours
1	Classification of Plates	01
2	Governing Equations	03
3	Boundary Conditions	01
4	Analysis of Rectangular and Circular Plates	08
5	Grid Floor as Orthotropic Plate	03
	Buckling of Plates	01
	Design Criteria and Code Specification	02
	Classification of Shells	01
6	Membrane Theory for Shells of Revolution with Axisymmetric and Non-Axisymmetric Loadings	04
7	Bending Analysis of Shells of Revolution for Axisymmetric Loadings	02
8	Membrane and Bending Theories of Cylindrical Shells	03
9	Theory of Edge Beams	02
10	Doubly Curved Shells	02
11	Membrane Theory and Design of Hyperbolic Shells	02
12	Buckling of Shells	01
13	Design Applications, Analysis and Design of Folded plates, Cooling towers, Silos and Bunkers,	04
14	Codal Specifications, Practical Considerations, Computer Applications	02
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	S.P. Timoshenko and S. Woinowsky-Krieger, "Theory of Plates and Shells", 5th Ed., McGraw- Hill.	1959
2.	J.N. Reddy, "Theory and Analysis of Elastic Plates", 2nd Ed., Taylor & Francis.	2006
3.	B.K. Chatterjee, "Theory and Design of Concrete Shells", 3rd Ed., Chapman and Hall.	1988
4.	V.S. Kelker and R.T. Sewell, "Fundamentals of the Analysis and Design of Shell Structures", 1st Ed., Prentice Hall.	1987
5.	R. Szilard, "Theory and Analysis of Plates : Classical and Numerical Methods, 1st Ed., Prentice Hall.	1973

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-645** Course Title : **Mechanics of Composites**
2. Contact Hours : **L: 3** **T : 1** **P: 0**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**

9. Objective: To analyze and design Laminated composite structures

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Introduction-Classification and Characteristics of Composite Materials, Basic Terminology, Uses of Fibrous Composites	02
2.	Behaviour of Lamina Stress-Strain Relationship for Anisotropic, Orthotropic and Isotropic Material.	04
3.	. Transformation of Elastic Constants	02
4.	Failure Criteria for an Orthotropic Lamina	02
5.	Introduction to Micromechanics: Laws of Mixture	03
6.	Behavior of Laminate: Classical Lamination Theory, Stress-Strain Relationship for a Laminate, Extensional, Bending and Coupling Stiffness, Different Configurations and Corresponding Stiffness	06
7.	Strength of Laminates	02
8.	Inter-laminar Stresses	02
9.	Shear Deformation Theories	02
10.	Behaviour and Analysis of Laminated Plates Subjected to Bending, Buckling and Vibrations	07
11.	Thin Walled Laminated Structures and Sandwich Constructions	03
12.	Behaviour of laminated composite Joints	03
13.	Examples on Practical Applications	04
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	R.M. Jones, "Mechanics of Composite Materials", 2nd Ed., Taylor & Francis.	1998
2.	I.M. Daniel & Ori Ishai, "Engineering Mechanics of Composite Materials", 2nd Ed., Oxford University Press.	2013
3.	Autar K. Kaw, "Mechanics of Composite Materials", 2nd Ed., CRC Press.	2005
4.	R.F. Gibson, "Principles of Composite Mechanics", 2nd Ed., CRC Press.	2007
5.	B.D. Agarwal, L.J. Broutman, L.J. Broutman, "Analysis and Performance of Fibre Composites", 2nd Ed., John Wiley.	1990

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-646** Course Title : **Engineering Design Optimization and Reliability**
2. Contact Hours : **L: 3** **T : 0** **P: 2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**

9. Objective: This course is designed to introduce graduate students to concepts and applications of structural reliability and design optimization. Upon completion of this course, students will be able to: (a) Compute first- and second-order estimates of failure probabilities of engineered systems; (b) Compute sensitivities of failure probabilities to assumed parameter values; (c) Measure the relative importance of the random variables associated with a system; (d) Update reliability estimates based on new observational data; (e) Identify the relative advantages and disadvantages of various analytical reliability methods, as well as Monte Carlo simulation; (f) Use reliability tools to calibrate simplified building codes

