भारतीय प्रौद्योगिकी संस्थान भुवनेश्वर

INDIAN INSTITUTE OF TECHNOLOGY BHUBANESWAR

School of Infrastructure

Curriculum and Syllabus for

M. Tech. (Structural Engineering)

Preceding Degree:

B.E / B.Tech or equivalent degree in Civil Engineering

Intake per year: 15 students

Compliance Report of M. Tech. (Structural Engineering) Curriculum

Components	Subjects	As per 64th Senate		Proposed Credit Structure for M.Tech (Transportation Engineering)	
		Nos.	Credits	Nos.	Credits
Theory	Total	9 to 10 Nos.	-	9 Nos.	30-35
	Departmental Core courses	-	-	4	15
	Electives	-	-	5	15-20
Labs		3 to 4 Nos.	-	3 Nos.	6
Seminar		-	-	-	-
Thesis		3 Parts	2+14+14	3 Parts	30
Total Credits			65-74		66-71

Curriculum for M.Tech. (Structural Engineering)

Semester I					
S. No.	**Subject**	**Code/ Type**	**L-T-P**	**Credit**	**Contact Hours**
1	Dynamics of Structures	CE6L301 (Dept. Core)	3-1-0	4	4
2	Theory of elasticity	CE6L303 (Dept. Core)	3-1-0	4	4
3	Elective 1	Dept. Elective/open elective	3-0-0/ 3-1-0	3/ 4	3 / 4
4	Elective 2	Dept. Elective/open elective	3-0-0/ 3-1-0	3/ 4	3 / 4
5	Elective 3	Dept. Elective/open elective	3-0-0/ 3-1-0	3/ 4	3 / 4
6	Advanced Structural Lab	CE6P301 (Core lab)	0-0-3	2	3
Semester II					
S. No.	**Subject**	**Code/ Type**	**L-T-P**	**Credit**	**Contact Hours**
1	Advanced Concrete Technology	CE6L304 (Dept. Core)	3-0-0	3	3
2	Finite Element Methods	CE6LXXX (Dept. Core)	3-1-0	4	4
3	Elective 4	Dept. Elective/open elective	3-0-0/ 3-1-0	3/ 4	3 / 4
4	Elective 5	Dept. Elective/open elective	3-0-0/ 3-1-0	3/ 4	3 / 4
5	Computational Lab	CE6P302 (Core lab)	0-0-3	2	3
6	Design of special structures	CE6P303* (Core lab)	0-0-3	2	3
7	Thesis part I	CE6D001	0-0-0	2	-
8	Industrial internship	Optional	-	-	-
Semester III					
S. No.	**Subject**	**Code/ Type**	**LTP**	**Credit**	**Contact Hours**
1	Thesis part II	CE6D002	0-0-0	14	-
Semester IV					
S. No.	**Subject**	**Code/ Type**	**LTP**	**Credit**	**Contact Hours**
1	Thesis part III	CE6D003	0-0-0	14	-
			Total Credits:	**66/71**	

Elective courses (I to V)*				
Name	**Subject Code**	**L-T-P**	**Credit**	**Contact Hour**
Advanced Structural Analysis	**CE6L302**	3-1-0	4	4
Theory of Plates & Shells	**CE6L305**	3-1-0	4	4
Seismic Design of Structures	**CE6L306**	3-1-0	4	4
Bridge Engineering	**CE6L307**	3-0-0	3	3
Infrastructure Maintenance and Rehabilitation	**CE6L308**	3-0-0	3	3
Modern Construction Materials	**CE6L309**	3-0-0	3	3
Advanced construction Techniques	**CE6L310**	3-0-0	3	3
Construction Project Management	**CE6L311**	3-0-0	3	3
Advanced Design of RC Structures	**CE6L312**	3-1-0	4	4
Theory of Elastic Stability	**CE6L313**	3-1-0	4	4
Vision-based Structural Sensing	**CE6LXXX**	2-0-2	3	4
Structural Health Monitoring	**CE6L029**	3-0-0	3	3
Mathematical Methods	**MA6L001**	3-1-0	4	4
Advanced Techniques in Operation Research	**MA6L002**	3-1-0	4	4

*Any other subjects of the same level offered by any other specializations of SIF or any other Schools can also be taken as an elective, as suggested by faculty advisor/PG Coordinators.

