CURRICULUM AND DETAILED SYLLABI

FOR

M.TECH DEGREE PROGRAMME

IN

CIVIL ENGINEERING

STRUCTURAL ENGINEERING

SEMESTERS I TO IV

2020 SCHEME
(AUTONOMOUS)

MAR BASELIOS COLLEGE OF ENGINEERING AND TECHNOLOGY

(Approved by AICTE, Autonomous Institution Affiliated to APJ Abdul Kalam Technological University)

MAR IVANIOS VIDYANAGAR, NALANCHIRA, THIRUVANANTHAPURAM – 695015, KERALA.

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MAR BASELIOS COLLEGE OF ENGINEERING AND TECHNOLOGY

Vision and Mission of the Institution

Vision:

To be an Institution moulding globally competent professionals as epitomes of Noble Values.

Mission:

To transform the Youth as technically competent, ethically sound and socially committed professionals, by providing a vibrant learning ambience for the welfare of humanity.

DEPARTMENT OF CIVIL ENGINEERING

Vision and Mission of the Department

Vision:

To be a Centre of Excellence in Civil Engineering education with a global perspective, creating ethically strong engineers for the service of society.

Mission:

To provide Engineering Education which can create exemplary professional Civil Engineers of high ethics with strong conceptual foundation coupled with practical insight, to serve the industry and community.

DEPARTMENT OF CIVIL ENGINEERING

M.Tech. Structural Engineering

For the students admitted from 2020-21

Scheduling of Courses

i) Knowledge Segments and Credits

Every course of M. Tech Programme is placed in one of the seven categories as listed in Table 1 below. No semester shall have more than six lecture-based courses and two laboratory courses, and/or drawing/seminar/project courses in the curriculum.

Table 1: Credit distribution and the Knowledge Domains

Sl. No.	Category	Category Code	Number of Courses	Total Credits
1	Programme Core Courses	PCC	7	24
2	Laboratory Courses		2	2
3	Programme Elective Courses	PEC	5	15
4	Mandatory Credit Course (Research Methodology)	MCC	1	2
5	Seminar	PWS	2	4
6	Mini Project		1	2
7	Project		2	18
		Total Mandatory Credits		**67**

*Note: 67 credits have been the requirement for award of degree in all M.Tech Programmes of the College which was approved by the University.

ii) Semester-wise Credit Distribution

Semester	**I**	**II**	**III**	**IV**	**Total Credits**
Credits for Courses	22	19	14	12	**67**

Semester I							
Slot	**Category Code**	**Course Number**	**Course Name**	**L**	**T**	**P**	**Credit**
A	PCC	CE1P60A	Advanced Numerical Methods	3	0	0	3
B	PCC	CE1P60B	Theory of Elasticity	3	1	0	4
C	PCC	CE1P60C	Structural Dynamics	3	1	0	4
D	PCC	CE1P60D	Advanced Theory and Design of RC Structures	3	0	0	3
E	PEC	CE1PXXX	Elective I	3	0	0	3
S	MCC	MC0P60A	Research Methodology	0	2	0	2
T	PCC	CE1P68A	Structural Engineering and Computational Lab	0	0	2	1
U	PWS	CE1P69A	Seminar I	0	0	2	2
Total				**15**	**4**	4	**22**

ELECTIVE I

Slot	Category Code	Course Number	Course Name	L	T	P	Credit
E	PEC	CE1P61A	Behaviour of Structural Materials and Instrumentation	3	0	0	3
		CE1P61B	Forensic Engineering	3	0	0	3
		CE1P61C	Structural Optimisation	3	0	0	3

Semester II							
Slot	**Category Code**	**Course Number**	**Course Name**	**L**	**T**	**P**	**Credit**
A	PCC	CE1P60E	Advanced Metal Structures	3	1	0	4
B	PCC	CE1P60F	Finite Element Method	3	0	0	3
C	PCC	CE1P60G	Analysis of Earthquake Resistant Design of Structures	3	0	0	3
D	PEC	CE1PXXX	Elective II	3	0	0	3
E	PEC	CE1PXXX	Elective III	3	0	0	3
T	PCC	CE1P68B	Structural Dynamics Lab	0	0	2	1
W	PWS	CE1P69B	Mini Project	0	0	4	2
Total				**15**	**1**	**6**	**19**

ELECTIVE II

Slot	Category Code	Course Number	Course Name	L	T	P	Credit
D	PEC	CE1P62A	Theory and Design of Plates and Shells	3	0	0	3
		CE1P62B	Composite Structures	3	0	0	3
		CE1P62C	Fracture Mechanics	3	0	0	3

ELECTIVE III

Slot	Category Code	Course Number	Course Name	L	T	P	Credit
E	PEC	CE1P63A	Advanced Prestressed Concrete Design	3	0	0	3
		CE1P63B	Analysis and Design of Substructures	3	0	0	3
		CE1P63C	High Rise Structures	3	0	0	3

Semester III							
Slot	**Category Code**	**Course Number**	**Course Name**	**L**	**T**	**P**	**Credit**
A	PEC	CE1PXXX	Elective IV	3	0	0	3
B	PEC	CE1PXXX	Elective V	3	0	0	3
U	PWS	CE1P79A	Seminar II	0	0	2	2
W	PWS	CE1P79B	Project (Phase I)	0	0	12	6
			Total	**6**	**0**	**14**	**14**

ELECTIVE IV

Slot	Category Code	Course Number	Course Name	L	T	P	Credit
A	PEC	CE1P71A	Design of Bridges	3	0	0	3
		CE1P71B	Structural Reliability	3	0	0	3
		CE1P71C	Operations Research	3	0	0	3

ELECTIVE V

Slot	Category Code	Course Number	Course Name	L	T	P	Credit
B	PEC	CE1P72A	Stability of structures	3	0	0	3
		CE1P72B	Random Vibration	3	0	0	3
		CE1P72C	Engineering Application of Artificial Intelligence and Expert	3	0	0	3

Semester IV							
Slot	**Category Code**	**Course Number**	**Course Name**	**L**	**T**	**P**	**Credit**
W	PWS	CE1P79C	Project (Phase II)	0	0	24	12
			Total	**0**	**0**	**24**	**12**

SEMESTER – I

Syllabus and Course Plan

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P60A	ADVANCED NUMERICAL METHODS	PCC	3	0	0	3	2020

i) COURSE OBJECTIVES:

This course deals with numerical solutions of linear and nonlinear systems of equations. Numerical methods are powerful problem-solving tools which are capable in handling large systems of equations, nonlinearities and complicated geometries that are common in science, engineering and industrial practices.

ii) COURSE OUTCOMES:

After the completion of the course the student will be able to:

CO 1	Explain various computational methods in engineering.	Understand
CO 2	Apply interpolation and data smoothening techniques.	Apply
CO 3	Solve linear and non-linear equations using various methods.	Apply
CO 4	Solve ordinary differential equations using numerical methods.	Apply
CO 5	Solve partial differential equations using numerical methods.	Apply

iii) SYLLABUS:

Introduction to numerical methods - Errors in numerical methods - Systems of linear algebraic equations; Solution techniques; Eigen Value problems - Solution methods - Practical examples; Systems of non-linear equations; Interpolation techniques - Quadratic and Cubic splines; Data smoothing by least squares criterion - Non-polynomial models - exponential model and power equation; Multiple linear regression; Ordinary Differential equations - Solution by use of Taylor series; Partial Differential equations ; Computer Algorithms.

iv) REFERENCES:

1) Chapra, S.C., and Canale, R.P., *Numerical Methods for Engineers*, Mc-Graw Hill, 7th Edition, 2016.
2) Grewal, B.S., *Numerical methods in Engineering and Science*, Khanna Publishers,11th Edition 2013.
3) Sastry, S.S., *Introductory Methods of Numerical Analysis*, Prentice Hall of India, 5th Edition, 2012.
4) Ketter and Prawel, *Modern Methods for Engineering Computations*, Mc-Graw Hill, 1969.

5) Rajasekharan, S., *Numerical Methods in Science and Engineering*, Chand & Company, 2nd Edition 2003.

6) Smith, G.D., *Numerical solutions for Differential Equations*, Mc-Graw Hill, 3rd Edition, 1985.

v) COURSE PLAN:

Module	Contents	No. of hours
I	Introduction to numerical methods - Errors in numerical methods -Systems of linear algebraic equations; Solution techniques – Elimination, iteration and factorization methods – ill-conditioned systems - symmetric and banded systems. Gauss Seidel iteration for sparse systems.	**7**
II	Eigen Value problems; Solution methods - Power method - Jacobi method - Practical examples; Systems of non-linear equations - Newton-Raphson method.	**8**
III	Interpolation techniques - Lagarangian and Hermitian interpolation - Quadratic and Cubic splines (Examples with equal intervals only); Data smoothing by least squares criterion - Non-polynomial models like exponential model and power equation; Multiple linear regression -Taylor series expansion of functions	**8**
IV	Ordinary Differential equations - 1st order equations - Solution by use of Taylor series- Euler method and its modifications- Runge-Kutta method and its modifications - Higher order equations of the initial value type - Predictor corrector methods - Milne's method and Hamming's method- Stability of solutions.	**8**
V	Ordinary differential equations of the boundary value type- Finite difference solution- Weighted residual methods for initial value problems and boundary value problems- Collocation method- Sub domain method- Method of least squares- Galerkin's method.(Application of Civil Engineering problem)	**7**
VI	Partial differential equations in two dimensions- Parabolic equations- Explicit finite difference method- Crank-Nicholson implicit method- Ellipse equations. Computer Algorithms - Numerical Solutions for Different Structural Problems, Fuzzy Logic and Neural Network	**7**
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P60B	THEORY OF ELASTICITY	PCC	3	1	0	4	2020

i) COURSE OBJECTIVES:

This course is intended to familiarise the students with basic equations of elasticity and to expose them to two dimensional problems in Cartesian and Polar coordinates which enhances their skill and capability in analysing and solving problems in Civil Engineering.

ii) COURSE OUTCOMES:

After the completion of the course the student will be able to:

CO 1	Explain the concepts, principles and governing equations related to the analysis of elastic solids in 3D.	Understand
CO 2	Analyse the transformation of stresses and strains in 3D.	Analyse
CO 3	Explain the engineering properties of materials, force-deformation, and stress-strain relationship using polar coordinates in 2D and Cartesian coordinates system in 3D.	Apply
CO 4	Apply different methods in the analysis of bars with different cross section under torsion.	Apply

iii) SYLLABUS:

Analysis of stress in 3D - Analysis of strain in 3D - Stress Strain relations – Two dimensional problems in Rectangular coordinates - Two dimensional problems in polar coordinates - Torsion of prismatic bars.

iv) REFERENCES:

1) Timeshenko, S. P. and Goodier, J. N., *Theory of Elasticity,* Mc-Graw Hill Education Private Ltd., 3rd edition, 2010.
2) Srinath, L. S., *Advanced mechanics of Solids*, Tata McGraw-Hill, 3rd edition, 2009.
3) Ameen, M., *Computational Elasticity*, Narosa Publishing House, 2009.
4) Singh, S., *Experimental Stress Analysis*, Khanna Publisher, 4th edition, 2017.
5) Sitharam, T.G. and Govindaraju, L., *Applied Elasticity*, Interline Publishing Pvt. Ltd., 2008.
6) Wang, C. T., *Applied Elasticity*, Mc Graw Hill Publication, NY, USA, 2000.
7) Singh, S., *Theory of Elasticity*, Khanna Publisher, 4th edition, 2013.

v) COURSE PLAN:

