DEPARTMENT OF APPLIED MECHANICS

Course Book for

M. Tech. in Structural Dynamics and Earthquake Engineering

For

Academic Year
2020 - 2021

Visvesvaraya National Institute of Technology,

Nagpur-440 010 (Maharashtra)

Institute Vision Statement

To contribute effectively to the National and International endeavour of producing quality human resource of world class standard by developing a sustainable technical education system to meet the changing technological needs of the Country and the World incorporating relevant social concerns and to build an environment to create and propagate innovative technologies for the economic development of the Nation.

Institute Mission Statement

The mission of VNIT is to achieve high standards of excellence in generating and propagating knowledge in engineering and allied disciplines. VNIT is committed to providing an education that combines rigorous academics with joy of discovery. The Institute encourages its community to engage in a dialogue with society to be able to effectively contribute for the betterment of humankind.

Department Vision Statement

The Department is committed to provide post graduate academic and research programs to produce high quality human resource with ability to meet the global challenges associated with built environment and to emerge as centre for advanced studies in the field of structural engineering.

Department Mission Statement

The mission of the department is to achieve excellence in structural and earthquake engineering education, research and professional service. It is endeavored to equip students to assume leadership positions in engineering practice, education, research and serve mankind with structures designed for safety, serviceability and economy.

Brief about Department of Applied Mechanics:

Established in 1966, the Department of Applied Mechanics offers two post graduate programs. The department offers structural engineering subjects to B.Tech. (Civil) and B.Arch, student along with the subject of Engineering Mechanics to the first year B. Tech. students. Since its inception, department has been actively involved in the consultancy work of structural design of structures, with emphasis on water tanks. In last decade, department has pursued many earthquakes engineering related activities. Faculty members have visited earthquake affected areas after Bhuj earthquake of 2001 and Andaman earthquake of 2004. At present, government funded research projects in the areas of seismic response control and damage detection are being pursued. Recently, department has procured servo-hydraulic shake table of 3m × 3m for seismic ground motion simulation.

List of Faculty Members

Sr. No.	Name of Faculty	Designation	Qualifications	Areas of Specialization
1	Mahajan, M. M.	Professor & Head	Ph. D.	Analysis and design of RC structures and Machine foundation
2	Gupta, L. M.	Professor	Ph. D.	Steel structures, pre stressing steel structure, Bridges rehabilitation and retrofitting of structures
3	Ingle, R. K.	Professor	Ph. D.	Analysis and design of bridges, Water tanks, Buildings and special structures, Earthquake-resistant design, FEM analysis
4	Jaiswal, O. R.	Professor	Ph. D.	Dynamic analysis of structures (wind and earthquake loads), Analysis and design of elevated water tank, Structural control
5	Ronghe, G. N.	Professor	Ph. D.	Structural Instrumentation, Prestressed steel structures
6	Sonparote, R. S.	Associate Professor	Ph. D.	Software development, Soil-structure interaction, Machine foundation
7	Bakre, S. V.	Associate Professor	Ph. D.	FE analysis, Response control and base isolation
8	Gadve, S. S.	Associate Professor	Ph. D.	Repairs, Rehabilitation, RC/PSC structures, Concrete technology, FE analysis
9	Borghate, S. B.	Associate Professor	Ph. D.	Concrete structures, Numerical/Finite Element Analysis and Computer Programming, Structural health monitoring and Structural auditing
10	Ratnesh Kumar	Associate Professor	Ph. D.	Performance-based design, Seismic evaluation and retrofitting, Seismic vulnerability and risk assessment
11	Vyavahare, A. Y.	Assistant Professor	Ph. D.	FEM analysis, Steel structures, Steel connection
12	Khatri, A. P.	Assistant Professor	Ph. D.	Steel structures, Stability of structures, RC and prestressed structures
13	Datta, D.	Assistant Professor	Ph. D.	Structural dynamics, Seismic response of structures, Structural reliability
14	Goel, M. D.	Assistant Professor	Ph. D.	Blast-resistant design of structures, Behavior of materials at low, medium and high rate of loadings, Numerical simulation and analysis of blast and impact events, Crashworthiness and impact mechanics

UG/PG Programs Offered by Department of Applied Mechanics:

The department offers following postgraduate programs:

	Program	Description
PG	M. Tech. in 1. Structural Engineering 2. Structural Dynamics and Earthquake Engineering	Intake 25 25

Credit System at VNIT

Education at the Institute is organized around the semester-based credit system of study. The prominent features of the credit system are a process of continuous evaluation of a student's performance/progress and flexibility to allow a student to progress at an optimum pace suited to his/her ability or convenience, subject to fulfilling minimum requirements for continuation. A student's performance/progress is measured by the number of credits he/she has earned, i.e. completed satisfactorily. Based on the course credits and grades obtained by the student, grade point average is calculated. Aminimum number of credits and a minimum grade point average must be acquired by a student in order to qualify for the degree.

Course credits assignment

Each course, except a few special courses, has certain number of credits assigned to it depending on lecture, tutorial and laboratory contact hours in a week.

For Lectures and Tutorials: One lecture hour per week per semester is assigned one credit and

For Practical/Laboratory/Studio: One hour per week per semester is assigned half credit.

Example: Course XXXXXX with (3-0-2) as (L-T-P) structure, i.e. 3 hrs. Lectures + 0 hr. Tutorial + 2 hrs. Practical per week, will have ($3\times1+0\times1+2\times0.5$ =) 4 credits.

Grading System

The grading reflects a student's own proficiency in the course. While relative standing of the student is clearly indicated by his/her grades, the process of awarding grades is based on fitting performance of the class to some statistical distribution. The course coordinator and associated faculty members for a course formulate appropriate procedure to award grades. These grades are reflective of the student's performance vis-à-vis instructor's expectation. If a student is declared pass in a subject, then he/she gets the credits associated with that subject.

Depending on marks scored in a subject, a student is given a Grade. Each grade has got certain grade points as follows:

Grade	Grade points	Description
AA	10	Outstanding
AB	9	Excellent
BB	8	Very good
BC	7	Good
CC	6	Average
CD	5	Below average
DD	4	Marginal (Pass Grade)
FF	0	Poor (Fail)/Unsatisfactory/Absence from end-semester examination
NP	-	Audit pass
NF	-	Audit fail
SS	-	Satisfactory performance in zero credit core course
ZZ	-	Unsatisfactory performance in zero credit core course
W	-	Insufficient attendance

Performance Evaluation

The performance of a student is evaluated in terms of two indices, viz, the Semester Grade Point Average (SGPA) which is the Grade Point Average for a semester and Cumulative Grade Point Average (CGPA) which is the Grade Point Average for all the completed semesters at any point in time. CGPA is rounded up to second decimal.