Syllabus

Subject Code: CE6L301	Name: Dynamics of Structures	L-T-P: 3-1-0	Credit: 4

Prerequisite: None

Single-degree-freedom systems: undamped and damped free vibration; Response to harmonic and periodic excitations; Response to non-periodic excitations; Numerical evaluation of dynamic response; Generalized single-degree-freedom systems. Elements of analytical dynamics: The principle of virtual work; Principle of D Alembert; Multi-degree-freedom systems: Equation of motion; undamped free vibration; Interpretation of modal orthogonality; Decomposition of response in terms of modal co-ordinates; Modal analysis; Response to external excitations; Systems with proportional damping; Systems with arbitrary viscous damping. Distributed parameter systems: axial and bending vibration of beams; orthogonality of modes; Response to external excitations; Rayleigh's quotient; Approximate methods. Earthquake response of linear systems: Earthquake excitations; Equations of motion; Response spectrum concept; Response spectrum characteristics; Modal analysis.

Text/Reference Books:

1. Dynamics of Structures, A K Chopra, Pearson
2. Structural Dynamics, M Paz, CBS Publisher
3. Dynamics of Structures, Clough and Penzin, Tata McGraw Hill

Subject Code: CE6L302	Name: Advanced Structural Analysis	L-T-P: 3-1-0	Credit: 4

Prerequisite: None

Basics of structural analysis: static & dynamic loading, linear & nonlinear structural behaviour, geometric & material nonlinearity, hysteretic behaviour; Classical linear analysis of frames and trusses: displacement method, slope deflection equations & matrix displacement method, effect of foundation settlement and temperature; Geometric nonlinear analysis of frames and trusses: displacement method, nonlinear slope-deflection equations & nonlinear behaviour, linearized iterative matrix displacement method, geometric stiffness matrix, tangent stiffness matrix, P- Δ effect, buckling of frames, tension structures; Material nonlinear analysis of frames: basics of plasticity, distributed plasticity & lumped plasticity, incremental nonlinear analysis.

Text/Reference Books:

1. Matrix Analysis of Framed Structures, W. Weaver and J. M. Gere, CBS Publisher
2. Matrix Methods of Structural Analysis, M. B. Kanchi, Wiley Eastern Limited
3. Structural Analysis, Thandavamoorthy, Oxford University Press
4. Intermediate Structural Analysis, C K Wang, McGraw Hill
5. Structural Analysis, R C Hibbeler, Pearson

Subject Code: CE6P301	Name: Advanced Structural Laboratory	L-T-P: 0-0-3	Credit: 2

Prerequisite: None

Non-destructive tests on hardened concrete, mix design and tests for self-compacting concrete, Durability tests for concrete, Natural period determination of SDOF system using free vibration, Buckling of Strut, Shear-center determination of various sections, Unsymmetrical bending of beams, Stress-strain behaviour of MS steel and high strength steel bars.

Subject Code: CE6L303	Name: Theory of Elasticity	L-T-P: 3-1-0	Credit: 4

Prerequisite: None

Introduction to elasticity theory; Stress, strain, constitutive relations; Boundary conditions, Description of an Elasticity problem as a boundary value problem, Plane stress, plane strain, axi-symmetric problems, Large displacements and large strains; Cartesian, cylindrical and spherical coordinates; Thermal stresses; Torsion of noncircular members; Curved Beams; Plasticity; failure theories; Energy methods; Introduction to viscoplasticity and viscoplasticity; Coupled axial force and bending moment problems; coupled torsion and bending moment problems.