10. Details of Course:

S. No.	Contents	Contact Hours
	Introduction to Design Optimization; Optimal Design Problem Formulation; Graphical Optimization and Basic Concepts	3
	Optimum Design Concepts: Optimality Conditions; Optimal Design with MATLAB	5
	Numerical Methods for Unconstrained Design Optimization; Numerical Methods for Constrained Design Optimization; Practical Applications of Optimization	8
	Genetic Algorithm for Optimum Design; Multi-objective Optimum Design Concepts and Methods	8
	Fundamentals of probability theory; Common probabilistic models	2
	General component reliability; First-order second-moment methods; First and Second-order reliability method	9
	Importance measures and parameter uncertainty; Sampling techniques; Surrogate Modelling	4
	Development of reliability based design codes; System reliability	3
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Jasbir S. Arora, "Introduction to Optimum Design", 3rd Ed., Academic Press.	2012
2.	Achintya Halder and Sankaran Mahadevan, "Probability, Reliability, and Statistical Methods in Engineering Design", John Wiley.	2000
3.	O. Ditlevsen, and H. O. Madsen, "Structural Reliability Methods", Internet Edition 2.3.7, John Wiley. http://www.web.mek.dtu.dk/staff/od/books.htm	2007
4.	A.H.S. Ang and W. H. Tang, "Probability Concepts in Engineering Planning and Design", Vol. I : Basic Principles, Wiley.	1975
5.	R. E. Melchers, "Structural Reliability Analysis and Prediction", 2nd Ed., Wiley.	1999

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-647** Course Title : **Condition Assessment and Retrofitting of Structures**
2. Contact Hours : **L: 3** **T : 0** **P: 2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**

9. Objective: To introduce the application of different techniques for evaluation and retrofitting of buildings

10. Details of Course:

S. No.	Contents	Contact Hours
1	Deterioration of Concrete Buildings: Embedded Metal Corrosion, Disintegration Mechanisms, Moisture Effects, Thermal Effects, Structural Effects, Faulty Construction	08
2	Evaluation of Concrete Buildings: Visual Investigation, Destructive Testing Systems, Non-Destructive Testing Techniques, Semi-Destructive Testing Techniques, Chemical Testing.	08
3	Surface Repair & Retrofitting Techniques: Strategy & Design, Selection of Repair Materials, Surface Preparation, Bonding repair Materials to Existing concrete, Placement Methods,	08
4	Epoxy Bonded Replacement Concrete, Preplaced Aggregate Concrete, Shotcrete/ Gunite, Grouting, Injection Grouting, Micro concrete.	06
5	Strengthening Techniques: Strengthening Techniques, Beam Shear Capacity Strengthening, Shear Transfer Strengthening between Members, Column Strengthening, Flexural Strengthening, and Crack Stabilization	08
6	Guidelines for Seismic Rehabilitation of Existing Buildings, Seismic Vulnerability and Strategies for Seismic Retrofit.	04
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1	Emmons, P.H., “Concrete Repair and Maintenance”, Galgotia Publication.	2001
2	Bungey, S., Lillard, G. and Grantham, M.G., “Testing of Concrete in Structures”, Taylor and Francis.	2001
3	Malhotra, V.M. and Carino, N.J., “Handbook on Non-destructive Testing of Concrete”, CRC Press.	2004
4	Bohni, H., “Corrosion in Concrete Structures”, CRC Press.	2005
5	FEMA 273; NEHRP Guidelines for the Seismic Rehabilitation of Buildings.	1997
6	ATC- 40: Seismic Evaluation and Retrofit of Concrete Buildings, Vol. 1 & 2.	1997
7	M.J.N., Seible, F. and Calvi, G.M., “Seismic Design and Retrofit of Bridges by Priestley”, John Wiley.	1996