The Earned Credits (ECR) are defined as the sum of course credits for courses in which students have been awarded grades between AA to DD. Grades obtained in the audit courses are not counted for computation of grade point average.

Earned Grade Points in a semester (EGP) = **Σ** (Course credits × Grade point) for courses in which AA- DD grade has been obtained.

SGPA = EGP/Σ (Course credits) for courses registered in a semester in which AA- FF grades are awarded

CGPA= EGP/Σ (Course credits) for courses passed in all completed semesters in which AA- DD grades are awarded

Overall Credits Requirement for Award of Degree

Sr. No.	Category of Course	Symbol	Credit Requirement			
			B. Tech. (4-Year)	**B. Arch. (5 Year)**	**M. Tech. (2 Year)**	**M. Sc. (2 Year)**
Program Core						
1	Basic Sciences (BS)	BS	18	04	-	-
2	Engineering Arts and Sciences (ES)	ES	20	18	-	-
3	Humanities	HU/HM*	05	06	-	-
4	Departmental Core	DC	79-82	168	33-39	54-57
Program Elective						
3	Departmental Elective	DE	33-48	17-23	13-19	06-09
4	Humanities and Management	HM	0-6	0-3	-	-
5	Open Course	OC	0-6	0-3	-	-
Total requirement: BS + ES + DC+ DE + HM + OC =			**170**	**219**	**52**	**63**
Minimum Cumulative Grade Point Average required for the award of degree			**4.00**	**4.00**	**6.00**	**4.00**

Attendance Rules

1. All students must attend every class and 100% attendance is expected from the students. However, in consideration of the constraints/unavoidable circumstances, the attendance can be relaxed by course coordinator only to the extent of not more than 25%. Every student must attend minimum of 75% of the classes actually held for that course.
2. A student with less than 75% attendance in a course during the semester, will be awarded W grade. Such a student will not be eligible to appear for the end semester and re-examination of that course. Even if such a student happens to appear for these examinations, then, answer books of such students will not be evaluated.
3. A student with W grade is not eligible to appear for end semester examination, reexamination and summer term.

Program Outcomes for M. Tech. in

Structural Dynamics and Earthquake Engineering

a) **PO1:**An ability to independently carry out research/investigation and development work to solve practical problems.
b) **PO2:** An ability to write and present a substantial technical report/document.
c) **PO3:**Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.
d) **PO4:** Student should be able to understand complex problem and select appropriate modern tool to solve it.
e) **PO5:** Student should be able to understand the state of art need, professional, ethical practices, services to the society and socio-economic relevance while executing the civil engineering project.

Scheme of Instructions for M. Tech. in Structural Dynamics and Earthquake Engineering

I. To be offered in Odd Semester

Sr. No.	Course Code	Course Title	Type DC/DE /AU	Structure L-T-P	Credits	Pre-requisite
1	AML523	Theory of Elasticity and Plasticity	DC	3-0-0	3	
2	AML	Finite Element Analysis	DC	3-0-2	4	
3	AML	Structural Dynamics	DC	3-0-2	4	
4	AML	Earthquake Engineering	DC	3-0-0	3	
5	AMP	Technical Writing and Communication Skills	DC	0-0-2	1	
6		Elective	DE	-	3/4	
7	AMD501	Project Phase-I	DC	-	3	25 Credits
8	AML541	Theory of Plates and Shells	DE	3-0-0	3	
9	AML547	Numerical Methods and Programming	DE	3-0-2	4	
10	AML	Foundations	DE	4-0-0	4	
11	AML542	Stability of Structures	DE	3-1-0	4	
12	AML	Masonry Structure and Retrofitting	DE	3-0-2	4	
13	AML	Advanced Concrete Technology and Testing	DE	3-0-2	4	
14	AML	Reinforced Concrete Design to IRC112	DE	3-0-2	4	
15	AML	Earthquake-Resistant Design of Structures	DE	3-0-0	3	
15	AML	Numerical Methods for Dynamic Systems	DE	3-0-2	4	
16	CEL520	Advanced Soil Mechanics	DE	3-0-0	3	

II. To be offered in Even Semester

Sr. No.	Course Code	Course Title	Type DC/DE / AU	Structure L-T-P	Credits	Pre-requisite
1	AML	Earthquake-Resistant Design of Concrete Buildings	DC	3-0-2	4	
2	AML	Earthquake-Resistant Design of Steel Buildings	DC	3-0-2	4	
3	AML543	Earthquake Dynamics	DC	2-0-2	3	
4		Elective	DE	-	3/4	
5		Elective	DE	-	3/4	
6		Elective	DE	-	3/4	
7	AMP	Research Methodology and Presentation	DC	0-0-2	1	

8	AMD502	Project Phase-II	DC	-	9	35 Credits + Project Phase-I
9	AML	Experimental Stress Analysis and Instrumentation	DE	2-0-2	3	
10	AML	Bridges	DE	3-0-2	4	
11	AML	Industrial Steel Structures	DE	3-0-2	4	
12	AML	Water Retaining Structures	DE	3-0-2	4	
13	AML	Multistoried Buildings	DE	3-0-2	4	
14	AML	Blast Loading of Structures	DE	4-0-0	4	
15	AML	Advanced Finite Element Analysis	DE	3-0-2	4	
16	AML	Machine Foundations	DE	4-0-0	4	
17	AML	Seismic Evaluation and Retrofitting of Structures	DE	2-0-2	3	
18	AML	Analysis and Design of Pipes	DE	3-0-2	4	
19	AML	Composite Structures	DE	4-0-0	4	
20	AML	Structural Health Monitoring and Rehabilitation	DE	2-0-2	3	
21	AML	Irrigation Structures	DE	3-0-2	4	
22	AML	Advanced Earthquake-Resistant Design of Structures	DE	3-0-0	3	
23	AML	Nonlinear Structural Analysis	DE	3-0-0	3	
24	AML	Prestressed Concrete Structures	DE	3-0-2	4	
25	CIV	Advanced Foundation Engineering	DE	3-0-0	3	
26	CIV	Design of Underground Structures	DE	3-0-0	3	
27	CIV	Soil Structure Interaction	DE			
28	AML566	Random Vibration Analysis	DE	3-0-0	3	
29	AML	Concrete structures	AU	3-0-2	4	
30	AML	Steel Structures	AU	3-0-2	4	