Text/Reference Books:

1. Elasticity: Theory, Applications and Numerics, Martin H. Sadd, Academic Press
2. Advanced Mechanics of Solids, L S Srinath, Tata McGraw Hill
3. Theory of Elasticity, S.P. Timoshenko and J.N. Goodier, McGraw Hill, Singapore.

Subject Code: CE6L304	Name: Advanced Concrete Technology	L-T-P: 3-0-0	Credit:3

Prerequisite: None

Fundamental of concrete - constituents, proportioning, mixing, transportation, placing and curing., Properties of fresh and hardened concrete., Quality control in concrete construction, Concrete mix design, Durability of concrete - alkali aggregate reaction, reinforcement corrosion, freezing and thawing, etc., Special concretes - high strength, low heat of hydration, high early strength, self-compacting, etc., Construction methods – shot-crete, roller compacted concrete, etc., Reinforcing materials - epoxy coated bars, fibre-reinforced plastics, Introduction to 'maintenance' of concrete structures - use of non-destructive testing, evaluation criteria.

Text/Reference Books:

1. Concrete Technology – ML Gambhir, Tata Mcgraw Hill
2. Concrete Technology, Neville and Brooks, ELBS/Longman
3. Properties of Concrete, Neville, ELBS/Longman
4. Construction Materials, D N Ghose, Tata Mcgraw Hill
5. Concrete Material, Microstructure and Properties, P K Mehta and P M J Montiero, (Tata Mcgraw Hill)

Subject Code: CE6P302	Name: Computational Laboratory	L-T-P: 0-0-3	Credit: 2

Prerequisite: None

Introduction to MATLAB or similar mathematical computing tools, Finite element modelling of structures for static and dynamic loads, Seismic and wind load analysis of structures, Pushover analysis.

Subject Code: CE6P303	Name: Design of Special Structures	L-T-P: 0-0-3	Credit: 2

Prerequisite: None

Design of overhead, underground, ground supported water tanks; Design of industrial structures; Design of bunkers and silos; Design of special RC elements: Design of slender columns, RC walls, ordinary and shear walls, Corbels, Deep beams, RCC

chimney; Design of simple cylindrical shell roof by beam theory.

Text/Reference Books:

1. Handbook on Seismic Analysis and Design of Structures, Farzad Naeim, Kluwer Academic Publisher.
2. Earthquake Resistant Design and Construction of Buildings - Code of Practice, IS 4326, Bureau of Indian Standard; New Delhi.
3. Guidelines for Seismic Design of Liquid Storage Tanks, Jain, S.K. & Jaiswal, O.R., NICEE, IIT Kanpur.
4. Handbook of Concrete Engineering, Fintel, M., CBS Publishers Delhi.

Subject Code: CE6L305	Name: Theory of Plates & Shells	L-T-P: 3-1-0	Credit: 4

Prerequisite: None

Pure Bending of Plates: Basic concepts, assumptions, and stress-strain behavior. Governing Differential Equations (GDE): Derivation in Cartesian and polar coordinates. Analytical Methods for Rectangular Plates: Navier's method and Levy's method for different boundary conditions. Thin Plate Theory (Kirchhoff Theory): Constitutive relations, strain-displacement relations, and equilibrium equations. Cylindrical Bending of Plates: Analysis under various loading conditions. Thick Plate Theory (Mindlin Plate Theory): Inclusion of transverse shear deformation; derivation of governing equations and boundary conditions using the energy method. Advanced Plate Theories: Improved shear and normal deformation theories; plate theories for layered composites. Introduction to Shell Structures: Shell geometry, classification, and theory of surfaces. Membrane Theory for Shells: Surfaces of revolution and elastic behavior under membrane action. Love's Thin Shell Theory: Formulation using energy method for elastic shells. Bending of Cylindrical Shells: Derivation and application; Donnell-Karman- Jenkins theory for nonlinear analysis.