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-648** Course Title : **Concrete Technology**
2. Contact Hours : **L: 3** **T : 0** **P: 2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective : The objective of this course is to provide detailed knowledge about concrete and its composition.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	Ingredients of Concrete: Review of Cements including Blended Cements, Manufacture, Chemical Composition, Aggregates: Review of Types; Elementary Mineralogy and Petrology; Sampling and Testing; Effects on Properties of Concretes, Chemical and Physical Processes of Hydration. Mineral Admixtures: Pulverized Fly Ash, Ground Granulated Blast Furnace Slag and Silica Fume; Chemical Composition,Physical Characteristics,Chemical and Physical Processes of Hydration and Interaction,Effects on Properties of Concretes.	8
2.	Admixtures:Review of Types and Classification, Chemical Composition,Effects on Properties of Concretes.	2
3.	Fresh-Concrete: Rheology of Mortars and Concretes; Workability, Segregation and Bleeding, Theory and Principles governing the correct transportation, Placing, Compaction and Curing of Concrete. Plastic Settlement and Plastic Shrinkage,Exothermic Characteristics:Early Age Thermal Movements,Strength Development,Maturity, Accelerated Curing,Hot and Cold Weather Concreting.	8
4.	Properties of Hardened Concrete: Strength,Deformation under Load,Elasticity,Creep,Drying Shrinkage and other volume Changes. Thermal Properties.	5
5.	Durability of Concrete and Concrete Construction: Durability Concept,Pore Structure and Transport Processes,Reinforcement Corrosion, Fire Resistance,Frost Damage, Sulfate Attack,Alkali Silica Reaction,Methods of Providing Durable Concrete.	7
6.	Concrete Mix Design: The process of Mix Selection, Factors governing the selection of Mix Proportions, Combining Aggregates to obtain Specified Grading, Different Methods of Mix Design, Concepts of Statistical Quality Control of Concrete Construction.	6
7.	Special Concretes: Lightweight Concrete,No-Fines Concrete, High Performance Concrete,High Density and Radiation-Shielding Concrete,Polymer Concrete,Fibre-Reinforced Concrete,Self Compacting Concrete, Roller Compacted Concrete, High Volume Fly Ash Concrete, Ready Mixed Concrete.	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	A.M. Neville and J.J. Brooks, “Concrete Technology”, 1st Ed.	2002
2.	P.K. Mehta and Paulo J.M. Monteiro, “Concrete: Microstructure, Properties and Materials”, 3rd Ed.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-649** Course Title : **Fracture Mechanics in Quasi-brittle Materials**
2. Contact Hours : **L: 3** **T : 1** **P: 0**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective: To introduce the mechanics of fracture and their applications to anisotropic and heterogeneous quasi-brittle materials
10. Details of Course:

S. No.	Contents	Contact Hours
1	**Basic concepts:** Basic modes of fracture, Elasticity solution to infinite and finite plate with a crack: Westergaard complex function and Muskhelishvili potential, Effect of free boundary, 3-Dimensional crack problems	5
2	**Linear elastic fracture mechanics(LEFM) based design concepts:** Energy release rate, Griffith's energy balance criterion, Crack resistance, Stress intensity factors, Small scale yielding, plastic zone corrections	6
3	**Elastic plastic fracture mechanics (EPFM) based design concepts:** J-integral, Crack tip opening displacement, Crack growth resistance concepts	3
4	**Introduction to fracture mechanics in Quasi-brittle material:** Trends in Fracture of quasi-brittle materials, Fracture process zone, Size effect: Sources, experimental evidence, statistical and energetic size effect	6
5	**Non-linear fracture mechanics:** Fictitious and Effective elastic crack approach, Nonlocal continuum modelling of damage localization	4
6	**Application of fracture mechanics to concrete structures:** Size effect on nominal strength, Tension of reinforced concrete members, Bending of reinforced concrete members, Shear in reinforced concrete beams, Fibre-reinforced concrete, Bi-material interface, Concrete dams	8
7	**Fatigue and fracture in concrete:** Introduction, Conventional methods of fatigue analysis, Fatigue crack propagation approach, Crack propagation models for constant and variable amplitude loading, Overload effect, Crack closure	5
8	**Finite elements in fracture mechanics:** Modelling of crack tip singularity, Approaches for the extraction of stress intensity factor, Discrete and smeared crack approach, Application to problems of LEFM and EPFM	5
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1	Broek, D.,Springer, "Elementary Engineering Fracture Mechanics", 3rd Ed.,.	1982
2	Kumar, P., "Elements of Fracture Mechanics", Wheeler Publishing.	1999
3	Anderson, T.L., "Fracture Mechanics: Fundamentals and Applications", 3rd Ed., CRC Press.	2005
4	Shukla, A., "Practical Fracture Mechanics in Design", 2nd Ed., CRC Press.	1989
5	Shah, S. P., Swartz, S. E. and Ouyang, "Fracture Mechanics of Concrete: Applications to Concrete, Rock and other Quasi-brittle Materials", C., John Wiley.	1995
6	Bazant, Z. P., and Planas, J., "Fracture and Size Effect in Concrete and Other Quasi-brittle Materials", CRC Press.	1997