Module	Contents	No. of hours
I	Analysis of stress in 3D: Concept of Stress, Stress Components, Stress tensor, Equilibrium Equations, Stress on a General Plane-Direction Cosines, Stress on Oblique Plane through a point, Stress Transformation, Principal Stresses, Stress Invariants, Hydrostatic and Deviatoric Stresses, Octahedral Stresses, Stress Boundary Condition Problem, Numerical examples	**10**
II	Analysis of strain in 3D: Strain tensor – Strain displacement relations for small deformations – Compatibility conditions – Strain transformations– Principal strains – Strain invariants, Octahedral strains, Hydrostatic and deviatoric strains, Numerical examples	**10**
III	Stress Strain relations: Generalised Hooke's law – Reduction in number of elastic constants for orthotropic, transversely isotropic and isotropic media (derivation for orthotropic only required), Boundary value problems of elasticity – Displacement, Traction and Mixed types. Navier's Equations, Beltrami-Michell's Equations, Saint Venant's principle. Uniqueness of Solution, Numerical examples	**10**
IV	Two dimensional problems in Rectangular coordinates: Plane stress and plane strain problems - Airy's stress function -Solution by polynomials – Bending of cantilever loaded at free end, Bending of simply supported beam with udl.	**10**
V	Two dimensional problems in polar coordinates: General equations - Equilibrium equations, Strain displacement relations and Stress strain relations, compatibility relations (no derivation required). Biharmonic equations and Airy's stress functions- Problems of axisymmetric stress distributions - Thick cylinders - Stress concentration due to circular hole in plates (Kirsch's problem), Numerical examples	**10**
VI	Torsion of prismatic bars: Saint Venant's Semi inverse and Prandtl's stress function approach – Torsion of Straight bars – Elliptic and Equilateral triangular cross section. Membrane Analogy - Torsion of thin walled open and closed tubes, Numerical examples	**10**
	Total hours	**60**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P60C	STRUCTURAL DYNAMICS	PCC	3	1	0	4	2020

i) COURSE OBJECTIVES:

This course deals with free and forced vibration characteristics of single degrees of freedom and multi degree of freedom systems. It also deals with the frequencies and mode shapes of the beam with different end conditions (distributed mass system).

ii) COURSE OUTCOMES:

After the completion of the course the student will be able to:

CO 1	Explain the concept structural dynamic systems.	Understand
CO 2	Calculate the free and forced vibration characteristics of a single degree of freedom system.	Analyse
CO 3	Analyse the free and forced vibration characteristics of a multi degree of freedom system (lumped mass concept).	Analyse
CO 4	Evaluate the vibration characteristics of beams with different end conditions.	Analyse
CO 5	Apply the concepts of dynamic effects of wind Loading, Vibrations caused by Traffic, Blasting and Pile Driving, Vibration isolation, Vibration measuring instruments and Methods of vibration control.	Apply

iii) SYLLABUS:

Importance of vibration studies. Systems with single degree of freedom - Free and forced vibration with and without damping - Response to support motion. Numerical solution of single degree of freedom systems. Multi-degree of freedom systems (Lumped mass) - Evaluation of natural frequencies and mode shapes - Co-ordinate coupling - Orthogonality of normal modes - Forced vibration analysis of multi-degree of freedom systems - Mode superposition method. Distributed mass (continuous) systems - Axial vibration of rods - Flexural vibration of single span beams - Evaluation of frequencies and mode shapes. Special Topics in Structural Dynamics (Concepts only).

iv) REFERENCES:

1) Paz, M., *Structural Dynamics - Theory and Computation*, CBS Publishers and Distributors, 2nd edition, 2004.
2) Mukhopadhyay, M., *Structural Dynamics - Vibrations and Systems*, Ane Books, 2nd edition, 2008.

3) Chopra, A. K., *Dynamics of Structures- Theory and Application to Earthquake Engineering*, Pearson Education, 1st edition, 2001.
4) Clough, R. W. and Penzien, J., *Dynamics of Structures*, McGraw Hill, 2nd edition, 1996.
5) Humar, J., *Dynamics of Structures*, CRC Press, 3rd edition, 2012.
6) Thomson, W. T., *Theory of Vibration with Application*, Pearson Education, 5th edition, 1998.
7) Weaver, W., Timoshenko, S. P. and Young, D. H., *Vibration Problems in Engineering*, John Wiley & Sons, 5th edition, 1992.

v) COURSE PLAN:

Module	Contents	No. of hours
I	**Introduction to structural dynamics:** Importance of vibration studies - Nature of exciting forces - Types of dynamic problems - D'Alembert's principle - Equations of motion - degrees of freedom - Mathematical modeling of dynamic systems.	**10**
II	**Single Degree of Freedom System:** Free and forced vibration with and without damping - Response to harmonic loading - Response to general dynamic loading using Duhamel's Integral - Response to support motion	**10**
III	**Numerical solution of single degree of freedom systems:** Central Difference Method - Average acceleration method - Wilson-θ method - Newmark-β method	**10**
IV	**Multi Degree of Freedom (Lumped parameter)** Free vibrations, natural modes, orthogonality conditions, shear frame, matrix iteration for eigenvalues and eigenvectors, forced vibrations, mode superposition method, damping in MDOF systems	**10**
V	**Distributed mass systems** - Axial vibration of rods - Flexural vibration of single span beams - simply supported beam, cantilever beam and fixed beam - Evaluation of frequencies and mode shapes	**10**
VI	**Special Topics in Structural Dynamics (Concepts only):** Dynamic effects of wind loading - Vibrations caused by Traffic, Blasting and Pile Driving - Vibration isolation- Vibration measuring instruments - Methods of vibration control - Tuned mass damper	**10**
	Total hours	**60**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P60D	ADVANCED THEORY AND DESIGN OF RC STRUCTURES	PCC	3	0	0	3	2020

i) COURSE OBJECTIVES:

Goal of this course is to expose the students to the design concepts of reinforced concrete structures and enhance their problem solving skills. It introduces the design and detailing of beams, columns, special RCC structures and structural members for fire resistance. It also provides an introduction to strut and tie model of design.

ii) COURSE OUTCOMES:

After the completion of the course the student will be able to:

CO 1	Explain the stress strain characteristics of concrete under different states of stress.	Understand
CO 2	Analyse the effectiveness in the design of flexural and compression members.	Analyse
CO 3	Apply the standard procedure to calculate defection and cracking in flexural members.	Apply
CO 4	Analyse the effectiveness in the design of special RCC members.	Analyse
CO 5	Explain strut and tie model.	Understand
CO 6	Analyse the performance of beam column joint designed using strut and tie model.	Analyse
CO 7	Analyse the response of structural members designed for fire resistance.	Analyse

iii) SYLLABUS:

Basic theory and design philosophies-Advanced theory in Stress-strain characteristics of concrete -Failure criteria for concrete- Design concepts-Limit state method-Estimation of deflection and control of cracking, -Design of special RC members- Design of concrete corbels, deep beams, ribbed slabs, pile caps-Strut and Tie Models- Development- Design methodology- RCC beam – column joints -Design of RCC members for fire resistance.

iv) REFERENCES:

1) Nilson, A. H., Darwin, D. and Dolan, C. W., *Design of Concrete Structures*, Tata Mc-Graw Hill Book Co., New York, 13th edition,2004.

2) Park, R. and Paulay, T., *Reinforced Concrete Structures*, John Wiley & Sons, New York, 1975.

3) Varghese, P. C, *Advanced of Reinforced Concrete Design*, Prentice Hall of India Pvt. Ltd, 2nd edition, 2011.

4) Relevant IS codes IS 456: 2000 (Reaffirmed 2005), IS 13920: -2016, SP 16-1980 Design Aids for Reinforced Concrete to IS 456:1978, SP 34-1987 Hand book on concrete reinforcement and detailing, Bureau of Indian Standards, New Delhi.

5) ACI 318-2002, *Building Code Requirements for Structural Concrete and Commentary*, American Concrete Institute.

v) COURSE PLAN:

Module	Contents	No. of hours
I	**Review on Basic theory and design philosophies**-Advanced theory in Stress-strain characteristics of concrete under uniaxial and multi axial states of stress, confined concrete, Effect of cyclic loading on concrete and reinforcing steel. Stress block parameters, Failure criteria for concrete. **Review on design of reinforced concrete members** in flexure, flexural shear, torsion, combined with flexure and flexural shear. Analysis and design of compression members, slender columns under biaxial bending.	**7**
II	**Ductile Detailing of Frames for Seismic Forces**: Introduction, General principles, Factors that increase ductility, Specifications of materials for ductility, ductile detailing of beams, Ductile detailing of columns and frame members with axial load (P) and moment (M). **Deflection of Reinforced Concrete Beams and Slabs**: Introduction, Short-term deflection of beams and slabs, Deflection due to imposed loads, Short-term deflection of beams due to applied loads, Deflection of slabs by IS 456 and comparison with foreign codes.	**8**
III	Introduction, Factors affecting crack width in beams, Mechanisms of flexural cracking, Calculation of crack width, Simple empirical method, Estimation of crack width in beams by IS 456.	**7**
IV	**Design of special RCC members**- Design of concrete corbels, deep beams, ribbed slabs, pile caps.	**8**

V	**Strut and Tie Models**- Development- Design methodology, selecting dimensions for struts, ACI Provisions, Applications, RCC beam–column joints, classification, shear strength, design of exterior and interior joints, wide beam joints.	**7**
VI	**Design of Reinforced Concrete Members for Fire Resistance**: Introduction, ISO 834 standard heating conditions, Grading or classifications, Effect of high temperature on steel and concrete, Effect of high temperatures on different types of structural members, Analytical determination of the ultimate bending moment, Capacity of reinforced concrete beams under fire.	**8**
	Total hours	**45**

Note: Use of Is 456:2000 and SP 16:1980 may be permitted for the examination

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P61A	BEHAVIOUR OF STRUCTURAL MATERIALS AND INSTRUMENTATION	PEC	3	0	0	3	2020

i) COURSE OBJECTIVES:

Goal of this course is to familiarize the students regarding the estimation of properties of the materials used in concrete. The course also aims to expose the students to different types of concrete, their mix design and evaluation of strength of concrete by destructive and non-destructive methods.

ii) COURSE OUTCOMES:

After the completion of the course the student will be able to:

C0 1	Outline the suitability of materials used for preparing RCC.	Understand
CO 2	Explain different types of concrete and their properties	Understand
CO 3	Apply the codal provisions to design concrete mix	Apply
CO 4	Describe the various destructive and non-destructive tests on concrete.	Understand
CO 5	Examine the load, strain and displacement using different instrumentation systems	Analyse
CO 6	Explain the instrumentation, testing and retrofitting of different RCC members.	Understand

iii) SYLLABUS:

Components of concrete, special concrete, mix design of various types of concrete, properties of hardened concrete, durability test, non-destructive testing, instrumentation and testing of reinforced concrete members.

iv) REFERENCES:

1) Nevile, A. M., *Properties of Concrete*, Pearson, 5th edition, 2011.
2) Mehta, P. K. and Monteiro, P. J. M., *Concrete: Microstructure, Properties and Materials,* McGraw Hill, 4th edition, 2014.
3) Santhakumar, A. R., *Concrete Technology*, Oxford University Press, 2nd edition, 2018.
4) Zongjin, L., *Advanced Concrete Technology,* John Wiley and Sons, Inc., Hoboken, New Jersey, 2011.