Text/Reference Books:

1. Timoshenko, S., & Woinowsky-Krieger, S. (1959). Theory of Plates and Shells (2nd ed.). New York: McGraw-Hill.
2. Szilard, R. (1974). Theory and Analysis of Plates: Classical and Numerical Methods. Englewood Cliffs, NJ: Prentice-Hall.
3. Kraus, H. (1967). Thin Elastic Shells: An Introduction to the Theoretical Foundations and the Analysis of Their Static and Dynamic Behavior. New York: John Wiley & Sons.

Subject Code: CE6L306	Name: Seismic Design of Structures	L-T-P: 3-1-0	Credit: 4

Prerequisite: None

Characteristics of earthquakes; Earthquake response of structures; Concept of earthquake resistant design; Response of Single Degree of Freedom System and Multi-degrees of Freedom systems to random excitations. Code provisions of design and detailing of buildings; Design for Liquefaction; Non-engineered construction; Seismic strengthening of existing buildings; Introduction to special topics on seismic behaviour and design of bridges, water tanks etc.

Text/Reference Books:

1. Duggal, S.K., Earthquake Resistant Design of Structures, Oxford University Press
2. Chopra, A.K., Dynamics of Structures: Theory and Applications to Earthquake

Engineering, Prentice Hall/Pearson Education
3. Paulay, T. and Priestley, M.J.N., Seismic Design of Reinforced Concrete and Masonry Buildings, Wiley International Publication
4. Bolt, B.A., Earthquakes, W.H. Freeman
5. Kramer, S.L., Geotechnical Earthquake Engineering, Pearson

Subject Code: CE6L307	Name: Bridge Engineering	L-T-P: 3-0-0	Credit: 3

Pre-requisite(s): None

Introduction, historical review, engineering and aesthetic requirements in bridge design, introduction to bridge codes of practice, economic evaluation of bridge projects, site investigation and planning, hydraulic calculations for bridges, loads on bridges, bridge foundations-open, pile, well and caisson, Piers, abutments and approach structures, superstructures-analysis and design of right, skew and curved slabs, Girder bridges, introduction to long span bridges- cantilever, arch, cable stayed and suspension bridges.

Text/Reference Books:

1. Krishna Raju N., Design of Bridges, Oxford & IBH Publishing.
2. Victor, D.J., Essentials of bridge engineering, Oxford & IBH Publishing
3. Ponnuswamy, S., Bridge Engineering, Tata Mcgraw Hill
4. Jagadeesh, T.R. and Jayaram, M.A., Design of Bridge Structures, Phi Learning
5. Bindra, S.P., Principles and Practice of Bridge Engineering, Dhanpat Rai Publications

Subject Code: CE6L308	Name: Infrastructure Maintenance and Rehabilitation	L-T-P: 3-0-0	Credit: 3

Pre-requisite(s): None

Quality assurance for concrete construction as built concrete properties strength, permeability, thermal properties and cracking. Influence on servicebility and durability: – Effects due to climate, temperature, chemicals, wear and erosion, Design and construction errors, corrosion mechanism, Effects of cover thickness and cracking, methods of corrosion protection, corrosion inhibitors, corrosion resistant steels, coatings, cathodic protection; Maintenance and repair strategies: – Definitions: Maintenance, repair and rehabilitation, Facets of Maintenance importance of Maintenance, Preventive measures on various aspects Inspection, Assessment procedure for evaluating a damaged structure, causes of deterioration , testing techniques; Materials: -Materials for Repair – Special Mortar and Concretes, Concrete Chemicals, Special Cements and High Grade Concrete, Expansive Cement, Polymer Concrete, Sulphur Infiltrated Concrete, Ferro Cement, Fiber Reinforced Concrete, and Admixtures of latest origin. Techniques for Repair- Surface Repair – Material Selection – Surface Preparation - Rust Eliminators and Polymers Coating For Rebar During Repair – Repair Of Cracks In Concrete and Masonry -Methods of Repair - Epoxy Injection, Mortar Repair For Cracks - Guniting and Shotcreting - Waterproofing Of Concrete Roofs; Strengthening Measures - Flexural Strengthening, Beam Shear Capacity Strengthening, Column Strengthening, Shoring, Under Pinning and Jacketing. Demolition of Buildings – Introduction, Planning, Precautions and protective measures in demolition work, Sequence of operations, demolition of structural elements.