III. Total credits to be earned for completion of the degree program:

a) Through DC category courses = 39 credits

b) Through DE category courses = 14/15 credits

Total = 53/54 credits

AML523 THEORY OF ELASTICITY AND PLASTICITY (DC) (Odd Semester)

Credit:	**3**
Contact hours (L-T-P):	**3-0-0**
Pre-requisites:	**Nil**
Overlaps with:	**Nil**
Course Assessment Method:	**As per Academic Rule Book**

Course Objective

The main objective of studying this course is to understand the theoretical concepts of material behavior with particular emphasis on their elastic and plastic properties.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability

- **CO1.** to define/understand 3D state of stress and strains, equilibrium and compatibility,
- **CO2.** to understand stress strain relationships,
- **CO3.** to derive the governing equations and their solutions for application to problems in plane stress state, plane strain state, bending,
- **CO4.** to understand various mode of failures in structure.

Relationship of Course Outcomes to Program Outcomes
H = High correlation; M = Medium correlation; L = Low correlation

POs → / COs ↓	PO1	PO2	PO3	PO4	PO5
CO1	H		H	M	L
CO2	H		H	M	
CO3	H		M		L
CO4	H			H	L

Syllabus

Stress transformation and strain transformation at a point in an elastic body, rigid body translation and rotation of an element in space. Generalized Hook's law, Principal stresses and strains.

Two dimensional problems in elasticity: Plain stress, Plain strain and Axisymmetric problems. Boundary conditions, stress functions.

Three dimensional problems in elasticity: Differential equation of equilibrium in 3D, condition of compatibility determination of displacement, principle of superposition, uniqueness theorem, torsion of bars. Membrane analogy

Theories of failure

Introduction to plasticity: Criterion of yielding strain hardening rules of plastic flow different stress strain relation,total strain theory, theorem of limit analysis, elasto-plastic bending and torsion of bars.

Reference Books/Material

1. Ugural, A. C., & Fenster, S. K. (2003). *Advanced strength and applied elasticity*. Pearson education.

2. Timoshenko, S. P., & Goodier, J. N. (1971). *Theory of Elasticity*. McGraw-Hill, New York, 1970.
3. Shames, I. H. (1964). *Mechanics of deformable solids (Book on mechanics of deformable solids, featuring cartesian tensor continuum approach and singularity functions)*. Englewood Cliffs, N. J., Prentice-Hall, INC., 1964. 532
4. P.Srinath, L. S. (2003). *Advanced mechanics of solids*. Tata McGraw-Hill.
5. Chakrabarty, J. (2012). *Theory of plasticity*. Butterworth-Heinemann.
6. Timoshenko, S. (1953). *History of strength of materials: with a brief account of the history of theory of elasticity and theory of structures.* Courier Corporation.
7. Boresi, A. P., Chong, K., & Lee, J. D. (2010). *Elasticity in engineering mechanics*. John Wiley & Sons.
8. Popov, E. P., &Balan,T. A. (1999).*Engineering Mechanics of Solids*.Prentice-Hall, New Jersey.
9. Hill, R. (1998). *The mathematical theory of plasticity* (Vol. 11). Oxford university press.
10. Lubliner, J. (2008). *Plasticity theory*. Courier Corporation.

AML FINITE ELEMENT ANALYSIS (DC) (Odd Semester)

Credit:	**4**
Contact hours (L-T-P):	**3-0-2**
Pre-requisites:	**Nil**
Overlaps with:	**Nil**
Course Assessment Method:	**As per Academic Rule Book**

Objective

The objectives of this course are to introduce concepts of finite element method for analysis of structures.

Course Outcome

After completion of this course, the student is expected to acquire,

CO1. knowledge of the basics of finite element method,
CO2. knowledge of development of stiffness matrix of element,
CO3. ability to analyze simple structures using finite element method.

Relationship of Course Outcomes to Program Outcomes
H = High correlation; M = Medium correlation; L = Low correlation

PO, CO	PO1	PO2	PO3	PO4	PO5
CO1	L				
CO2				L	
CO3		M			

Syllabus

Introduction to stiffness and flexibility approach, Displacement vectors, Local and Global co-ordinate system, Transformation matrices, Global stiffness matrix and load vectors, Assembly of structure stiffness matrix with structural load vector, Solution of equations, Gauss elimination method, Cholesky Decomposition method,

Introduction to Finite element method, Rayleigh Ritz Method, Total potential approach, Virtual work approach, Stress-strain relationship, strain displacement relationship, Equilibrium equations. Displacement formulation, Shape function (Cartesian and Iso-parametric shape functions) Stiffness matrix, Numerical Integration

Formulation of one-dimensional or line element: BAR/TRUSS, BEAM, FRAME, etc

Formulation of area elements: Plane stress, Plane strain

Convergence study, Constraint equations (Penalty method, Lagrangian method), Patch test

Analysis of plane truss, plane frame structure, Plane stress, Plane strain problems using finite element method.

Advanced topics: Effect of axial load on stiffness of members, Analysis of building systems for horizontal loads, Buildings with and without rigid diaphragm, various mathematical models, Buildings with braces, shear walls, non-orthogonal column members, static condensation, substructure technique, constraint equations, symmetry and anti-symmetric conditions, modeling guidelines for framed structures using analysis software

Reference Books / Material

1. Bathe, K. J. (2008). *Finite element method*. John Wiley & Sons, Inc.
2. Zienkiewicz, O. C., Taylor, R. L., Zienkiewicz, O. C., & Taylor, R. L. (1977).*The finite element method* (Vol. 3). London: McGraw-hill.
3. Hughes, T. J. (2012*). The finite element method: linear static and dynamic finite element analysis.* Courier Corporation.
4. Cook, R. D. (2007). *Concepts and applications of finite element analysis*. John Wiley & Sons.
5. Cook, R. D. (1995). *Finite element modeling for stress analysis*. John Wiley & Sons
6. Chandrupatla, T. R., Belegundu, A. D., Ramesh, T., & Ray, C. (1997).*Introduction to finite elements in engineering* (pp. 279-300). Upper Saddle River: Prentice Hall.
7. Livesley, R. K. (2013). *Matrix Methods of Structural Analysis*, Pergamon International Library of Science, Technology, Engineering and Social Studies. Elsevier.
8. McGuire, W., Gallaghar R. H. &Zimian, R. D. ()1979. *Matrix Structure Analysis.* John Willey Publication.
9. Przemieniecki J. S. (1985). *Theory of Matrix Structural Analysis*, Dover Publication Inc. New York

AML STRUCTURAL DYNAMICS (DC) (Odd Semester)

Credit:	**4**
Contact hours (L-T-P):	**3-0-2**
Pre-requisites:	**Nil**
Course Assessment Method:	**As per Academic Rule Book**

Course Objective

To introduce fundaments of vibrations of SDOF, MDOF and continuous systems.