5) Prasad, J., Nair, C. G. K., *Non-Destructive Test and Evaluation of Materials*, Mc-Graw Hill, 2nd edition, 2011.
6) Jan, G. M. V. M., *Fracture Processes of Concrete: Assessment of Material Parameters for Fracture Models,* CRP Press, 1997.
7) IS 10262: 2019, *Concrete Mix Proportioning – Guidelines*, Bureau of Indian Standards, New Delhi, India, 2019.
8) IS 1489 (Part 1): 2015, *Specification for Portland Pozzolana Cement*, Bureau of Indian Standards, New Delhi, 2015.
9) IS 383: 2016, *Specification for Coarse and Fine Aggregates from Natural Sources for Concrete (Third revision)*, Bureau of Indian Standards, New Delhi, 2016.
10) IS 2386 (Part III): 1963 (R2016), *Methods of Test for Aggregates for Concrete - Specific Gravity, Density, Voids, Absorption and Bulking,* Bureau of Indian Standards, New Delhi, 2016.
11) IS 516 – 1959, *Method of Tests for Strength of Concrete*, Bureau of Indian Standards, New Delhi, 1959.
12) IS 456: 2000 (Reaffirmed 2005), *Plain and Reinforced Concrete Code of Practice*, Bureau of Indian Standards, New Delhi, 2005.
13) IS 2770 (Part I): 1967 (R2017), *Methods of Testing Bond in Reinforced Concrete*, Bureau of Indian Standards, New Delhi, 2017.

v) COURSE PLAN:

Module	Contents	No. of hours
I	**Concrete Components**: Cement – Bogue's Compounds, Hydration Process, Types of Cement. Aggregates – Gradation Charts, effects on properties of concrete, Combined Aggregate, Alkali Silica Reaction. Interface between aggregates and cement matrix, Interface properties: strength and fracture energy. Admixtures – Chemical and Mineral Admixtures. Fresh Concrete, Segregation and bleeding. Steel: Types, stress strain curve – mild steel and tor steel, young's modulus	**7**
II	**Properties of hardened concrete:** Microstructure of hardened concrete – Aggregate phase, hydrated cement paste, interfacial transition zone. Strength of concrete, behaviour of concrete under various stress states, stress strain behaviour – cyclic load, Dimensional stability of concrete – Elastic behaviour, shrinkage and creep. Test on bond strength between steel and concrete	**7**

	Durability of concrete: Durability concept; factors affecting, reinforcement corrosion; fire resistance; frost damage; sulphate attack; alkali silica reaction; concrete in sea water, statistical quality control, acceptance criteria as per BIS code.	
III	**Special concretes** – Fibre reinforced concrete, High strength concrete, High performance concrete, Ultra High Performance concrete, Self-compacting concrete, Geo polymer concrete, Lightweight concrete, Polymer concrete **Proportioning of concrete mixtures:** Factors considered in the design of mix, IS method of mix design, Mix design of special concrete - High performance concrete - Self compacting concrete-Geo polymer concrete	**8**
IV	**Non-destructive testing of concrete**: Surface Hardness, Ultrasonic pulse velocity, Penetration resistance, Pull-out test, chemical testing for chloride and carbonation- core cutting - measuring reinforcement cover. Scanning Electron Microscopy, X-Ray Microanalysis, SEM, Interpretation of concrete deterioration from SEM/EDXA Techniques for Corrosion Investigation in Reinforced Concrete, basic principles of corrosion, Surface Area Measurements, Pore structure, Permeation Analysis, Image analysis, Introduction to X-ray Microtomography	**8**
V	**Retrofitting techniques** – Need for retrofitting, retrofitting of structural members i.e., column and beams by Jacketing technique, Externally bonding (ERB) technique, near surface mounted (NSM) technique, External post- tensioning, Section enlargement, ferrocement.	**7**
VI	**Measurement of Strain**: Strain Gauge Characteristics- - Strain gauge types, circuits - Strain Gauge rosettes. **Force transducers**: Load cells - different types-tension, compression, shear beam, bending. **Measurement of displacement**: Linear variable differential transformer – principle and working. **RC Members - Testing and instrumentation:** Test on RC beams for flexure, shear and torsion, compression test on RC columns, test on beam column joints – cyclic and reverse cyclic.	**8**
	Total hours	**45**

Note: Use of Is 456:2000 and IS 10262:2019 may be permitted for the examination

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P61B	FORENSIC ENGINEERING	PEC	3	0	0	3	2020

i) COURSE OBJECTIVES:

Goal of this course is to equip the students to identify reasons of distress in structures and suggest repair/ remedial measures.

ii) COURSE OUTCOMES:

After the completion of the course the student will be able to:

CO 1	Explain the causes of failure of structures.	Understand
CO 2	Infer the level of distress of structures.	Understand
CO 3	Interpret the effect of various environmental problems and natural hazards.	Understand
CO 4	Classify the different methods of repair of structures.	Apply
CO 5	Explain the modern techniques of retrofitting.	Apply

iii) SYLLABUS:

Failure of Structures, review of the construction theory, performance problems. Causes of deterioration in concrete and steel structures. Diagnosis and Assessment of Distress, Visual inspection, non-destructive tests. Fibre optic method for prediction of structural weakness. Effect of Environmental Problems and Natural Hazards. Methods of repair of concrete and steel structures. Modern Techniques of Retrofitting.

iv) REFERENCES:

1) Raikar, R. N., *Learning from Failures – Deficiencies in Design*, Construction and Service, R&D Centre (SDCPL), Raikar Bhavan, 2002.

2) Dovkaminetzky, *Design and Construction Failures*, Galgotia Publication, New Delhi, 2001.

3) Raina, V. K., *Bridge Rehabilitation*, Shroff Publications, New Delhi, 2006.

4) Feld, J. and Carper, K. L., *Structural Failures*, Wiley Europe, 2008.

5) Johnson, S. M., *Deterioration, Maintenance and Repair of Structures*, McGraw Hill Book Company, New York, 1965.

v) COURSE PLAN:

Module	Contents	No. of hours
I	Failure of Structures: Review of the construction theory – performance problems – responsibility and accountability – case studies – learning from failures – causes of distress in structural members – design and material deficiencies – over loading.	**7**
II	Causes of deterioration in concrete and steel structures. Preventive measures, maintenance.	**6**
III	Diagnosis and Assessment of Distress: Visual inspection – non-destructive tests – ultrasonic pulse velocity method – rebound hammer technique – ASTM classifications – pullout tests – Bremor test – Windsor probe test – crack detection techniques – case studies – single and multistorey buildings – Fibre optic method for prediction of structural weakness.	**8**
IV	Environmental Problems and Natural Hazards: Effect of corrosive, chemical and marine environment – pollution and carbonation problems – durability of RCC structures – damage due to earthquakes, flood and fire - strengthening of buildings – provisions of BIS 1893 and 4326	**8**
V	Methods of repair of cracks, repairing spalling and disintegration, repairing concrete floors and pavements. Repairing of corrosion damage of reinforced concrete. Repair of steel structures.	**7**
VI	Modern Techniques of Retrofitting: Structural first aid after a disaster – guniting - jacketing – use of chemicals in repair – application of polymers – ferrocement and fiber concretes as rehabilitation materials – rust eliminators and polymer coating for rebars - foamed concrete - mortar repair for cracks - shoring and underpinning -strengthening by pre-stressing.	**9**
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P61C	STRUCTURAL OPTIMISATION	PEC	3	0	0	3	2020

i) COURSE OBJECTIVES:

Goal of this course is to introduce the concept of optimisation and review the major conventional and modern optimisation methods used in structural optimisation applications.

ii) COURSE OUTCOMES:

After the completion of the course the student will be able to:

CO 1	Outline the general optimisation techniques.	Understand
CO 2	Illustrate the framework of structural optimisation problems.	Apply
CO 3	Use the various unconstrained and constrained optimisation techniques for structural applications.	Apply
CO 4	Apply linear and non-linear programming methods for structural optimisation.	Apply
CO 5	Illustrate the specialized optimisation techniques.	Apply

iii) SYLLABUS:

Problem formulation with example, Single Variable Unconstrained Optimisation Techniques, Multi Variable Unconstrained Optimisation Techniques, Constrained Optimisation Techniques - Indirect methods - Direct methods, Specialized Optimisation techniques.

iv) REFERENCES:

1) Rao, S.S., *Engineering Optimisation – Theory and Practice*, John Wiley & Sons, Inc., 5th edition, 2019.

2) Deb, K., *Optimisation for Engineering Design – Algorithms and examples*, Prentice Hall, 2nd edition, 2012.

4) Kirsch, U., *Optimum Structural Design*, Mc-Graw Hill, 1993.

5) Rajeev, S. and Krishnamoorthy, C.S., *Discrete Optimisation of Structures using Genetic Algorithms, Journal of Structural Engineering*, Vol. 118, No. 5, 1223-1250, 1992.

6) Arora J. S., *Introduction to Optimum Design*, 4th edition, Mc-Graw Hill, 2016.

v) COURSE PLAN:

Module	Contents	No. of hours
I	**Introduction to structural optimisation**-Problem formulation with examples.	**7**
II	**Single Variable Unconstrained Optimisation Techniques**– Optimality Criteria - Interpolation methods Quadratic Interpolation, Cubic Interpolation -Gradient Based methods-Bisection, Newton Raphson, Secant Methods.	**7**
III	**Multi Variable Unconstrained Optimisation Techniques**-Optimality Criteria. Unidirectional Search-Direct Search Methods-Pattern Search, Simplex method. Gradient based methods-Cauchy's method, Newton's method, Quasi Newton Methods, Fletcher Reeves method, Marquardt's method.	**8**
IV	**Constrained Optimisation Techniques**-Classical Methods-Direct substitution method, constrained variation method, method of Lagrange multipliers, Kuhn-Tucker conditions. Linear programming problem Standard form, Simplex method.	**8**
V	Indirect methods- Transformation Techniques, Exterior and Interior penalty function. Direct methods—Zoutendijk's method of feasible direction, Rosen's gradient Projection method.	**8**
VI	**Specialized Optimisation techniques** –Dynamic programming, Geometric programming, Genetic Algorithms.	**7**
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
MC0P60A	RESEARCH METHODOLOGY	MCC	0	2	0	2	2020

i) COURSE OBJECTIVES:

Goal of this course is to prepare the student to do the M. Tech project work with a research bias. The student will be able to formulate a viable research problem, do a critical analysis of publications in the area of research, and identify the appropriate research methodology. The student will be able to write a technical paper based on the project findings.

ii) COURSE OUTCOMES:

After the completion of the course the student will be able to:

CO 1	Explain research ethics	Understand
CO 2	Explain Citation, Impact factor and Plagiarism.	Understand
CO 3	Explain that IPR helps to foster research work, leading to creation of improved products, thus helping in economic growth and social benefits.	Understand
CO 4	Explain research problem formulation.	Apply
CO 5	Analyze research related information	Apply
CO 6	Write a technical paper	Understand

iii) SYLLABUS:

Introduction to Research Methodology- Meaning of research, types of research, research problem- scope-objectives, data collection and analysis, literature review.

Ethical issues- Research ethics, Plagiarism, Effective technical writing.

Developing a Research Proposal, Format of research proposal-presentation-assessment by a review committee.

Copy right- royalty- Intellectual property rights and patent law, Patents, Designs, Process of Patenting and Development, Procedure for grant of patents.

Scope of Patent rights, Licensing and transfer of technology, Patent information and databases, Geographical Indications. Administration of Patent system- Biological systems-Computer software.

iv) REFERENCES:

1) Melville, S. and Goddard, W., *Research methodology: an introduction for science & engineering students.*
2) Goddard, W., and Melville, S., *Research Methodology: An Introduction*.
3) Kumar, R., 2nd Edition, *Research Methodology: A Step by Step Guide for beginners*.
4) Halbert, *Resisting Intellectual Property*, Taylor & Francis Ltd ,2007.
5) Mayall, *Industrial Design*, McGraw Hill, 1992.
6) Niebel, *Product Design*, McGraw Hill, 1974.
7) Asimov*, Introduction to Design*, Prentice Hall, 1962.
8) Merges, R. P., Menell, P. S., Lemley, M. A., *Intellectual Property in New Technological Age*, 2016.
9) Ramappa, T.*, Intellectual Property Rights Under WTO*, S. Chand, 2008.

v) COURSE PLAN:

Module	Contents	No. of hours
I	Introduction to Research Methodology: Motivation towards research, Types of research. Professional ethics: Ethical issues -ethical committees. Copy right - royalty - Intellectual property rights and patent law - Reproduction of published material - Plagiarism. New developments in IPR of Biological Systems, Computer Software etc. Citation and acknowledgement, Impact factor. Identifying major conferences and important journals in the concerned area.	**6**
II	Defining and formulating the research problem - Literature Survey, choose two papers in the area and analyze to understand how the authors have undertaken literature review, identified the research gaps, developed the objectives, formulated their problem and developed a hypothesis.	**5**
III	Research design and methods: Analyze the chosen papers to understand formulation of research methods, both analytical and experimental methods.	**4**

IV	Data Collection and analysis: Analyze the chosen papers and study the methods of data collection, data processing, analysis strategies, and tools used for analyzing the data.	**5**
V	Technical writing - Structure and components, contents of a typical technical paper, difference between abstract and conclusion, layout, illustrations and tables, bibliography, referencing and footnotes.	**5**
VI	Identification of a simple research problem – Literature survey - Research design - Methodology –paper writing based on a hypothetical result.	**5**
	Total hours	**30**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P68A	STRUCTURAL ENGINEERING AND COMPUTATIONAL LAB	PCC	0	0	2	1	2020

i) COURSE OBJECTIVES:

Goal of this course is to familiarize the students with experimental evaluation of properties of materials used in concrete and to study the behaviour of concrete members. The students will be exposed to the instruments for measurement of strain, deflection, operations of UTM, hydraulic loading systems, force measuring devices etc. The course also aims to familiarize the students with software packages for analysis, design and detailing of reinforced concrete structures.

ii) COURSE OUTCOMES:

After the completion of the course the student will be able to:

CO 1	Explain the basic concepts of concrete technology and design of RCC members.	Understand
CO 2	Judge the suitability of materials used for preparing a concrete mix.	Evaluate
CO 3	Apply the IS method of mix design to develop a concrete mix.	Apply
CO 4	Evaluate the hardened properties and quality of concrete mix using destructive and non-destructive testing methods.	Evaluate
CO 5	Assess the modes of failure and bond strength between concrete and reinforcement bars.	Evaluate
CO 6	Assess the failure modes and behaviour of reinforced concrete and prestressed concrete members prepared using the developed mix.	Evaluate
CO 7	Apply software tools in the analysis and design of structural elements and framed structures subjected to gravity loads.	Apply

iii) SYLLABUS:

- Material properties – 1 session
- Design of concrete mix – 2 sessions
- Hardened property – 1 session
- Durability test and NDT – 1 session

- Bond strength test – 1 session
- Test on RC members – 3 sessions
- Analysis and design – 5 sessions

iv) REFERENCES:

1) Relevant IS codes (IS 10262: 2019, IS 1489 (Part 1): 2015, IS 383: 2016, IS 2386 (Part III): 1963, IS 516 – 1959, IS 456-2000 (Reaffirmed 2005), IS 2770 (Part I): 1967 (Reaffirmed 2007), Bureau of Indian Standards, New Delhi.