Text/Reference Books:

1. Campbell-Allen, D. and Roper, H., Concrete Structures, Materials, Maintenance and

Repair, Longman Scientific and Technical, UK
2. Allen, R.T and Edwards, S.C, Repair of Concrete Structures, Blakie and Sons, UK
3. Santhakumar A.R., Concrete Technology, Oxford University Press
4. Dayaratnam, P. and Rao, R., Maintenance and Durability of Concrete Structures, University Press, India
5. CPWD, Handbook on Repairs and Rehabilitation of RCC Buildings.

Subject Code: CE6L309	Name: Modern Construction Materials	L-T-P: 3-0-0	Credit: 3

Prerequisite: None

Basics (Introduction to the course, Science, Engineering and Technology of Materials); Microstructure (Atomic Bonding, Structure of solids, Movement of atoms, Development of microstructure); Material behaviour (Surface properties, Response to stress, Failure theories, Fracture mechanics, Rheology, Thermal properties); Structural Materials (Review of Construction Materials and Criteria for Selection, Wood and Wood Products, Polymers, Fibre Reinforced Polymers, Metals, Bituminous Materials, Concrete, Glass); : Non-structural materials, accessories and finishes (Review of Non-structural Materials and Criteria for Selection, Waterproofing materials, Polymer Floor Finishes, Paints, Tiles, Acoustic Treatment, Dry walls, Anchors); Environmental Concerns, Social Perception of Construction Materials.

Text/Reference Books:

1. Varghese, P.C., Building Materials, Prentice-Hall India
2. Callister, W.D., Materials Science and Engineering: An introduction, John Wiley
3. Raghavan, V., Materials Science and Engineering, Prentice Hall
4. Higgins, R.A., Properties of Engineering Materials, Industrial Press
5. Construction materials: Their nature and behaviour, Eds. J.M. Illston and P.L.J. Domone, Spon Press
6. Young, J.F., Mindess, S., Gray, R.J. and Bentur, A., The Science and Technology of Civil Engineering Materials, Prentice Hall
7. Neville, A.M., Properties of concrete, Pearson

Subject Code: CE6L310	Name: Advanced construction Techniques	L-T-P: 3-0-0	Credit: 3

Prerequisite: None

Sub Structure Construction -Box jacking, Pipe Jacking, Under Water Construction of diaphragm walls and Basement, Tunnelling Techniques, Piling Techniques, Driving Well and Caisson Sinking, Cofferdam, Cable Anchoring and Grouting, Driving Diaphragm Walls, Sheet Piles-Laying Operations For Built Up Offshore System-Shoring For Deep Cutting-Large Reservoir Construction with membranes and Earth system-well points-Dewatering and stand by Plant equipment for underground open excavation ; Super Structure Construction- Vacuum dewatering of concrete flooring-Concrete paving technology, Techniques of construction for continuous concreting operation in Tall buildings of various shapes and Varying sections, Launching Techniques-Suspended formwork-erection techniques of tall structures, Large span structures-Launching techniques for heavy decks-in-situ pre-stressing in high rise structures, aerial transporting ,handling, erecting light weight components on tall structures-erection of lattice towers and rigging of transmission line structures; Construction Sequences- in cooling towers, Silos Chimney, Sky scrapers, bow string bridges, cable stayed bridges; Launching and pushing of box decks, support structure for heavy Equipment and conveyor and machinery in heavy industries, erection of articulated structures, braced domes and space decks;

Repair Construction: Mud Jacking Grout through Slab Foundation, Micro Piling for Strengthening Floor and Shallow Profile, Pipeline Laying, Protecting Sheet Piles, Sub Grade Water Proofing, Underpinning Advanced Techniques and Sequence in Demolition and Dismantling.