Course Outcomes (COs)

At the completion of this course, the student shall acquire knowledge and ability

- **CO1.** to convert structure into SDOF system and calculate natural frequency,
- **CO2.** to calculate free and forced vibration response of SDOF system,
- **CO3.** to calculate free and forced vibration response of MDOF system,
- **CO4.** to understand numerical methods for calculation of response of SDOF and MDOF system,
- **CO5.** to understand time history analysis and concept of response spectra.

Relationship of Course Outcomes to Program Outcomes
H = High correlation; M = Medium correlation; L = Low correlation

POs → / COs ↓	PO1	PO2	PO3	PO4	PO5
CO1	M				
CO2	M				
CO3	H		H	H	
CO4	H			H	
CO5	L		H		

Syllabus

Introduction: Vibrations and the nature of time dependent phenomena, inertia, dynamic equilibrium and mathematical models of physical systems; Energy storing and dissipation mechanisms.

Dynamics of Single Degree of Freedom Systems: Undamped and damped, free and forced vibrations; Steady-state and transient response, impulse response; Harmonic response and applications to vibration isolation; Convolution integral and solution of equation of motion;

Numerical methods for solution of linear and non-linear equations of motion;

response/shock spectra, Response spectrum;

Dynamics of Multi-Degree of Freedom Systems: Lagrange's equations; equations of motion for MDOF systems; Algebraic eigen value problem and free vibration analysis; Undamped and damped normal modes; Mode superposition method and response spectrum method for dynamic analysis of linear systems; Mode-truncation and correction for the missing mass.

Dynamics of Continuous Systems: Hamilton's principle; Axial and transverse vibrations of beams, torsional vibrations of shafts; Normal modes; Free and forced vibration analysis by mode superposition;
Approximate Methods for Vibration Analysis: Rayleigh quotient, Rayleigh-Ritz method.
Time history analysis and generation of Response spectra

Reference Books/Material

1. Chopra, A. K. (1995). *Dynamics of structures* (3 Ed.). New Jersey: Prentice Hall.
2. Clough, R. W., &Penzien, J. (1993). *Dynamics of structures*, 2Edition, McGraw-Hill..
3. Humar, J. L. (1990). *Dynamics of Structures*, Prentice-Hall, Englewood Cliffs, NJ, 1990.
4. Paz, M. (2012). *Structural dynamics: theory and computation.* Springer Science & Business Media.
5. Timoshenko, S. P., & Young, D. H. (1948). *Advanced dynamics*. McGraw Hill
6. Meirovitch, L. (1975). *Elements of vibration analysis*. McGraw-Hill.
7. Biggs, J. M., & Testa, B. (1964). *Introduction to structural dynamics*.McGraw Hill
8. Craig, R. R., &Kurdila, A. J. (2006). *Fundamentals of structural dynamics*. John Wiley & Sons.
9. Filiatrault, A. (2013). *Elements of earthquake engineering and structural dynamics*. Presses inter Polytechnique.
10. Buchholdt, H. A. (1997). *Structural dynamics for engineers*. Thomas Telford.
11. Paultre, P. (2013). *Dynamics of structures*. John Wiley & Sons.
12. G.B. Warburton, "*The Dynamic Behaviour of Structures*", 2nd edition PergamonPress, 1976

STRUCTURAL DYNAMICS LABORATORY

List of experiments

1. To find the period of compound pendulum
2. To find natural frequency of SDOF system
3. To find natural frequency of two DOF system
4. To find natural frequency of three DOF system
5. To observe liquefaction of soil
6. To observe phenomenon of vibration absorption
7. Frequency analysis of MDOF systems using software
8. Generation of response spectrum
9. Response of MDOF system using modal superposition
10. Response spectrum analysis of MDOF system using software

AML EARTHQUAKE ENGINEERING (DC) (Odd Semester)

Credits:	**3**
Contact hours (L-T-P):	**3-0-0**
Pre-requisites:	**Nil**
Overlaps with:	**Nil**
Course Assessment Method:	**As per Academic Rule Book**

Course Objectives

A. To expose students to fundamentals of earthquake engineering and environmental conditions of the country and world.
B. To learn method of deterministic seismic hazard analysis.
C. To train the students to analyze earthquake characteristics and associated effects on structures.
D. To communicate the concepts of dynamic analysis for civil engineering applications.
E. To teach the various methods for strength, stress and load-resistant design.
F. To impart the basic principles for seismic design and construction of structures in accordance with the provisions of Indian Standard Codes.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability

- **CO1.** to understand the fundamentals of earthquake engineering and seismicity conditions of the country and world,
- **CO2.** to perform site specific deterministic seismic hazard analysis,
- **CO3.** to analyze earthquake characteristics and associated effects on structures, including linear responses,
- **CO4.** to understand the concepts of dynamic equations of motion and perform analysis for dynamic systems in civil engineering applications,
- **CO5.** to evaluate the magnitude and distribution of seismic loads for strength, stress and load-resistant design,
- **CO6.** to apply the basic principles for seismic design and construction of structures in accordance with the provisions of Indian Standard Codes.

Relationship of Course Objective to Program Outcome
H = High correlation; M = Medium correlation; L = Low correlation

POs → / COs ↓	PO1	PO2	PO3	PO4	PO5
CO1			H	M	L
CO2	H	H	M	H	
CO3	H	H	M	H	
CO4	M	H	M		
CO5	H	H			
CO6		H			H

Syllabus

Origin of earthquakes, Engineering geology, Seismicity of the world, Faults, Propagation of earthquake waves. Quantification of earthquake (magnitude, energy, intensity of earthquake), Measurements of earthquake (accelerograph, accelogram recording), Determination of magnitude, Epicental distance, focal depth, etc. Ground motion and their characteristics, Factors affecting ground motions.
Concept of response spectra, generation of site-specific spectrum, Estimation of PGA, Earthquake design spectrum and inelastic spectra.
Introduction to MATLAB or similar software.
Concept of earthquake-Resistant design, design philosophy, Four virtues of EQRD: Stiffness, Strength, ductility and Configurations, Introduction to Capacity design concepts, Introduction to IS:1893(P1), Codal Coefficient and Response Spectrum Method.