2) Reference Manual of the Relevant Software.

v) COURSE PLAN:

Module	Contents	No. of hours
I	Evaluate the suitability of given materials for preparing a concrete mix	**2**
II	Develop a concrete mix which is suitable for structural applications	**4**
III	Evaluate the tensile and flexural strength of developed mix and relate it with the compressive strength	**2**
IV	Evaluate the quality of concrete using durability and non-destructive testing methods a) RCPT test b) Rebound hammer test c) Ultrasonic pulse velocity test	**2**
V	Determine the modes of failure and bond strength between concrete and reinforcement bars	**2**
VI	Study the modes of failure and behaviour of reinforced concrete members prepared using the developed mix a) Test on reinforced concrete beam b) Test on prestressed concrete beam c) Test on reinforced concrete column	**6**
VII	Analysis and design of RCC elements with different support conditions	**2**
VIII	Analysis and design of multistoreyed buildings subject to different types of loading	**10**
	Total hours	**30**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P69A	SEMINAR I	PWS	0	0	2	2	2020

i) COURSE OBJECTIVES:

To make students

1. Identify the current topics in the specific stream.
2. Collect the recent publications related to the identified topics.
3. Do a detailed study of a selected topic based on current journals, published papers and books.
4. Present a seminar on the selected topic on which a detailed study has been done.
5. Improve the writing and presentation skills.

ii) APPROACH:

Students shall make a presentation for 20-25 minutes based on the detailed study on the project and submit a report of the study.

iii) EXPECTED OUTCOMES:

Upon successful completion of the Seminar, the student should be able to:

CO 1	Identify promising new directions of various cutting edge technologies
CO 2	Organize information after the study of research papers related to the branch of study
CO 3	Develop effective written and oral communication

SEMESTER – II

Syllabus and Course Plan

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P60E	ADVANCED METAL STRUCTURES	PCC	3	1	0	4	2020

i) COURSE OBJECTIVES:

Goal of this course is to develop the students with an ability to perform analysis and design of steel members and their connections. It enables students to identify structural members based on their behaviour. An expertise in professional and contemporary issues in advanced steel design is also acquired.

ii) COURSE OUTCOMES:

After the completion of the course, the student will be able to:

CO 1	Choose the various design philosophies and the concepts of connections.	Apply
CO 2	Apply the designs of various types of connections.	Apply
CO 3	Inspect the various types of beam to column connections.	Analyse
CO 4	Identify the application of tubular connections.	Apply
CO 5	Evaluate the performance of column bases and their connections designed as per standards.	Evaluate
CO 6	Analyse the design of crane and gantry girders.	Analyse
CO 7	Utilize the concepts of steel-concrete composite structures and light gauge steel structures in designing members.	Apply
CO 8	Classify the concepts of aluminium structures and their designs as per standards	Analyse

iii) SYLLABUS:

Design Philosophies, Connections, Beam to column connections, Splices, Tubular connections, Industrial buildings, Steel-Concrete Composite structures, Light gauge steel structures, Aluminium structures

iv) REFERENCES:

1) Dayaratnam, P., *Design of Steel Structures*, S. Chand Publishing, 1st edition, 2015.
2) Subramanian, N., *Design of Steel Structures*, Oxford University Press, 2015.
3) Johnson, R. P., *Composite Structures in Steel and Concrete*, Blackwell Scientific Publications, UK, 2nd edition, 2008.

4) Wie-Wen Yu, *Cold-Formed Steel Structures*, John Wiley & Sons, 4th edition, 2019.

5) IS 800: 2007, *General Construction in Steel – Code of Practice*, Bureau of Indian Standards, New Delhi, Third Revision, 2007.

6) IS 801: 1975 (Reaffirmed 2010), Code of Practice for use of Cold formed Light gauge Steel Structural members in General Building Construction, Bureau of Indian Standards, New Delhi, First Revision, 2010.

7) IS 8147: 1976 (Reaffirmed 2006), Code of Practice for use of Aluminium alloys in Structures, Bureau of Indian Standards, New Delhi, First Revision, 2006.

v) COURSE PLAN:

Module	Contents	No. of hours
I	**Design Philosophies:** Existing methods, Introduction to Limit State Design. **Connections:** - Classification (Simple, Rigid, Semi rigid), Beam to Column and Beam to Beam connections , web angle and end plate connections; defects in connections	**10**
II	**Beam to column connections:** Seat angle, stiffened beam seat connection; lug angles and shear lag **Splices:** Need for splices, Beam and column splices, bolted and welded splices; Prying force. **Tubular connections**: Welded tubular joints, Curved weld length at intersection of tubes	**10**
III	**Column Bases:** Design of slab base and gusseted base; eccentrically loaded base plate **Special connections:** Connections from column base to footings - anchor bolts and shear connectors	**10**
IV	**Industrial buildings:** Layout, Roof System, Design of crane and gantry girders **Steel-Concrete Composite structures:** Composite behaviour, Connections for composite action, composite sections under positive and negative bending (concepts only)	**10**
V	**Light gauge steel structures:** Types of sections, basic terminology; Form factor; Design of tension, compression members and beams, local and post buckling of thin sections	**10**
VI	**Aluminium Structures:** Introduction, Stress-strain relationship, Permissible stresses; Design of Aluminium members – Tension members, Compression members and Beams.	**10**
	Total hours	**60**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P60F	FINITE ELEMENT METHODS	PCC	3	0	0	3	2020

i) COURSE OBJECTIVES:

This course imparts an understanding of fundamental knowledge and technique of FEM. This course enables the students to develop tools to analyse engineering problems using FEM and typical commercial FEA packages.

ii) COURSE OUTCOMES:

After the completion of the course, the student will be able to:

CO 1	Apply the variational principles and weighted residual methods for analysing structures.	Analayse
CO 2	Explain the concept of finite element method.	Apply
CO 3	Evaluate the one-dimensional bar & plane truss structures and calculate the nodal displacement, stresses and reaction forces.	Evaluate
CO 4	Evaluate the two dimensional triangular or rectangular problems using FEM and calculate the nodal displacement, stresses and reaction forces.	Evaluate
CO 5	Explain the assembly procedure and storage techniques of stiffness matrix in finite element method.	Apply
CO 6	Explain the computer Implementation of FEM procedure.	Analyse

iii) SYLLABUS:

Review of theory of elasticity- Equations of equilibrium, Strain-displacement relation, constitutive relation; Energy principles; Introduction to weighted residual methods; Evolution of FEM, Review of direct stiffness method, Outline of the FE procedure; Element properties, convergence requirements, equilibrium and compatibility in the solution; Types of finite elements; Plane stress and plane strain problems; Stiffness matrix for truss and beam elements, Development of consistent nodal load vector; Concept of iso parametric formulation- Line element, Plane bilinear element, Sub parametric and super parametric elements; Assembly procedure and storage techniques of stiffness matrix, Application of boundary Conditions, Solution techniques; Computer Implementation of FEM procedure.

iv) REFERENCES:

1. Krishnamoorthy, C. S., *Finite Element Analysis: Theory and Programming*, Tata McGraw Hill, 2nd edition, 2007.
2. Chandrupatla, T. R. and Belegundu, A. D., *Introduction to Finite Elements in Engineering*, Pearson Education, 4th edition, 2012.

3. Mukhopadhyay, M. and Sheikh, A. H., *Matrix and Finite Element Analyses of Structures*, Ane Books, 1st edition, 2015.

4. Cook, R. D., Malkus, D. S., Plesha, M. E. and Witt, R. J., *Concepts and Applications of Finite Element Analysis*, John Wiley & Sons, 4th Edition, 2001.

5. Zienkiewicz, O. C. and Taylor, R. W., *Finite Element Method*, Elsevier Butterworth-Heinemann, 5th edition, 2005.

6. Hutton, D. V., *Fundamentals of Finite Element Analysis*, Tata McGraw Hill, 1st edition, 2004.

v) COURSE PLAN:

Module	Contents	No. of hours
I	**Review of theory of elasticity**- Equations of equilibrium, Strain-displacement relation, constitutive relation **Energy principles**- Principle of virtual work, Principle of stationary potential energy; Variational formulation-Rayleigh-Ritz method; Introduction to weighted residual methods	7
II	**Introduction to FEM**: Evolution of FEM, Review of direct stiffness method, Outline of the FE procedure; Element properties- Displacement functions, convergence requirements, equilibrium and compatibility in the solution, Development of equilibrium equation	7
III	**Types of finite elements**- Development of shape functions for truss and beam, CST, LST; Lagrange and Serendipity elements; Plane stress and plane strain problems. Introduction to plate and shell elements; Types of 3D elements	8
IV	**Development of stiffness matrix** - truss and beam elements; Development of consistent nodal load vector;	8
V	**Concept of isoparametric formulation**- Line element, Plane bilinear element; Sub-parametric and super-parametric elements. Gauss quadrature technique	8
VI	**Assembly procedure and storage techniques** of stiffness matrix, Application of boundary Conditions; Solution techniques of equilibrium equation- LDLT Technique; patch test; static condensation. **Computer Implementation of FEM procedure** - Pre-Processing, Solution, Post-Processing, Use of Commercial FEA Software.	7
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P60G	ANALYSIS AND DESIGN OF EARTHQUAKE RESISTANT STRUCTURES	PCC	3	0	0	3	2020

i) COURSE OBJECTIVES:

This course imparts the basic concept about seismology and seismic design of structures. This course also deals with different methods for the seismic analysis of buildings.

ii) COURSE OUTCOMES:

After the completion of the course, the student will be able to:

CO 1	Explain the basic concept such as ground motion parameters, Response spectrum and design spectrum.	Apply
CO 2	Describe the seismic design philosophies.	Understand
CO 3	Analyse buildings by equivalent static method.	Analyse
CO 4	Analyse the building by response spectrum.	Analyse
CO 5	Explain the concepts of time history analysis and push over analysis.	Apply
CO 6	Evaluate the performance of structures subjected to seismic loads using software package	Evaluate

iii) SYLLABUS:

Earthquake seismology – Causes of earthquake, Plate tectonics, Earthquake fault sources, Elements of earthquake engineering. Seismic performance of structures and structural components during earthquakes; Response spectrum, design spectrum. Seismic Design Philosophy: Force based vs. displacement-based design, performance-based design, seismic input characteristics and their effect on seismic design, comparative study of different national codes Seismic Analysis of Buildings: Equivalent static analysis, response spectrum analysis, mode superposition method; Time history analysis. Push over analysis - Introduction - Modern concepts - Analysis and design of Building systems to Earthquake Loads (Hands on session using packages like ETABS).

iv) REFERENCES:

1) Duggal, S. K., *Earthquake Resistant Design of Structures*, Oxford University Press, 2nd edition, 2007.
2) Agarwal, P. and Shrikhande, M., *Earthquake Resistant Design of Structures*, Prentice Hall, 9th edition, 2011.
3) Anil, K. Chopra, *Dynamics of structures: Theory and application to earthquake engineering*, Prentice Hall of India, 2nd edition, 2012.