Text/Reference Books:

1. Brown, R., Practical foundation engineering hand book, McGraw Hill Publications
2. Powers, J.P., Corwin, A.B., Schmall, P.C. and Kaeck, W.E., Construction Dewatering: New Methods and Applications, John Wiley and Sons
3. Irvine, J., Advanced Construction Techniques, California Rocketry
4. National Building Code of India, Part-IV and VII – 2006
5. Mohan, R. and Jaisingh. M.P., Advances in Building Materials and Construction, CBRI Roorkee
6. Hand Book on concrete Mixes based on Indian standards, SP-23 (S&T)

Subject Code: CE6L311	Name: Construction Project Management	L-T-P: 3-0-0	Credit: 3

Prerequisite: None

Principles of Project Management, Project Planning, Introduction to scheduling - work/project break down structures, Bar-charts; Principles of application of CPM and PERT; Precedence Method; Updating; Time - cost trade-offs, Resource constrained scheduling; Resource leveling Project control; Performance Measurement, Earned value; Multiple Construction Projects; Other network techniques; Project Management Software Packages.

Text/Reference Books:

1. Jha, N.K., Construction Project Management, Pearson Education India
2. Williams, T., Construction Management, Pearson Education India
3. Chitkara, K., Construction Project Management Techniques And Practice, Tata McGraw Hill
4. Purifoy, R., Schexnayder, C.J., Shapira, A. and Schmitt, R., Construction Planning, equipment and Methods, McGraw Hill, Tokyo, Japan

Subject Code: CE6L312	Name: Advanced Design of RC Structure	L-T-P: 3-1-0	Credit: 4

Prerequisite: None

Design of overhead, underground, ground supported water tanks, dams; Design of industrial structures; Design of bunkers and silos, Airy's theory, Janssen's theory; Design of special RC elements: Design of slender columns, RC walls, ordinary and shear walls, Corbels, Deep beams, RCC chimney; Introduction to shell and folded plate roofs, their forms and structural behaviour. Design of simple cylindrical shell roof by beam theory, Yield line analysis of slabs by virtual work, Yield line analysis by equilibrium methods.

Text/Reference Books:

1. Varghese , P.C., Advanced Reinforced Concrete Design, PHI Learning
2. Naeim, F., Handbook on Seismic Analysis and Design of Structures, Kluwer Academic Publisher
3. IS 4326, Earthquake Resistant Design and Construction of Buildings - Code of Practice, Bureau of Indian Standard; New Delhi
4. Jain, S.K. and Jaiswal, O.R., Guidelines for Seismic Design of Liquid Storage Tanks, NICEE, IIT Kanpur
5. Fintel, M., Handbook of Concrete Engineering, CBS Publishers Delhi

Subject Code: MA6L001	Name: Mathematical Methods	L-T-P: 3-1-0	Credit: 4

Prerequisite: None

Probability and Statistics : Random variables (rv) and their properties, some standard discrete and continuous rv, Expectation, Variance, moments, moment generating functions, functions of a rv, their distribution and moments, joint, marginal and conditional distribution and independence of rvs, Hypothesis testing.

Numerical solutions of systems of linear equations: Gauss elimination, LU decomposition, Gauss-Jacobi and Gauss-Seidel methods.

Numerical methods of ODE and PDE: Runge-Kutta and finite difference methods for ODE, Finite difference methods for solving 2-D Laplace's equation, Poisson's equation, 1-D heat equation : Bender Schmidt, Crank Nicholson method and Du Fort Frankel methods, 1-D wave equation using Explicit method. Consistency and stability analysis.