Reference Books/Material

1. Dowrick, D. L. (1987).*Earthquake Resistance Design for Engineers and Architects*, John Willey & Sons, 2nd Edition.
2. Housner, G. W. &Jenning, P.C. (1982). *Earthquake Design Criteria*, Earthquake Engineering Research Institute, Oakland, California, USA.
3. Newmark, N. M. & Hall, W.J. (1982). *Earthquake Spectra &Design , Earthquake Design Criteria*, Earthquake Engineering Research Institute, Oakland, California, USA.
4. Wakabayashi, M. (1986). *Design of Earthquake Resistance Buildings*, McGraw Hill Books Company.
5. Okamoto, S. (1984). *Introduction to Earthquake Engineering*, University of Tokyo press, 2ndEdition,.
6. Kramer, S. L. (1996).*Geotechnical Earthquake Engineering*, Prentice Hall, New Jersey.
7. Bolt, B. A. (1988). *Earthquakes*, W. H. Freeman & Company, NY.
8. Datta, T. K. (2010). *Seismic analysis of structures*. John Wiley & Sons.

AMP TECHNICAL WRITING AND COMMUNICATION SKILLS (DC) (Odd Semester)

Credit: 1
Contact hours (L-T-P): 0-0-2
Pre-requisites: Nil
Overlaps with: Nil

Course Objective
The objective is to develop habit of understanding the state of art of research on given subject area and develop skill of good report writing and presentation.

Course Outcome
The Students will be able to
CO1. The Student will learn techniques and method of analyzing a research problem, technical report writing and presentation.

Relationship of Course Objective to Program Outcome
H = High correlation; M = Medium correlation; L = Low correlation

POs → / COs ↓	PO1	PO2	PO3	PO4	PO5
CO1	M	H	L	M	M

Content
The seminar will be on review research paper given by faculty and it will be evaluated by faculties of the department (team wise).

AML541 THEORY OF PLATES AND SHELLS (DE) (Odd semester)

Credit: 3
Contact hours (L-T-P): 3-0-0
Pre-requisites: Nil
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective

To understand the basic concept, mathematical modelling, behaviour and analysis of plate and shell structures**.**

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to understand

- **CO1.** the behaviour of plate under different loadings and boundary conditions,
- **CO2.** to solve the two dimensional complex structural problems,
- **CO3.** to develop mathematical models of structural systems,
- **CO4.** mathematical solution techniques to calculate the response of plates subjected to various loadings as well as boundary conditions.

Relationship of Course Outcomes to Program Outcomes
H = High correlation; M = Medium correlation; L = Low correlation

POs → / COs ↓	PO1	PO2	PO3	PO4	PO5
CO1	H	L	H	H	
CO2	H		H	H	
CO3	H		H	M	
CO4	H		H	H	

Syllabus

Governing differential equations of thin rectangular Plates with various boundary conditions and loadings
Bending of long thin rectangular plate to a cylindrical surface, Kirchhoff plate theory, Introduction to orthotropic plates
Circular plates with various boundary conditions and loadings
Numerical methods for solution of plates, Navier's, Levy's solutions
General shell geometry, classifications, stress resultants, equilibrium equation, Membrane theory for family of Shells (Parabolic, Catenary, Cycloid, Circular, hyperbolic)
Classical bending theories of cylindrical shells with and without edge beams such as approximate analysis of cylindrical shells

Reference Books/ Material

1. Timoshenko, S., &Woinowsky-Krieger, S. (1959). *Theory of plates and shells* (Vol.2, p. 120). New York: McGraw-hill.

2. Szilard, R. (1974). *Theory and analysis of plates,Classical and Numerical Methods,* Prentice-Hall, Englewood Cliffs, New Jersey .
3. Novozhilov, V. V. (1959). *The Theory of Thin Shells*. English translation, Noordhoff, P., Groningen, The Netherlands.
4. Ramaswamy, G. S. (1968). *Design and construction of concrete shell roofs*.McGraw-Hill.
5. Chandrashekhara, K. (2001). *Theory of plates*. Universities press.

AML547 NUMERICAL METHODS AND PROGRAMMING (DE) (Odd Semester)

Credit:	**4**
Contact hours (L-T-P):	**3-0-2**
Pre-requisites:	**Nil**
Overlaps with:	**Nil**
Course Assessment Method:	**As per Academic Rule Book**

Course Objectives

1. To empower students with higher level computer programming skill.
2. Learn numerical techniques for variety of mathematical problems.
3. Analyze the validity and error in the numerical results
4. To develop computer programming with application of various numerical methods to solve large scale computation heavy problems.

Course Outcomes:

At the completion of this course, the student shall acquire knowledge and ability

CO1. to derive numerical methods for various mathematical operations and tasks, such as interpolation, curve fitting, differentiation, integration, the solution of linear and nonlinear equations, the solution of differential equations, Initial value, boundary-value and Eigenvalue Problems,

CO2. to select appropriate numerical methods to apply to various types of problems in engineering and science in consideration of the mathematical operations involved, accuracy requirements, and available computational resources,

CO3. to develop higher level computer programming/codes/software for solution using appropriate numerical techniques and present results in an informative way.

Relationship of Course Outcomes to Program Outcomes
H = High correlation; M = Medium correlation; L = Low correlation

POs → / COs ↓	PO1	PO2	PO3	PO4	PO5
CO1	H	L	H	M	
CO2	M	L	H	H	
CO3	M	H	H	M	

Syllabus

I) Computer Programming:

Computer programming Fortran / C / MATLAB– Programming fundamentals, Introduction to algorithm development, Computer Implementation of Matrices, Guidelines for development of a large sized problem with application of various numerical methods.