4) Relevant IS codes (IS 1893 (Part 1): 2016, IS 4326: 2013, IS 13920: 2016), Bureau of Indian Standards, New Delhi.
5) Chowdhary, I. and Dasgupta, S.P., *Dynamics of structure and foundation – A unified approach: 2 Applications*, CRC Press, 1st edition, 2008.
6) Clough, R. W. and Penzien, J., *Dynamics of structures*, McGraw Hill, 2nd edition,2019.
7) Datta, T. K., *Seismic analysis of structures*, John Wiley & Sons (Asia) Pte Ltd., 1st edition, 2010.

v) COURSE PLAN:

Module	Contents	No. of hours
I	**Earthquake seismology** – Causes of earthquake, Plate tectonics, Earthquake fault sources, Seismic waves, Elastic rebound theory, Quantification of earthquake, Intensity and magnitudes, Earthquake source models.	**7**
II	**Basic Concepts**: Seismic performance of structures and structural components during earthquakes; Ground motion parameters; Response spectrum, design spectrum.	**7**
III	**Seismic Design Philosophy**: Concept of strength, overstrength and ductility, Concept of equal displacement and equal energy principles, capacity design; seismic design consideration in buildings with irregularities.	**8**
IV	**Performance-based design:** Force based vs. displacement-based design, seismic input characteristics and their effect on seismic design, comparative study of different national codes	**8**
V	**Seismic Analysis of Buildings**: Equivalent static analysis, response spectrum analysis, mode superposition method; Time history analysis. Push over analysis - Introduction - Modern concepts	**8**
VI	**Computer Aided Analysis and Design** (Only for Internal Assessment) Computer Analysis and design of Building systems to Earthquake Loads – Hands on session using software package.	**7**
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P62A	THEORY AND DESIGN OF PLATES AND SHELLS	PEC	3	0	0	3	2020

i) COURSE OBJECTIVES:

Goal of this course is to impart an understanding on various thin walled structures in the form of plates and shells suitable for their use in various structural systems. It develops an ability to study the behaviour of the plates and shells with variable geometry under the action of different types of loads. An ability to apply these concepts in structures is also developed.

ii) COURSE OUTCOMES:

After the completion of the course, the student will be able to:

CO 1	Identify the concepts of various types of plates and their boundary conditions.	Apply
CO 2	Utilize the theory of plates to estimate the deflections in various plates.	Apply
CO 3	Inspect the deformations in circular and annular plates.	Analyse
CO 4	Select shells based on their deflections.	Apply
CO 5	Simplify the expressions for deflections in shells under various conditions.	Analyse
CO 6	Apply the concepts of classical plate theory and theory of folded plates.	Apply
CO 7	Classify special forms of shells and their uses.	Analyse

iii) SYLLABUS:

Introduction to plates, Pure bending of plates, Deflections of laterally loaded plates, Simply supported rectangular plates, Classical Plate theory, Circular plates, Annular plates, Introduction to shells, General theories of cylindrical shells, Theory of folded plates, Special forms of shells

iv) REFERENCES:

1) Timoshenko, S.P. and Krieger, S. W., *Theory of Plates and Shells*, Tata McGraw Hill, 2nd edition, 2017.
2) Chandrashekhara, K., *Theory of Shells*, Universities (India) Press Ltd., 2009.
3) Ramaswamy, G. S., *Design and Construction of Concrete Shell Roofs*, CBS Publishers, 2ndedition, 2018.
4) Kelkar, V. S. and Sewell, R.T., *Fundamentals of the Analysis and Design of Shell Structures*, Prentice Hall Inc., 2014.

5) Varadan, T. K. and Bhaskar, K., *Analysis of Plates – Theory and Problems*, Narosa Publishing Co., 2016.
6) Reddy, J. N., *Theory and Analysis of Plates and Shells*, Taylor and Francis, 2nd edition, 2012.

v) COURSE PLAN:

Module	Contents	No. of hours
I	**Introduction to plates:** Classification of plates – thin, thick plates; Assumptions in the theory of thin plates - Differential equation to bending of long rectangular plates to a cylindrical surface. **Pure bending of plates:** Relation between slope and curvature, bending moments and curvature; Particular cases of pure bending.	7
II	**Deflections of laterally loaded plates:** Differential equation for small deflections in laterally loaded plates **Simply supported rectangular plates:** Solution by Navier's method and Levy's method **Classical Plate theory:** Orthotropic plates, layered plates; Mindlin's plate theory.	8
III	**Circular plates:** Differential equations for symmetrical bending of circular plates - uniformly loaded circular plates with simply supported and fixed edges. **Annular plates:** Plates subjected to uniform moments and shear forces along the boundaries.	7
IV	**Introduction to shells:** Classifications, Membrane theory of shells, application to spherical, conical and cylindrical shells, Deformation of shells without bending - definitions and notations; shells in the form of a surface of revolution and loaded symmetrically with respect to their axis	8
V	**General theories of cylindrical shells:** Deformation of cylindrical shells with supported edges, circular cylindrical shell loaded symmetrically with respect to its axis	7
VI	**Theory of folded plates**: Concepts, Classification of folded plates, Aspects of reinforced concrete folded plates **Special forms of shells:** Hyperbolic shells, hyperbolic paraboloid shells and Conoids; applications of these inn structures	8
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P62B	COMPOSITE STRUCTURES	PEC	3	0	0	3	2020

i) COURSE OBJECTIVES:

Goal of this course is to expose the students to the concepts of composite materials that are finding immense application in the field of aerospace, automobile and civil engineering presently due to its outstanding material capability. It deals with the fundamentals of composite materials for designing composite structures in various fields.

ii) COURSE OUTCOMES:

After the completion of the course, the student will be able to:

CO 1	Describe the properties of fiber and matrix materials used in commercial composites and common manufacturing techniques.	Understand
CO 2	Develop the stress-strain relationship of a unidirectional orthotropic lamina.	Apply
CO 3	Explain the concept of linear elasticity and effective moduli of continuous fibre reinforced lamina.	Understand
CO 4	Describe the micro mechanical behaviour of composite laminates.	Understand
CO 5	Analyse the failure strength of a laminated composite plate.	Analyse
CO 6	Explain the effect of hygrothermal and free-edge interlaminar stresses on the material properties of laminates.	Understand
CO 7	Develop the governing equations of laminated beams and plates subjected to bending and buckling.	Apply
CO 8	Calculate the deflection of composite beams and plates under transverse loads for different boundary conditions.	Apply

iii) SYLLABUS:

Introduction to composites - Composite Fundamentals, Structural applications of Composite Materials, Manufacturing Processes. Mechanics of Composite Lamina, Failure theories. Micro Mechanical Behaviour of Composite Laminates - Classical Lamination Theory, stress-strain variation, In-plane forces, bending and twisting moments, special cases of laminate stiffness. Laminate strength analysis procedure, Failure envelopes,. Free-Edge Interlaminar Effects, Analysis of free edge interlaminar stresses, Effects of stacking sequence- Bending and Buckling of Laminated Beams and Plates.

iv) REFERENCES:

1) Reddy, J. N., *Mechanics of Laminated Composite Plates: Theory and Analysis*, CRC Press, 2nd edition, 2003.
2) Gibson, R. F., *Principles of Composite Material Mechanics*, CRC Press, 4th edition, 2016.
3) Buragohain, M. K., *Composite Structures: Design, Mechanics, Analysis, Manufacturing and Testing*, CRC press, 1st edition, 2017.
4) Springer, G.S., *Mechanics of Composite Structures*, Cambridge University Press, 1st edition, 2009.
5) Barbero, E.J., *Introduction to Composite Materials Design*, CRC Press, 2nd edition, 2014.

v) COURSE PLAN:

Module	Contents	No. of hours
I	**Composite Fundamentals:** Definition of composites-constituents- Classification of composites-Structural applications of Composite Materials-Manufacturing Processes. Review of Basic Mechanics of Materials Equations and Linear Elasticity in 3D and 2-D plane stress and plane strain	7
II	**Lamina Stress-Strain Relationships:** Number of elastic constants and reduction from 81 to 2 for different materials. Stress-Strain relations for a unidirectional and orthotropic lamina **Effective Moduli of a continuous fibre-reinforced lamina:** Models based on mechanics of materials and theory of elasticity - Failure of Continuous Fibre-reinforced orthotropic Lamina - Maximum stress/strain criteria, Tsai-Hill and Tsai-Wu criterion.	8
III	**Micro mechanical behaviour of composite laminates:** Classical Lamination Theory, stress-strain variation, In-plane forces, bending and twisting moments, special cases of laminate stiffness.	7
IV	**Analysis of Laminates:** Laminate strength analysis procedure-Failure envelopes-Progressive failure Analysis. Free-Edge Interlaminar Effects-Analysis of free edge interlaminar stresses - Effects of stacking sequence - Hygrothermal effects on material properties in laminates.	7
V	**Bending of Laminated Beams and Plates:** Governing equations and boundary conditions - Solution techniques - deflection of composite beams and plates under transverse loads for different boundary conditions	8
VI	**Buckling of laminated beams and plates:** Conditions for in-plane loads and under different boundary conditions.	8
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P62C	FRACTURE MECHANICS	PEC	3	0	0	3	2020

i) COURSE OBJECTIVES:

Goal of this course is to expose the students to Significance of fracture mechanics and enhance their problem solving skills. It introduces Linear Elastic Fracture Mechanics, Elastic Plastic Fracture Mechanics, Experimental and Modelling tools and Numerical Simulation of plain concrete fracture experiments.

ii) COURSE OUTCOMES:

After the completion of the course, the student will be able to:

CO 1	Explain concepts of fracture mechanics, linear elastic fracture mechanics and elastic plastic fracture mechanics.	Understand
CO 2	Use stress intensity factor, energy release rate, J integral, Crack tip opening displacement for finding out damage tolerance.	Apply
CO 3	Discuss the role played by plastic zone at the crack tip.	Understand
CO 4	Explain experimental and modelling tools associated with fracture mechanics.	Apply
CO 5	Explain numerical simulation of plain concrete fracture experiments.	Apply

iii) SYLLABUS:

Significance of fracture mechanics, Griffith energy balance approach, Irwin's modification to the Griffith theory, Stress intensity approach, Cack tip plasticity, Fracture toughness, sub-critical crack growth, Linear Elastic Fracture Mechanics (LEFM), Cack Tip Plasticity, LEFM Testing, Plane strain and plane stress fracture toughness testing, Elastic Plastic Fracture Mechanics (EPFM), Fatigue Cack Growth, Sustained Load Fracture, Experimental and Modelling tools, Numerical Simulation of plain concrete fracture experiments.

iv) REFERENCES:

1) Anderson, T. L., *Fracture Mechanics Fundamentals and Applications*, Taylor & Francis Group, the academic division of T&F Informaplc, CRC Pub, Third edition, 2005.
2) Broek, D., *Elementary Engineering Fracture Mechanics*, Sijthoff & Noordhoff International Publishers, 3rd edition, 2020.

3) Simha, K.R.Y., *Fracture Mechanics for Modern Engineering Design*, University Press, 1st edition, 2001.