Text/Reference Books:

1. Grawel, B.S. Numerical Methods
2. Jain, M.K., Iyengar, S.R.K. and Jain, R.K. Numerical Methods-problem and solutions, Wiley Eastern Limited, 2001.
3. Ross, S. Introduction to Probability Models, Wiley India
4. Gun, A.M., Gupta, M.K. and Gupta, B.S. Fundamentals of Statistics
5. Hayter, A.J., Probability and Statistics, Duxbury, 2002
6. Scarborough, J.B., Numerical mathematical analysis, Oxford & IBH Publishing Co.Pvt.,2000
7. Hamming, R.W., Numerical Methods for Scientist and Engineers, McGraw Hill, 1998
8. Mathews, J.H. and Fink, K.D. Numerical Methods using MATLAB, Pearson Education, 2004.

Subject Code: MA6L002	**Name: Advanced Techniques in Operation Research**	**L-T-P: 3-1-0**	**Credit: 4**

Prerequisite: None

One variable unconstrained optimization, multivariable unconstrained optimisation, Karush-Kuhn-Tucker (KKT) conditions for constrained optimization, quadratic programming, separable programming, convex and non convex programming, steepest and Quasi-Newton method.

Dynamic Programming: Characteristics of dynamic problems, deterministic dynamic programming and probabilitistic dynamic programming, Network analysis, Shortest path problems, minimum spanning tree problem, maximum flow problem, minimum cost flow problem, network simplex, interior point methods, stochastic programming, Nonlinear goal programming applications, Geometric Programming.

Multi-objective Optimization Problems: Linear and non linear programming problems, Weighting and Epsilon method, P-norm methods, Gradient Projection Method, STEM method, Convex Optimization.

Text/Reference Books:

1. Rao, S.S., Engineering Optimization Theory and Practices, John Wiley and Sons, 2009
2. Ehrgott, M. Multi-criteria Optimization, Springer 2006
3. Miettien, K.M, Non-linear multi-objective optimization, Kluwers International Series, 2004
4. Deb, K., Multi-Objective Optimization using Evolutionary Algorithms, John Wiley & Sons, 2001.

Subject Code:	**Subject Name:**	**L-T-P: 3-0-0**	**Credit: 3**

CE6L029	Structural Health Monitoring		

Prerequisite: None

Introduction to structural health monitoring; Sensors and sensing technologies; Application of Artificial Intelligence in non-destructive evaluations, vibration and vision-based damage assessment; Sub-surface imaging of defects; Predictive maintenance; Introduction to IoT and Digital Twins; Sensor placement optimization; Operational modal analysis.

Text/Reference Books:

1. Karvari an Ansari, "Structural health monitoring of civil infrastructure", Elsevior.
2. Adams Douglas E., "Health Monitoring of Structural Materials and Components: Methods with Application" John Wiley and Sons Inc.
3. Ferrar and Worden "Structural Health Monitoring: A Machine Learning Perspective" John Wiley and Sons Inc.
4. Daniel Balageas, Claus-Peter Fritzen, Alfredo Güemes "Structural Health Monitoring" John Wiley and Sons Inc.
5. Ostachowicz, Wiesław, Güemes, Alfredo, "New Trends in Structural Health Monitoring" Springer

Subject Code: CE6L313	Subject Name: Theory of Elastic Stability	L-T-P: 3-1-0	Credit: 4

Pre-requisite(s): None

Principles of elastic stability; Approximate methods in elasticity; Variational principles in elasticity; Principles of total potential energy; Concepts of elastic stability; Stability of rigid body systems; Buckling of Euler column: Large deflection theory, buckling of column column with initial imperfection; Stability of columns with various boundary conditions; Eccentrically loaded columns; Inelastic stability analysis of column. Introduction to beam-columns with lateral loads; Rotationally restrained columns; Critical load of portal frames with different boundary conditions; Stability analysis of frames by matrix stiffness method; Slope deflection equation; Buckling of thin walled open cross- section: torsional buckling and torsional - flexural buckling; Lateral buckling due to various loads; Buckling and Post Buckling behaviour of Plate; Shell Buckling by using Small Deflection Theory and Finite Deflection Theory; Post Buckling of Axially Compressed Cylindrical Shell Panel; Buckling of rings, curved bars and arches.