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-650** Course Title : **Design of Bridge Substructures**
2. Contact Hours : **L: 3** **T : 0** **P: 2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**

9. Objective: To introduce the behaviour and design of bridge substructures.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Hydraulic calculations related to bridge design	04
2.	Analysis and design of piers and pier caps	06
3.	Seismic restrainers	01
4.	Analysis and design of abutments	04
5.	Analysis and design of well foundations	15
6.	Analysis and design of pile foundations	12
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Vijay Singh, “Wells and Cassions” Nem Chand & Sons.	1981
2.	S. Saram, “Analysis and Design of Substructures”.	2012
3.	Ponnuswamy, “Bridge Engineering”.	1986
4.	D. J. Victor, “Essentials of Bridge Engineering”.	2001
5.	Rakshit, “Design and Construction of Highway Bridges”.	2004

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-651** Course Title : **Wind Engineering**
2. Contact Hours : **L: 3** **T : 0** **P: 2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective: To introduce the theoretical and experimental approaches available to analyze the effect of wind loading on various wind sensitive structures

10. Details of Course:

S. No.	Contents	Contact Hours
1	Atmospheric Pressure and Gradient Wind, Wind Climate and Structure, Peak 3-sec, 10 min and Hourly Mean Wind Speeds. Low Cycle Energy and Large Scale Pressure Systems, Wind Energy and Turbulence, Spectral Distribution and Boundary Layer (ABL) & its Characteristics.	07
2	Aerodynamics of Bluff Bodies, Vortex Shedding and Associated Unsteady Along and Across Wind Forces. Peak Factor and Gust factor Estimation. Buffeting and Ovalling, Galloping and Flutter. Extreme Winds, Correlation and Spectral Function.	07
3	Random Vibration Theory, Auto Correlation Function, Power Spectral Density, Narrow and Wide Band Random Processes. Response of SDF in the Frequency Domain to Random Excitation. Application to MDF Systems.	06
4	Experimental Procedures for Response Studies. Wind Tunnel and its Salient Features, ABL Simulation. Basic Wind Tunnel Instrumentation for the Measurement of Flow Parameters, Forces, Displacements and Strains. Use of Statistical Methods for the Analysis of Measured Data and its Interpretation. Analytical Procedures for Along Wind and Across Wind Forces.	08
5	Wind Effects on Buildings, Chimneys, Towers and Bridges. Pressure Coefficients and Internal Pressures, Case Studies.	08
6	Codal Provisions, Design Wind Velocities, Wind Resistant Design- Indian Codes and other International Codes of Practice.	06
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1	E. Simiu and R.H. Scanlan, “Wind Effects on Structures”, Wiley.	1996
2	E. Simiu and T. Miyata, “Design of Buildings and Bridges for Wind”, Wiley.	2006
3	J.D. Holmes, “Wind Loading on Structures”, F & FN Spon.	2001