II) Numerical Methods:

Preliminaries: Number Representation, Normalized Floating Point representation, Significant Digits, Accuracy and Precision, Rounding and Chopping, Error Analysis

Numerical Solution of Linear System of Equations: Direct methods (Gauss elimination, Gauss-Jordan method, LU decomposition and Cholesky decomposition), iterative methods (Gauss Seidel method, Gauss-Jacobi method), matrix inversion, the power method for eigenvalue problems

The Solution of Nonlinear Equations f(x) = 0 i.e. Root finding methods: The Bisection Method, The Method of False Position or Regula Falsi, Fixed Point Iteration Method, The Newton-Raphson Method, The Secant Method, Muller's method

Interpolation and Polynomial Curve Fitting: Errors in polynomial Interpolation, Maclaurin and Taylor Series, Finite Differences, Newton Interpolation Polynomial, Central Difference Interpolation Formulae, Lagrange Interpolation Polynomial, Hermite's Interpolation , Spline Interpolation, Cubic Spline, Legendre Polynomials

Curve Fitting by Regression : Least Square Regression, Interpolation, Linear Least Square Regression, Linearization of Non-linear Relationship, Polynomial Regression , Multiple Linear Regression, Fast Fourier Transform (FFT)and Trigonometric Polynomials

Numerical integration: Trapezoidal rule, Simpson's rules, Newton-Cotes integration formulae, Duhamel Integral, Method of Gauss Quadrature

Numerical differentiation: finite difference method, high accuracy differentiation formulas, Richardson Extrapolation

Numerical solution of initial value and boundary value problems involving ordinary differential equations: Euler method, midpoint method, Heun's method, Runge-Kutta methods, Runge-Kutta-Fehlberg Method, Milne-Simpson's Method, Predictor-Corrector Methods, Finite Difference Method for Solution of Partial Differential Equations, Spring-Mass Systems

Boundary-value and Eigenvalue Problems: Shooting Method, Finite Difference Method, Eigenvalue Problems, Polynomial Method, Eigen Vectors, Power Method.

Applications of numerical methods
Tools to be used: Any one of FORTRAN Language / C- Langauage / MATLAB/Mathematica.

Numerical Analysis and Programming Lab:

The interactive experiments in this lab will give the students an opportunity for learning and better understanding of the basic concepts and constructs of computer programming.

List of experiments

1. Expression Evaluation
2. Basic Control Flow
3. Arrays
4. Functions
5. Structures
6. Strings
7. Numerical analysis & Approximation

Knowledge of writing programs in any programming language is expected. No prior experience with data structures is required.

Reference Books

1. Mathews, J. H. , and Fink, K. D. (2004*) Numerical Methods using MATLAB*, 4th Edition, Prentice Hall

2. Chapra, S. C. (2012) *Applied Numerical Methods with MATLAB for Engineers and Scientists*, 3rd Edition, McGraw Hill
3. McCormic J. M. and Salvadori M. G (1966*) Numerical Methods in FORTRAN*, Prentice Hall of India, New Delhi.
4. Rajaraman, V. (1988) *Fortran-9* 5, Prentice Hall of India
5. Kanetkar Y. P. (2017) *Let us C* , BPB Publication, New Delhi.
6. Scarborough J. B (1966) *Numerical Mathematical Analysis*, Oxford and IBH publishers.
7. Gerald C. F .(1970) *Applied Numerical Analysis*, Addison – Wesley Publishing Company.
8. Jain M. K., Iyengar S. R. K. and Jain R. K (1993) *Numerical Methods for Scientific and Engineering Computations*, John Wiley – New Age International Limited.
9. BalgurusamyE.(2001) *Numerical Methods* , Tata McGraw Hill, New Delhi, Fifth Edition.
10. Press, W.H; Tenkolsky, S.A.; Vetterling, W.T.; & Flannery, B.P. (1993) *Numerical Recipes-the art of scientific Computing*; 2nd Edition, Cambridge University Press.
11. Süli, E. and Mayers, D. F. (2003) *An Introduction to Numerical Analysis*, Cambridge University Press
12. Burden, R. L. (2012) *Numerical Analysis*, 9 th Edition, Cengage Learning India
13. Conte, S. D., and Boor, C. (1980) *Elementary Numerical Analysis: An Algorithmic Approach*, 3 rd Edition, McGraw Hill.

AML FOUNDATIONS (DE) (Odd Semester)

Credit: **4**
Contact hours (L-T-P): **4-0-0**
Pre-requisites: **Nil**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective
To enhance the understanding of various methods for analyze and design different types of foundations

Course Outcomes
At the completion of this course, the student is expected to acquire
- **CO1.** knowledge of stability analysis of isolated and combined footing, retaining wall,
- **CO2.** knowledge of analysis of raft foundation, pile foundation,
- **CO3.** ability to interpret analysis results and design of foundation.

Relationship of Course Outcomes to Program Outcomes
H = High correlation; M = Medium correlation; L = Low correlation

PO, CO	PO1	PO2	PO3	PO4	PO5
CO1		M			
CO2				M	
CO3			M		

Syllabus
Introduction geotechnical aspects for foundation design (Bearing capacity, modulus of subgrade reactions etc.) and relevant IS codes
Analysis and design of shallow foundations: Individual and combined footings for axial and bending loads (Uniaxial and biaxial), Loss of contacts and calculation of liftoff
Analysis and design of raft foundations, Annular Footings, Rigid and flexible foundations, Beams and slabs on elastic foundations, computer applications using soil structure interaction
Analysis and design of pile and pile cap
Analysis and design of Well foundations
Analysis and design of Retaining walls including Reinforced earth walls
Analysis of sheet piles, Improvement techniques for SBC

Reference Books / Material

1. Hetényi, M. (1971). *Beams on elastic foundation: theory with applications in the fields of civil and mechanical engineering*. University of Michigan.
2. Bowles, J. E. (1988). *Foundation analysis and design*.McGraw-Hill Book Company, New York
3. Saran, S. (1999). *Soil dynamics and machine foundations*. Galgotia Publication Pvt. Ltd. New Delhi, India, 486.
4. Srinivasulu, P., &Vaidyanathan, C. V. (1976). *Handbook of machine foundations*. Tata McGraw-Hill Education.

5. Kurian, N. P. (1982). *Modern foundations: introduction to advanced techniques*. Tata McGraw-Hill.
6. Reese, L. C., Isenhower, W. M., & Wang, S. T. (2006). *Analysis and design of shallow and deep foundations* (Vol. 10). Hoboken, NJ: Wiley.
7. Portney, L. G., & Watkins, M. P. (2000). *Foundations of clinical research: applications to practice* (Vol. 2). Upper Saddle River, NJ: Prentice Hall.
8. McCarthy, D. F., & McCarthy, D. F. (1977). *Essentials of soil mechanics and foundations* (p. 505). Reston Publishing Company.