Text/Reference Books:

1. Chajes, A., Principles of Structures Stability Theory, Prentice Hall, Inc., Englewood Cliffs, NJ, 1974.
2. Timoshenko, S.P. and Gere, J.M., Theory of Elastic Stability, McGraw Hill, New Delhi, 2012.
3. Bazant, Z.P. and Cedolin, L., Stability of Structures, World Scientific, Singapore, 2010.
4. Kumar, A., Stability Theory of Structures, Allied Publishers Ltd., New Delhi, 2003.
5. Gambhir, M. L., Stability Analysis and Design of Structures, Springer, New York, 2004.
6. Simitses, G.J, and Hodges D.H, Fundamentals of structural stability. Butterworth-Heinemann, UK, 2006

Subject Code: CE6LXXX	Subject Name: Vision-based Structural Sensing	L-T-P: 2-0-2	Credit: 3

Pre-requisite(s): None

Introduction to vision-based sensing, case studies on successful structural health monitoring projects; Fundamentals of image processing and computer vision – image formation, transforms, linear and nonlinear filtering, interest point detection and matching, homography estimation, image alignment, registration and stitching, edge detection, morphological operations, template matching, optical flow; Extraction of color, textural and spectral features for detection of structural defects like corrosion, cracks, spalling, and potholes; quantitative damage evaluation; Monitoring of structural vibration, measurement of strain and displacement, digital image correlation; Generation of point clouds and 3D reconstruction of structures, photogrammetric and laser scanning-based inspection approaches, structural change detection, depth estimation; Deep learning-based inspection data analytics, detection of structural defects like corrosion, cracks, spalling, and potholes, identification of structural components in buildings and bridges, image-based and point cloud-based detection approaches.

Text/Reference Books:

1. Multiple view geometry in computer vision by Richard Hartley and Andrew Zisserman, Cambridge University Press.
2. Computer vision: Algorithms and Applications by Richard Szeliski, Springer Nature.
3. Infrastructure Computer Vision by Ioannis Brilakis and Carl Haas, Butterworth-Heinemann.
4. Artificial Intelligence in Vision-Based Structural Health Monitoring by Khalid M. Mosalam and Yuqing Gao, Springer.

Newly proposed course

Subject Code: CE6LXXX	**Subject Name: Finite Element Methods**	**L-T-P: 3-1-0**	**Credit: 4**

Prerequisite: None

Introduction to Finite Element Analysis, Variational principles and weighted residual techniques, Rayleigh-Ritz Formulation, Development of bar and beam element, Application to truss and frames. Equivalence between energy formulation and Galerkin approach, Derivation of element shape functions (Lagrangian and Hermite), Element types: Triangular, Rectangular, Quadrilateral, Iso-parametric elements and Numerical integration. Applications to problems in engineering: Plane stress and plane strains, Axisymmetric stress analysis, three-dimensional stress analysis, Bending of plates, Heat conduction and Transient problems. Computer implementation procedures for finite element analysis.

Text/Reference Books:

- J N Reddy, "An Introduction to the Finite Element Method", Tata McGraw-Hill, New Delhi, 3rd Edition, 2005.
- K J Bathe, "Finite Element Procedures", Prentice Hall, Indian edition, 2006.
- R D Cook, D S Malkus, M E Plesha, R J Witt, "Concepts and Applications of Finite Element Analysis", John Wiley & Sons, 4th edition, 2002.
- OC Zienkiewicz and RL Taylor, "The Finite Element Method", Volume 1 & 2, 5th edition, Butterworth Heinemann, New Delhi, 2000.

- David V. Hutton, “Fundamentals of Finite Element Analysis”, McGraw Hill, 2004.
- J Fish and T Belytschko, “A first Course in Finite Elements”, Wiley, USA, 2007.