4) Kumar, P., *Elements of Fracture Mechanics*, Wheeler Publishing, 7th edition ,2014.

v) COURSE PLAN:

Module	Contents	No. of hours
I	**Introduction**, Significance of fracture mechanics, Griffith energy balance approach, Relations for practical use, Irwin's modification to the Griffith theory, Stress intensity approach, Crack tip plasticity, Fracture toughness, sub-critical crack growth, Influence of material behaviour, I, II & III modes, Mixed mode problems.	**7**
II	**Linear Elastic Fracture Mechanics (LEFM),** Elastic stress field approach, Mode I elastic stress field equations, Expressions for stresses and strains in the crack tip region, Finite specimen width, Superposition of stress intensity factors (SIF), SIF solutions for well known problems such as centre cracked plate, single edge notched plate and embedded elliptical cracks.	**7**
III	**Crack Tip Plasticity,** Irwin plastic zone size, Dugdale approach, Shape of plastic zone, State of stress in the crack tip region, Influence of stress state on fracture behaviour, Determination of SIF from compliance, Slow stable crack growth and R-curve concept, Description of crack resistance. Determination of R-curves, Effects of yield strength and specimen thickness on fracture toughness, Practical use of fracture toughness and R-curve data.	**8**
IV	**Elastic Plastic Fracture Mechanics (EPFM),** Development of EPFM, J-integral, Crack opening displacement (COD) approach, COD design curve, Relation between J and COD, Tearing modulus concept, Standard JIc test and COD test. Fatigue Crack Growth:- Description of fatigue crack growth using stress intensity factor, Effects of stress ratio and crack tip plasticity – crack closure, Prediction of fatigue crack growth under constant amplitude and variable amplitude loading, Fatigue crack growth from notches – the short crack problem.	**8**
V	**Experimental and Modelling tools,** Boundary Conditions, Specimen selection, Data acquisition, Theory of experimental designs, Need for standard testing, Fictitious crack model, Lattice model Conventional Finite Elements, Special Crack Tip Elements, Quarter Point Eight Node Isoparametric Elements.	**7**

VI	**Numerical Simulation of plain concrete fracture experiments**, Uniaxial tension, Combined tension and shear, Uniaxial compression, Failure contours Fracture mechanics for structural analysis, Analysis of bond-slip between steel and concrete, Analysis of anchor pull-out, Evaluation of brittlenessof structures Fracture Toughness of Fiber Reinforced Brittle Matrix Composites Crack	**8**
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P63A	ADVANCED PRESTRESSED CONCRETE DESIGN	PEC	3	0	0	3	2020

i) COURSE OBJECTIVES:

Goal of this course is to make students familiar with the concepts and design of typical pre-stressed concrete structural elements and to have knowledge about the provisions in the code of practice.

ii) COURSE OUTCOMES:

After the completion of the course, the student will be able to:

CO 1	Explain the principles, materials and methods of prestressing.	Understand
CO 2	Analyze prestressed concrete structural members and estimate the losses of prestress.	Analyse
CO 3	Apply the concepts of flexure, shear and torsion in the design of prestressed concrete beams.	Apply
CO 4	Analyse the behaviour of prestressed concrete slabs designed as per standards.	Apply
CO 5	Analyze prestressed concrete compression members.	Apply
CO 6	Analyze the behaviour of circular elements subjected to prestressing	Analyse
CO 7	Summarize the concept of transfer of prestress.	Understand

iii) SYLLABUS:

Basic concept and principles of pre-stressed concrete systems, Analysis for flexure, Loss Of pre-stress, Design philosophy and design for flexure, shear and torsion, Codal provisions, Calculation of deflection (short & long term), Design of PSC slabs, Design of compression members, prestressing of statically indeterminate structures, Transfer of prestress, Design of End block

iv) REFERENCES:

1) Dayaratnam, P., *Prestressed Concrete Structures*, Oxford & IBH Publishing Co., 6th edition, 2017.
2) Krishna, R.N., *Prestressed Concrete*, Tata McGraw Hill Publishing Company Ltd., New Delhi, 6th edition, 2018.
3) Lin, T.Y. and Ned H.B., *Design of Prestressed Concrete Structures*, John Wiley and sons, New York, 3rd edition.

4) Praveen, N., *Prestressed Concrete Design*, Pearson Education India, Delhi, 1st edition, 2013.
5) Lin, T.Y., *Design of Prestressed Concrete Structures*, Asia Publishing House, Bombay 2013.
6) Mallic, S.K. and Gupta, A.P., *Prestressed Concrete*, Oxford and IBH publishing Co. Pvt. Ltd., 2017.
7) Ramaswamy, G.S., *Modern Prestressed Concrete Design*, Arnold Heinimen, New Delhi, 2007.
8) IS 1343 – 2012 (Reaffirmed 2012), *Preststressed Concrete Code of Practice*, Bureau of Indian Standards, 2012.

v) COURSE PLAN:

Module	Contents	No. of hours
I	**Introduction:** Principles – advantages – materials for prestressed concrete - definition of Type I, Type II and Type III structures – requirements. **Methods of prestressing** – pre-tensioning and post-tensioning – anchorage systems. **Analysis**: Assumptions – Analysis of Prestress – Resultant Stresses at a section –Thrust Line – Concept of load balancing – Stresses in tendons – Cracking Moment.	**8**
II	**Loss of Prestress** - Stages of losses, Types of losses in pre-tensioning and post-tensioning due to Elastic shortening, Shrinkage, Creep, Relaxation, Anchorage Slip, Friction - Concept of reduction factor. **Design for flexure**: Philosophy - limit states - concepts - collapse and serviceability - service load - basic requirements - stress range approach - Lin's approach - Magnel's approach - cable layouts. **Design for shear:** Shear and principal stresses - limit state shearing resistance of cracked and uncracked sections - design of shear reinforcement by limit state approach.	**8**
III	**Design for torsion:** Behaviour under torsion - modes of failure - design for combined torsion, shear and bending as per IS 1343: 2012.	**7**

	Deflection: Deflection - short and long term deflection of uncracked and cracked members as per IS 1343 : 2012 Design and analysis of post and pre-tensioned PSC slabs.	
IV	**Design of Compression members** (Concepts only, no design expected):- Design of compression members with and without flexure, its application in the design of Piles, Flag masts and similar structures. **Prestressing of statically indeterminate structures:** Advantages, Effect, Method of achieving continuity, Primary, Secondary and Resultant moments, Pressure line, Concept of Linear transformation, Guyon's theorem, Concordant cable profile.	**7**
V	**Tanks and pipes:** Circular prestressing in liquid retaining tanks - analysis for stresses - design of tank wall. PSC pipes - types - design of non cylinder pipes (Codal provisions only).	**7**
VI	**Transfer of prestress**: Transmission of prestressing force by bond in pretensioned members - Transmission length - Factors affecting transmission length - check for transmission length - transverse tensile stresses Anchorage zone stresses in post-tensioned members - Magnel's method - Calculation of bearing stress and bursting tensile forces - code provisions - Reinforcement in anchorage zone.	**8**
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P63B	ANALYSIS AND DESIGN OF SUBSTRUCTURES	PEC	3	0	0	3	2020

i) COURSE OBJECTIVES:

Goal of this course is to equip students to identify soil-structure interaction, select suitable foundation for different types of structures, analyse and design foundations.

ii) COURSE OUTCOMES:

After the completion of the course, the student will be able to:

CO 1	Interpret the selection of foundation.	Understand
CO 2	Analyse the effectiveness in the design of combined footing and raft foundation.	Analyse
CO 3	Explain about single pile and pile groups.	Understand
CO 4	Analyse the effectiveness in the design of pile and pile cap.	Analyse
CO 5	Analyse the effectiveness in the design of well foundation.	Analyse
CO 6	Analyse the behaviour of retaining walls designed as per standards.	Apply

iii) SYLLABUS:

Introduction to soil-structure interaction, selection of foundations. Structural Design of Shallow Foundation. Introduction to pile foundation, efficiency of pile groups. Structural Design of Pile and pile cap. Design of well foundation.

iv) REFERENCES:

1) Murthy, V. N. S., *Advanced Foundation Engineering*, CBS Publishers & Distributors Pvt. Ltd., New Delhi, 1st edition, 2007.
2) Saran, S., *Analysis and Design of Substructures*, Oxford and IBH Publishing Company Pvt. Ltd., New Delhi, 2nd edition, 2013.
3) Coduto, D. P., *Foundation Design: Principles and Practices,* Dorling Kinderseley India Pvt. Ltd., 3rd edition, 2012.
4) Varghese, P. C., *Foundation Engineering*, Prentice Hall India, New Delhi, 1st edition, 2005.

v) COURSE PLAN:

Module	Contents	No. of hours
I	Introduction to soil-structure interaction - Soil-structure interaction problems. Contact pressure distribution beneath rigid and flexible footings on sand and clay - Contact pressure distribution beneath raft. Selection of foundations.	**7**
II	Structural Design of Shallow Foundation- spread footing, combined Footing and raft foundation.	**8**
III	Pile foundation: Introduction - Estimation of pile capacity by static and dynamic formulae- Settlement of single pile - Laterally loaded piles - Brom's method - Ultimate lateral resistance of piles - Pile groups - Consideration regarding spacing - Efficiency of pile groups.	**8**
IV	Structural Design of Pile and pile cap.	**7**
V	Introduction to well foundations – Elements of well foundations – Types – Sinking stresses in wells – Design of well cap, Well steining, well curb, cutting edge and bottom plug.	**7**
VI	Retaining Walls-Types - Stability analysis of cantilever retaining walls against overturning and sliding-Bearing capacity considerations- Structural design of retaining walls	**8**
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P63C	HIGH RISE STRUCTURES	PEC	3	0	0	3	2020

i) COURSE OBJECTIVES:

The goal of this course is to impart knowledge in fundamental and latest concepts, techniques in the analysis and design of wind & seismic-resistant tall structures.

ii) COURSE OUTCOMES:

After the completion of the course, the student will be able to:

CO 1	Analyse the performance of transmission/ TV tower, mast and trestles designed for different loading conditions.	Analyse
CO 2	Analyse the response of cooling towers designed as per standards.	Analyse
CO 3	Analyse the effectiveness of RC and steel chimney designed as per standards.	Analyse
CO 4	Analyse the performance of tall buildings subjected to different loading conditions designed using relevant codes.	Analyse
CO 5	Analyse the performance of high rise structures designed using computational software.	Analyse
CO 6	Analyse the performance of structures subjected to seismic loads using software package	Analyse

iii) SYLLABUS:

Analysis and design of Transmission/ TV tower, Mast and trestles, Cooling towers, RC and Steel Chimney and Tall Buildings, Structural systems, Application of software in analysis and design

iv) REFERENCES:

1) Byran, S. and Alex, C., *Tall Building Structures*, Wiley, 1st edition, 1991.
2) Manohar, S. N., *Tall Chimneys-Design and Construction*, Tata McGraw-Hill, 1st edition, 1985.
3) Murthy, S. S. and Santhakumar, A. R., *Transmission Line Structures*, McGraw-Hill, 1st edition, 1990.
4) Relevant IS codes (IS 4998 (Part 1): 1992 (Reaffirmed 2012), IS 6533 (Part 2): 1989 (Reaffirmed 2003), IS 6533 (Part 2): 1989 (Reaffirmed 2003)), Bureau of Indian Standards, New Delhi.
5) Raju, K. N., *Advanced Reinforced Concrete Design*, University Press, 4th edition, 2007.
6) Yaoqing, G., *Tall Building Structures on Elastic Subgrade and Research of Semi-Analytical Method*, Tsinghua University, 1999.

v) COURSE PLAN:

Module	Contents	No. of hours
I	**Transmission/ TV tower, Mast and trestles:** Configuration, bracing system, analysis and design for vertical transverse and longitudinal loads.	8
II	**Cooling towers:** types, components, design forces, analysis and design	8
III	**RC and Steel Chimney:** wind load analysis, design,Foundation design for varied soil strata.	8
IV	**Tall Buildings:** Structural Concept, Configurations, Various structural systems - Rigid frame Structures, Braced frames, Infilled frames, Shear walls, Coupled shear walls, Wall frame structures, Tubular structures, core structures, outrigger braced structures.	7
V	**Wind and Seismic loads:** Dynamic approach, structural design considerations and IS code provisions. Fire-fighting design provisions.	
VI	**Application** of software in analysis and design.	7
	Total hours	45

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P68B	STRUCTURAL DYNAMICS LAB	PCC	0	0	2	1	2020

i) COURSE OBJECTIVES:

Goal of this course is to study the dynamic response of structures and to understand the concept of amplification, liquefaction and soil structure interaction of structures. The course is also intended to familiarize the students with the various finite element software packages available for structural applications.

ii) COURSE OUTCOMES:

After the completion of the course the student will be able to:

CO 1	Investigate the dynamic response of structures subjected to harmonic and non-harmonic base motion.	Analyse
CO 2	Investigate the effectiveness of vibration isolation system and vibration absorber.	Analyse
CO 3	Analyse the dynamic response of a four storied building frame with and without an open ground floor.	Analyse
CO 4	Analyse the vibration of single and two span beams.	Analyse
CO 5	Demonstrate seismic parameters, response and soil structure interaction of structures.	Apply
CO 6	Apply software tools to analyse of plates	Apply
CO 7	Explain the fundamentals of MATLAB	Understand

iii) SYLLABUS:

- Dynamics of a single storied building frame with planar asymmetry subjected to harmonic base motion - 1 session
- Dynamics of a three storied building frame with and without planar asymmetry subjected to periodic (non-harmonic) base motion - 1 session
- Vibration isolation of a secondary system - 1 session
- Dynamics of a vibration absorber - 1 session
- Dynamics of a four storied building frame with and without an open ground floor - 1 session
- Dynamics of a single and two span beams - 1 session
- Earthquake induced waves in rectangular water tanks, Dynamics of free standing rigid bodies under base motion, Seismic wave amplification, liquefaction and soil structure interaction (Demonstration only) - 1 session
- Introduction to finite element software packages - 1 session

- Stress analysis of plates: Circular plate, Rectangular plate, Rectangular plate with a circular hole - 4 sessions
- Introduction to MATLAB and study of basic matrix operations using MATLAB - 2 sessions

iv) REFERENCES:

1) Paz, M., *Structural Dynamics – Theory and Computation*, CBS Publishers and Distributors, 2004.
2) Mukhopadhyay, M., *Structural Dynamics - Vibrations and Systems*, Ane Books, 2nd edition, 2008.
3) Chopra, A. K., *Dynamics of Structures- Theory and Application to Earthquake Engineering*, Pearson Education, 1st edition, 2001.
4) IS 1893 (Part 1): 2016, *Criteria for Earthquake Resistant Design of Structures*, Bureau of Indian Standards, New Delhi, 2016.
5) Reference manual of the relevant software

v) COURSE PLAN:

Module	Contents	No. of hours
I	Dynamics of a single storied building frame with planar asymmetry subjected to harmonic base motion	**2**
II	Dynamics of a three storied building frame with and without planar asymmetry subjected to periodic (non-harmonic) base motion	**2**
III	Vibration isolation of a secondary system	**2**
IV	Dynamics of a vibration absorber	**2**
V	Dynamics of a four storied building frame with and without an open ground floor	**2**
VI	Dynamics of a single and two span beams	**2**
VII	a) Earthquake induced waves in rectangular water tanks (Demonstration only) b) Dynamics of free standing rigid bodies under base motion (Demonstration only). c) Seismic wave amplification, liquefaction and soil structure interaction (Demonstration only)	**3**
VIII	Introduction to finite element software packages	**2**
IX	Stress analysis of plates: Circular plate, Rectangular plate, Rectangular plate with a circular hole	**8**
X	Introduction to MATLAB and study of basic matrix operations using MATLAB	**5**
	Total hours	**30**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P69B	MINI PROJECT	PWS	0	0	4	2	2020

i) COURSE OBJECTIVES:

Goal of this course is to enable students to take up small problems in their field of study as mini project and collect the recent publications related to the topic and present the observations and findings related to the project work.

ii) COURSE OUTCOMES:

After the completion of the course, the student will be able to:

CO 1	Identify promising new directions of various cutting edge technologies
CO 2	Organize information after the study of research papers related to the branch of study
CO 3	Develop effective written and oral communication
CO 4	Identify potential research areas in the field of their study
CO 5	Formulate and propose a plan for creating a solution for the research plan identified
CO 6	Analyse and interpret data to provide valid conclusions.

iii) APPROACH:

1) Students shall make a presentation for 20-25 minutes based on the detailed study on the project and submit a report of the study.
2) There will be two interim progress review of the Mini project work. The first review will focus on the topic, objectives, methodology, design and expected results.

SEMESTER – III

Syllabus and Course Plan

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P71A	DESIGN OF BRIDGES	PEC	3	0	0	3	2020

i) COURSE OBJECTIVES:

This course is to expose the students to the fundamentals of design of bridges by imparting knowledge on the various methods of analysis of loads acting on different types of bridge structures using IRC code.

ii) COURSE OUTCOMES:

After the completion of the course the student will be able to:

CO 1	Explain the different components of a bridge and forces acting as per IRC codes.	Understand
CO 2	Apply the different methods of analysis according to the type of bridge.	Apply
CO 3	Analyse the performance of RC deck slab, T-beam and slab, single vent box girder and balance cantilever bridges designed according to IRC codes.	Analyse
CO 4	Analyse the effectiveness in the design of prestressed concrete bridges.	Analyse
CO 5	Analyse the behaviour of substructure, foundation and bearing designed for the load coming from bridge deck.	Analyse

iii) SYLLABUS:

Introduction to Bridge Engineering: types of bridges, forces and design criteria, IRC loads, Bridge Deck Analysis - Design of RCC deck slab, T-beam and slab, box girder, balanced cantilever bridge - Analysis and design of Prestressed concrete bridge - Design of substructure and foundation, bearings

iv) REFERENCES:

1) Victor, D. J., *Essentials of Bridge Engineering*, Oxford, IBH publishing Co., Ltd, 7th edition, 2006.

2) Raju, N. K., *Prestressed Concrete Bridges*, CBS Publishers & Distributors, McGraw-Hill Education, 6th edition, 2018.

3) Raju, N. K., *Design of Bridges*, Oxford and IBH Publishing Co., Ltd., 5th edition, 2015.

4) Relevant IRC codes: IRC 6-2017, IRC: 22-2015, IRC: 112-2011, IRC: 78-2014, IRC: 83-2015, Part I, IRC: 83, 2018, Part II, *Standard Specifications and Code of Practice for Road Bridges,* Indian Road Congress, New Delhi.

5) IS 456-2000, (Reaffirmed 2005), *Plain and Reinforced Concrete Code of Practice*, Bureau of Indian Standards, New Delhi, 2005.
6) Jagadish, T.R. and Jayaram, M.A., *Design of Bridge Structures*, 2nd edition, 2009.
7) Vazirani, Ratvani and Aswani, *Design of Concrete Bridges*, Khanna Publishers, 5th edition, 2006.

v) COURSE PLAN:

Module	Contents	No. of hours
I	**Introduction to Bridge Engineering:** Components on bridge structures, Planning of bridges (traffic, hydro-technical, geotechnical, environmental and constructability/economic feasibility studies) - Bridge types and selection criteria - Geometric design considerations	**5**
II	**Bridge Loads and Design Methods:** Highway bridge loads as per IRC codes - Load combinations **Bridge Deck Analysis:** Simplified deck analysis and load distribution methods (Pigeaud, Courbon, Morrice-Little, Hendry- Jaegar methods)	**8**
III	**R. C. Bridges:** Design of R. C bridge decks-slab bridges-Straight and skew slab bridges - Design of T beam bridges	**8**
IV	**Other Bridges:** Introduction - continuous girder bridges, rigid frame bridges, arch bridges, suspension bridges and cable stayed bridges **Box girder bridges**: Design of box girder (Single cell only) **Balanced Cantilever Bridge:** Design of Balanced cantilever bridge	**9**
V	**Pre-stressed Concrete Bridges**: Design of single span bridges- Introduction to various forms - Slab bridges-girder bridges- box girder	**8**
VI	**Substructure:** parts of substructures, types of substructures, Loads acting on substructures, Design of pier and pier cap, Design of different types of foundation – Open & well foundation **Bearings:** Forces, types - Design of elastomeric bearings-expansion joints	**8**
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P71B	STRUCTURAL RELIABILITY	PEC	3	0	0	3	2020

i) COURSE OBJECTIVES:

This course aims to introduce the basics of the structural reliability analysis procedures and to familiarize students with the applications of probability analysis and reliability techniques in structural engineering.

ii) COURSE OUTCOMES:

After the completion of the course the student will be able to:

CO 1	Discuss the mathematical tools for quantifying uncertainties using theories of probability, random variables and random processes.	Understand
CO 2	Explain the methods of reliability analysis using Monte Carlo simulations.	Understand
CO 3	Apply reliability methods to analyse structural systems.	Apply
CO 4	Apply code provisions for reliability based design.	Apply

iii) SYLLABUS:

Fundamentals of probability theory, resistance distributions and parameters, probabilistic analysis for loads, basic structural reliability, level 2 reliability methods, Monte Carlo study of structural safety, reliability of structural system, reliability based design.

iv) REFERENCES:

1) Melchers, R.E., *Structural Reliability Analysis and Prediction*, John Wiley & Sons, 3rd edition, 2018.
2) Ranganathan, R., *Reliability Analysis and Design of Structures*, Tata McGraw Hill, New edition, 2006.
3) Ang, A. H. S. and Tang, W. H., *Probability Concepts in Engineering Planning and Design*, Volume 1-Basic Principles, John Wiley & Sons, New York,1st edition, 1975.
4) Ang, A. H. S. and Tang, W. H., *Probability Concepts in Engineering Planning and Design*, Volume II, John Wiley & Sons, Inc., New York, 1st edition, 1984.
5) Benjamin, J. R. and Cornell, C. A., *Probability, Statistics and Decision for Engineers*, Mc-Graw-Hill, Reprint edition, 2014.

v) COURSE PLAN:

Module	Contents	No. of hours
I	**Fundamentals of Probability theory**: Concepts of Structural safety, design method, basic statistics and probability data reductions. Histograms, sample correlation, Random variables, functions of random variables, moments and expectation, discrete and continuous variables, common probability distributions.	7
II	**Resistance distributions and parameters**: Introduction, Statistics of properties of concrete, steel and other building materials, statistics of dimensional variations, characterization of variables, allowable stresses based on specified reliability. **Probabilistic analysis** for live load, gravity load and wind load.	7
III	**Basic structural reliability:-** Introduction, computation of structural reliability, reliability analysis of simple elements.	7
IV	**Level 2 Reliability methods**: Introduction, basic variables and failure surface, first order second moment methods (FOSM).	8
V	**Monte Carlo study of structural safety**: -General, Monte Carlo method, applications. **Reliability of Structural system**: Introduction, system reliability, modelling of structural systems, bounds of system reliability, reliability analysis of frames.	8
VI	**Reliability based design:** Introduction, resistance factors of design, safety checking formats and code calibrations, IS Code provisions, introduction to stochastic process.	8
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P71C	OPERATIONS RESEARCH	PEC	3	0	0	3	2020

i) COURSE OBJECTIVES:

Goal of this course is to introduce important ideas in Operation Research, develop skill in formulating and building models, translate a verbal description of a decision problem into an equivalent mathematical model and demonstrate the cohesiveness of Operation Research methodology.

ii) COURSE OUTCOMES:

After the completion of the course the student will be able to:

CO 1	Apply the dynamic programming to solve problems of discrete and continuous variables.	Apply
CO 2	Apply the concept of non-linear programming.	Apply
CO 3	Demonstrate sensitivity analysis.	Apply
CO 4	Develop the real world problem and simulate it.	Analyse

iii) SYLLABUS:

Optimization Techniques, Model Formulation, Sensitivity Analysis, Inventory Control Models, Formulation of a LPP, Nonlinear programming, Scheduling and sequencing, Competitive Models, Single and Multi-channel Problems, Sequencing Models, Dynamic Programming, Flow in Networks, Elementary Graph Theory, Game Theory Simulation.

iv) REFERENCES:

1) Panneerselvam, *Operations Research,* Prentice Hall of India, 2010.
2) Wagner, H.M., *Principles of Operations Research,* Prentice Hall of India, 2010.
3) Taha, H.A., *Operations Research, an Introduction*, PHI, 8th Edition, 2013.
4) Pant, J.C., *Introduction to Optimisation: Operations Research*, Jain Brothers, Delhi, 7th Edition, 2015.
5) Libermann, H., *Operations* Research: McGraw Hill Pub., 10th Edition, 2017.

v) COURSE PLAN:

Module	Contents	No. of hours
I	Optimization Techniques, Model Formulation, models, General L.R Formulation, Simplex Techniques, Sensitivity Analysis, Inventory Control Models	**7**
II	Formulation of a LPP - Graphical solution revised simplex method - duality theory - dual simplex method - sensitivity analysis - parametric programming	**8**
III	Nonlinear programming problem - Kuhn-Tucker conditions min cost flow problem - max flow problem - CPM/PERT	**8**
IV	Scheduling and sequencing - single server and multiple server models - deterministic inventory models - Probabilistic inventory control models - Geometric Programming.	**8**
V	Competitive Models, Single and Multi-channel Problems, Sequencing Models,	**7**
VI	Dynamic Programming, Flow in Networks, Elementary Graph Theory, Game Theory Simulation	**7**
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P72A	STABILITY OF STRUCTURES	PEC	3	0	0	3	2020

i) COURSE OBJECTIVES:

Goal of this course is to expose the students to buckling phenomenon which occurs in the structures like columns, beam-columns, frames, plates and shells. It thus helps them to understand the stability of engineering structures.

ii) COURSE OUTCOMES:

After the completion of the course the student will be able to:

CO 1	Explain the stability of columns using small and large deformation theories.	Understand
CO 2	Explain the imperfect column behaviour and inelastic buckling of columns.	Understand
CO 3	Analyse the stability of columns using various approximate methods.	Analyse
CO 4	Explain the buckling of built-up columns and the effect of shear on critical load of axially loaded columns.	Understand
CO 5	Calculate the critical load of beam-columns and frames.	Apply
CO 6	Illustrate the concept of torsional buckling of columns and the lateral buckling of beams.	Apply
CO 7	Analyse the stability of a plate uniformly compressed in one direction under different boundary conditions.	Analyse

iii) SYLLABUS:

Buckling of Columns -Methods of Neutral Equilibrium, Large Deformation Theory for Columns, Energy method for calculating critical loads, Buckling of Beam Columns, Torsional Buckling, Buckling of Frames, Stability of a frame by Matrix Analysis, Buckling of Plates, Instability of shells

iv) REFERENCES:

1) Timoshenko, S. P. and Gere, J. M., *Theory of Elastic Stability,* Dover Publications, 2nd edition, 2009.
2) Chajes, A., *Principles of Structural Stability Theory*, Prentice Hall Inc., 1974.