AML542STABILITY OF STRUCTURES (DE) (Odd Semester)

Credit:	**4**
Contact hours (L-T-P):	**3-1-0**
Pre-requisites:	**Nil**
Overlaps with:	**Nil**
Course Assessment Method:	**As per Academic Rule Book**

Course Objective

The main objective of studying this course is to understand the fundamental principles of structural stability and behavior.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability

CO1. to understand the basics of elastic stability analysis,

CO2. to determine elastic critical loads for simple structures and the limitations of such analysis,

CO3. to apply approximation methods based on energy to determine the stability of simple systems.

Relationship of Course Outcomes to Program Outcomes

H = High correlation; M = Medium correlation; L = Low correlation

POs → / COs ↓	PO1	PO2	PO3	PO4	PO5
CO1	L	M	H	H	L
CO2	H	M	H	H	L
CO3	H	H	H	H	L

Syllabus

Elastic stability: Geometric Non linearity –Basic Concepts

Elastic buckling of bars, Euler's formula

Buckling of continuous beams, buckling of nonprismatic members, effect of shear force on buckling of bars, use of energy method

Analysis of beam-columns with various end conditions, Use of trigonometric series, Buckling of single span portal frames

Torsional buckling: Pure torsion of thin walled open cross section, warping and warping rigidity, Torsional buckling of columns, combined buckling by torsion and flexure

Lateral torsional buckling of beams, lateral buckling of beams in pure bending, lateral torsional buckling of cantilever and S.S. beams

Introduction to buckling of plates

Reference Books/Material

1. Chajes, A. (1974). *Principles of structural stability theory*. Prentice Hall.
2. Iyengar, N. G. R. (2007). *Elastic Stability of Structural Elements*. Macmillan.

3. Gambhir, M. L. (2004). *Stability analysis and design of structures*. Springer Science & Business Media.
4. Timoshenko, S. P., Goodier, J. N., & Abramson, H. N. (1970). *Theory of elasticity*. Journal of Applied Mechanics, 37, 888.
5. Timoshenko, S. (1953). *History of strength of materials: with a brief account of the history of theory of elasticity and theory of structures*. Courier Corporation.
6. Gerard, G. (1961). *Introduction to structural stability theory*. McGraw-Hill.

AML MASONRY STRUCTURES AND RETROFITTING (DE) (Odd Semester)

Credit:	**4**
Contact hours (L-T-P):	**3-0-2**
Pre-requisites:	**Nil**
Overlaps with:	**Nil**
Course Assessment Method:	**As per Academic Rule Book**

Course Objective

To provide insight into relevant theories, simulation techniques and principles of earthquake-resistant design and construction for various types of masonry structures and to introduce various codal provisions.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability

- **CO1.** to design masonry structures considering the effect of earthquake forces,
- **CO2.** to develop design report and structural drawings,
- **CO3.** to assess the present condition of building and apply suitable techniques for its retrofitting.

Relationship of Course Objective to Program Outcome
H = High correlation; M = Medium correlation; L = Low correlation

	PO1	PO2	PO3	PO4	PO5
CO1		H			
CO2			M		
CO3	M			L	

Syllabus

Material Properties of Masonry units- stones, brick and concrete blocks, hollow and solid units, Manufacturing process of Mortar and grout; Various tests and standards.

Behavior of masonry under compression: Prism strength, Failure mechanism, types of construction and bonds; Eccentric loading; Slenderness – effective length and effective height, effect of openings; Code provisions.

Behavior of masonry structures during past earthquakes, Common modes of failure, effect of unit shapes and mortar type, effect of roof and floor systems, Common deficiencies.

Masonry under lateral loads: In-plane and out-of-plane loads, bending parallel and perpendicular to bed joints; Shear and flexure behavior of piers; Test and standards; lateral force distribution for flexible and rigid diaphragms; Arching action; Combined axial and bending actions.

Earthquake-Resistant Measures: Analysis for earthquake forces, role of floor and roof diaphragm; Concept and design of bands, bandages, splints and ties; Reinforced masonry; Vertical reinforcement at corners and jambs; Measures in random-rubble masonry; Confined masonry; Code provisions.

Complete design of single storey and two storey masonry building with report and construction drawings.

Retrofitting of Masonry Building: Techniques of repair and retrofitting of masonry buildings; IS: 13935-1993 provision for retrofitting.

Reference Books/Material

1. Drysdale, R. G., Hamid, A. A., & Baker, L. R. (1994). *Masonry structures: behavior and design*. Prentice Hall.
2. Schneider, R. R., & Dickey, W. L. (1994). *Reinforced masonry design*. Pearson College Division.
3. PaulayT. and Priestley, M. J. N. (1992). *Seismic Design of Reinforced Concrete and Masonry Buildings*, John-Wiley & Sons, Inc.
4. Hochwalt, J. M., &Amrhein, J. E. (2012). *Reinforced Masonry Engineering Handbook*. Masonry Institute of America and International Code Council, Torrance, CA.Hendry, A. W. (1990). *Structural masonry*. Scholium International.
5. Tomazevic, M. (1999). *Earthquake-resistant design of masonry buildings*. World Scientific.
6. Anderson, D., &Brzev, S. (2009). *Seismic design guide for masonry buildings*. Canadian Concrete Masonry Producers Association.
7. Agarwal, Pankaj and Shrikhande, Manish (2006). *Earthquake Resistant Design of Structures*, PHI Learning Pvt. Ltd, Eastern Economy Edition.

AML ADVANCED CONCRETE TECHNOLOGY AND TESTING (DE) (Odd Semester)

Credit: **4**
Contact hours (L-T-P): **3-0-2**
Pre-requisites: **Nil**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objectives
To impart knowledge on advanced concrete materials and technology

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability

CO1. to understand various techniques of mix design with various admixtures
CO2. to understand and design structures with high performance concrete
CO3. to understand various aspects of durability of concrete

Relationship of Course Outcomes to Program Outcomes
H = High correlation; M = Medium correlation; L = Low correlation