3) Iyenger, N. G. R., *Structural Stability of columns and plates*, Affiliated East West Press Pvt. Ltd., 1990.

4) Bazant, Z.P. and Cedolin, L., *Stability of Structures: Elastic, Inelastic, Fracture and damage Theories*, World Scientific Publishing, 1st edition, 2010.

5) Gambhir, M.L.., *Stability Analysis and Design of Structures*, Springer, 1st edition, 2004.

v) COURSE PLAN:

Module	Contents	No. of hours
I	Buckling of Columns: Introduction - Concepts of Stability - Methods of Neutral Equilibrium - Euler Column - Eigen Value Problem – Axially Loaded Column - Effective Length Concept and Design Curve.	7
II	Large Deformation Theory for Columns. Behaviour of Imperfect Columns: Initially bent column- Eccentrically Loaded Column. Inelastic Buckling of Columns- Double Modulus Theory- Tangent Modulus Theory.	7
III	Energy method for calculating critical loads: Rayleigh Ritz Method - Galerkin Method. Numerical Methods- Matrix Stiffness Method – Flexural and Compression Members	7
IV	Buckling of Built up Columns: Non-prismatic members- Effect of shear on critical Loads. Beams and Beam Columns: Introduction- Beam Column with Concentrated and Distributed Loads - Effect of Axial Load on Bending Stiffness. Design of Beam Columns- Interaction Formula.	8
V	Buckling of Frames: Introduction - Modes of Buckling - Critical Load using Neutral Equilibrium Methods. Stability of a frame by Matrix Analysis. Torsional Buckling: Torsional and Torsional-Flexural Buckling of Columns, Lateral Buckling of Beams. Continuous beams with axial load.	8
VI	Buckling of Plates: Differential Equation of Plate Buckling - Critical Load of a plate uniformly compressed in one direction. Tension field behaviour in Plate Girder Webs - Post-buckling behaviour of axially compressed plates. Instability of shells.	8
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P72B	RANDOM VIBRATION	PEC	3	0	0	3	2020

i) COURSE OBJECTIVES:

The course gives an overview of statistical concepts in random vibration analysis and the behaviour of dynamic systems subjected to random vibrations.

ii) COURSE OUTCOMES:

After the completion of the course the student will be able to:

CO 1	Discuss the probability theory and describe the important properties of random processes.	Understand
CO 2	Classify random excitations.	Understand
CO 3	Compute power spectral and cross spectral density functions.	Apply
CO 4	Explain the properties of Guassian, Poisson and Markov process.	Understand
CO 5	Compute the response of linear SDOF, MDOF and continuous systems subjected to random excitation.	Apply
CO 6	Discuss the basics of nonlinear random vibration.	Apply

iii) SYLLABUS:

Basic concepts in Probability Theory – Random process - spectral density functions – Properties of various random processes - Random vibration - response of linear SDOF, MDOF and continuous systems – Basics of nonlinear random vibration.

iv) REFERENCES:

1) Nigam, N. C., *Introduction to Random Vibration*, MIT Press, 1983.
2) Andre, P. *Random Vibration and Spectral Analysis*, Kluwer Academic Publishers, 1994.
3) Lin, Y. K., Probabilistic Structural Dynamics Advanced Theory and Applications, Mc-Graw Hill., Illustrated edition, 2004.
4) Cho, T. W. S., *Nonlinear Random Vibration*, Taylor and Francis, 2nd edition, 2000.
5) Lalanne, C., *Random Vibration*, CRC Press, 2002.
6) Wirsching, P. H, Paez, T. L. and Ortiz, H., *Random Vibration*, Dover Publications, 2006.
7) Nigam N.C and Narayanan S., *Applications of Random Vibration*, Narosa, 1994.

v) COURSE PLAN:

Module	Contents	No. of Lectures
I	Probability Theory – Random variables, Probability distribution and density functions – Expected value mean, variance, conditional probability, characteristic functions, Chebyshev inequality, functions of random variable	**8**
II	Random process - concepts of stationary and ergodicity– nonstationary process – auto and cross correlation and covariance functions – Mean square limit, differentiability and integrability	**7**
III	Spectral decomposition, power spectral and cross spectral density functions – Wiener Khintchine relation	**7**
IV	Properties of Guassian, Poisson and Markov process. Broad band and narrow band random process – white noise	**7**
V	Random vibration - response of linear SDOF and MDOF systems to stationary and non-stationary random excitation. Response of continuous systems – normal mode method	**9**
VI	Nonlinear random vibration - Markov vector – equivalent linearisation and perturbation methods - Level crossing, peak and envelope statistics – First excursion and fatigue failures - Applications	**7**
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P72C	ENGINEERING APPLICATION OF ARTIFICIAL INTELLIGENCE AND EXPERT SYSTEMS	PEC	3	0	0	3	2020

i) COURSE OBJECTIVES:

Goal of this course is to introduce the different algorithms that can be applied in Artificial Intelligence and demonstrate an idea about how the algorithms can be used to solve Civil Engineering problems.

ii) COURSE OUTCOMES:

After the completion of the course the student will be able to:

CO 1	Explain basic concepts of Artificial Intelligence.	Understand
CO 2	Classify various concepts in expert systems.	Apply
CO 3	Explain knowledge representation and search techniques.	Apply
CO 4	Summarize different computer vision processing techniques.	Apply
CO 5	Explain concepts of machine learning and neural network.	Understand

iii) SYLLABUS:

Introduction to Artificial Intelligence, Knowledge representation, Expert system & Search, Search techniques Computer Vision, Advanced Topics- Machine Learning Genetic Algorithm – Neural Networks.

iv) REFERENCES:

1) Cawsey, A., *The Essence of Artificial Intelligence*, Pearson Education Ltd., 2011.
2) Charniak and McDermott, *Introduction to Artificial Intelligence*, Pearson Education Ltd., 2007.
3) Patterson, D. W., *Introduction to Artificial Intelligence and Expert Systems,* Pearson Education Ltd., 2015.
4) Winston, *Artificial Intelligence*, Addison-Wesley, 2002.
5) Nilsson, *Quest for Artificial Intelligence*, Cambridge University Press, 2009.
6) Rich, E., Knight K., Nair, S. B., *Artificial Intelligence*, M-Graw Hill, 2017.

v) COURSE PLAN:

Module	Contents	No. of hours
I	Introduction to AI – Definition – Typical AI Problems – Knowledge representation and search – philosophical issues – Requirements of knowledge representation languages – semantic Networks – Frames – Predicate Logic – Rule Based Systems – Forward and Backward chaining – Comparison of different – representation methods.	**8**
II	Expert system & Search – Heuristic – Knowledge Engineering – expert System – Designing an Expert System – Backward chaining – Rule based expert systems – Explanation facilities – Bayers's theorem – case study of MYCIN	**8**
III	Search techniques, Breadth first search, depth first search, Heuristic search – Hill climbing, Best – first – search, A* algorithm	**7**
IV	Graphs and Tree Representation. Problem solving as search, Planning, Game planning – Minimax and alpha – beta proving. Searching AND –OR Graph, Optimal Search – The Best path and Redundant Path	**8**
V	Computer Vision – Different levels of vision processing – Low level processing edge deletion line filling – depth & Orientation information – Object recognition – Practical vision system.	**7**
VI	Advanced Topics – Machine Learning – Introduction – Genetic Algorithm – Neural Networks – Back propagation – Multi layer network – Applications – Software agents – Robots – different types – applications.	**7**
	Total hours	**45**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P79A	Seminar II	PWS	0	0	2	2	2020

i) COURSE OBJECTIVES:

To make students

1. Identify the current topics in the specific stream.
2. Collect the recent publications related to the identified topics.
3. Do a detailed study of a selected topic based on current journals, published papers and books.
4. Present a seminar on the selected topic on which a detailed study has been done.
5. Improve the writing and presentation skills

ii) APPROACH:

Students shall make a presentation for 20-25 minutes based on the detailed study of the topic and submit a report based on the study

iii) EXPECTED OUTCOMES:

Upon successful completion of the Project (Phase I), the student should be able to:

CO 1	Identify promising new directions of various cutting edge technologies.
CO 2	Organize information after the study of research papers related to the branch of study.
CO 3	Develop effective written and oral communication

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P79B	PROJECT (PHASE 1)	PWS	0	0	12	6	2020

i) COURSE OBJECTIVES:

To make students

1) Do an original and independent study on the area of specialization.
2) Explore in depth a subject of his/her own choice.
3) Start the preliminary background studies towards the project by conducting literature survey in the relevant field.
4) Broadly identify the area of the project work, familiarize with the tools required for the design and analysis of the project.
5) Plan the experimental platform, if any, required for project work.

ii) APPROACH:

1) There will be three interim progress review of the Project (Phase I). The first review shall focus on the topic, and objectives. This review will be conducted within one month of the commencement of third semester classes.
2) The second review shall focus on the methodology. This review will be conducted within two months of the commencement of third semester classes.
3) The third review shall focus on the design and expected results, and scope of the work which has to be accomplished in the fourth semester. This review will be conducted towards the close of the third semester.

iii) EXPECTED OUTCOMES:

Upon successful completion of the Project (Phase I), the student should be able to:

CO 1	Identify a topic of interest in the field of structural Engineering.
CO 2	Interpret and summarize several available literature in the preferred field of study.
CO 3	Develop comprehensive solution to issues identified.
CO 4	Develop effective written and oral communication.

SEMESTER – IV

Syllabus and Course Plan

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
CE1P79C	PROJECT (PHASE 2)	PWS	0	0	24	12	2020

i) COURSE OBJECTIVES:

To continue and complete the project work identified in Project (Phase I).

ii) APPROACH:

1) There will be three interim progress review of the Project (Phase II). The first review shall focus on the progress of the implementation of the design made in Project (Phase I). This review will be conducted within one month of the commencement of third semester classes.
2) The second review shall focus on the quality and quantum of the work completed.

   This review will be conducted within two months of the commencement of third semester classes.
3) The third review shall focus on the completed implementation and the results. This review will be conducted towards the close of the third semester.
4) At least one technical paper has to be prepared and published in journals / conferences based on their project work.

iii) EXPECTED OUTCOMES:

Upon successful completion of the Project (Phase II), the student should be able to:

CO 1	Make use of equipment or software to investigate experimentally/ numerically the response of structures/ structural systems.
CO 2	Analyse data to solve the problem identified.
CO 3	Interpret the results of the detailed studies conducted to arrive at valid conclusions.
CO 4	Develop effective written and oral communication