POs → COs ↓	PO1	PO2	PO3	PO4	PO5
CO1	H		M	M	L
CO2	H		H	H	L
CO3	H	L	M	M	M

Syllabus
Importance of Bogue’s compounds, Structure of a Hydrated Cement Paste, Volume of hydrated product, porosity of paste and concrete, transition Zone, Elastic Modulus, factors affecting strength and elasticity of concrete, Rheology of concrete in terms of Bingham’s parameter.
Chemical Admixtures- Mechanism of chemical admixture, Plasticizers and super Plasticizers and their effect on concrete property in fresh and hardened state, Marsh cone test for optimum dosage of super plasticizer, retarder, accelerator, Air-entraining admixtures, new generation superplasticiser.
Mineral Admixture-Fly ash, Silica fume, GCBS, and their effect on concrete property in fresh state and hardened state.
Mix Design - Factors affecting mix design, design of concrete mix by BIS method using IS10262 and current American (ACI)/ British (BS) methods. Provisions in revised IS10262-2004.
RMC - manufacture, transporting, placing, precautions,
Methods of concreting- Pumping, under water concreting, shotcrete, mass concreting, hot and cold weather concreting

Special concrete - High volume fly ash concrete - concept, properties, typical mix. Fiber reinforced concrete - Fibers types and properties, Behavior of FRC in compression, tension including pre-cracking stage and post-cracking stages, behavior in flexure and shear, Self-compacting concrete concept, materials, tests, properties, application and Typical mix. Ferro cement-materials, techniques of manufacture, properties and application Light weight concrete-materials properties and types. Typical light weight concrete mix High density concrete and high performance concrete-materials, properties and applications, typical mix. Reactive Powder Concrete and Bendable Concrete and Polymer concrete, Pumpable concrete - materials, properties and applications

Durability of Concrete - Introduction, Permeability of concrete, chemical attack, acid attack, efflorescence, Corrosion in concrete. Thermal conductivity, thermal diffusivity, specific heat. Alkali Aggregate Reaction, IS456-2000 requirement for durability.

Test on hardened concrete-Effect of end condition of specimen, capping, H/D ratio, rate of loading, moisture condition. Compression, tension and flexure tests. Tests on composition of hardened concrete-cement content, original w/c ratio. NDT tests concepts-Rebound hammer, pulse velocity methods. Recycling & re-use of industrial waste material.

Reference Books/Material

1. Neville, A. M. (1995). *Properties of concrete (Vol. 4)*. London: Longman.
2. Shetty, M. S. (2005). *Concrete Technology (ME)*. S. Chand.
3. Santhakumar, A. R. (2007). *Concrete Technology*. oxford university press.
4. Mehta, P. K. (1986). *Concrete. Structure, properties and materials*.
5. ACI 211, *Code for Mix Design*.
6. IS 10262-2009, *Concrete Mix Proportioning – Guidelines*. BIS New Delhi
7. Raju, N. K. (1983). *Design of concrete mixes*. CBS Publishers &Distributors.
8. Gambhir, M. L. (1992). *Concrete manual*. Dhanpat Rai.
9. Newman, J., & Choo, B. S. (Eds.). (2003). *Advanced concrete technology 3: processes*. Butterworth-Heinemann.
10. Prasad, J., & Nair, C. K. (2008). *Non-Destructive Test and Evaluation of Materials*. Tata McGraw-Hill Education.
11. Aïtcin, P. C. (2011). *High performance concrete*. CRC Press.
12. Powers, T. C. (1968). *The properties of fresh concrete,* John Wiley and Sons

AML REINFORCED CONCRETE DESIGN TO IRC 112 (DE) (Odd Semester)

Credit:	**4**
Contact hours (L-T-P):	**3-0-2**
Pre-requisites:	**Nil**
Overlaps with:	**Nil**
Course Assessment Method:	**As per Academic Rule Book**

Course Objective

To introduce method for design of RC members/building with loading standards using IRC 112 / Eurocode

Course Outcomes

CO1. Students will develop ability to carry out research in RC design and development work

CO2. Students will be capable of developing design report and structural drawings.

CO3. Students will be capable of designing RC members considering Eurocode.

CO4. Student should be able to understand complex behavior of RC buildings and select appropriate modern tool to solve it.

Relationship of Course Objective to Program Outcome
H = High correlation; M = Medium correlation; L = Low correlation

	PO1	PO2	PO3	PO4	PO5
CO1	M				
CO2		M			
CO3			L		
CO4				L	

Syllabus

Introduction to design and properties of reinforced concrete, limit state design, Analysis of the structures at the ultimate state, analysis of section (rectangular, flanged beams etc), shear, bond and torsion, serviceability, durability and stability requirements, design of RCC beams(rectangular, flanged beams etc), slabs, columns (uniaxial, biaxial, slenderness effect, charts etc), Introduction to composite action with shear connections.

Prestressed:

Introduction to basic concepts and general principles of prestressed concrete, techniques of prestressing, prestressing systems, limit state of collapse – flexure and shear as applied to prestressed concrete beams, kern points, choice and efficiency of sections, cable profile and layouts, cable zone, deflection of prestressed concrete sections.

Analysis of prestressed concrete sections for flexure under pretensioned and post tensioned conditions, losses in prestress, application to simply supported beams and slabs

End zone stresses in prestresses concrete members, pretension transfer bond, transmission length, end block of post tensioned members.

Reference Books / Material

1. Penelis, G. G., &Kappos, A. J. (1997). *Earthquake Resistant Concrete Structures*. E & FN Spon
2. Darwin, D., Dolan, C.W. &Nilson, A.H., (2016). *Design of concrete structures*. McGraw-Hill Education.
3. Reynolds, C. E., Steedman, J. C., &Threlfall, A. J. (2007). *Reinforced concrete designer's handbook*. CRC Press.
4. Reynolds, C. E. (1962). *Basic Reinforced Concrete Design: Elementary* (Vol. 1). Concrete Publications.
5. Fintel, M. (Ed.). (1974). *Handbook of concrete engineering* (p. 801). New York: Van Nostrand Reinhold.
6. Nilson, A. (1997). *Design of concrete structures* (No. 12th Edition).
7. Mosley, W. H., Hulse, R., &Bungey, J. H. (2012). *Reinforced concrete design: to Eurocode 2*. Macmillan International Higher Education.

AML EARTHQUAKE-RESISTANT DESIGN OF STRUCTURES (DE) (Odd Semester)

Credit: 3
Contact hours (L-T-P): 3-0-0
Pre-requisites: Nil
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective
To course will provide insight into design of structures to withstand earthquake forces and related seismic safety issues.

Course Outcomes

CO1. Students will be capable of investigating the behavior of structures during past earthquake in correlation with hazard level.
CO2. Students will learn structural behavior under seismic loading and application of various tools to analyze its behavior.
CO3. Students will be capable of designing structural and nonstructural elements considering seismic effect.

Relationship of Course Objective to Program Outcome
H = High correlation; M = Medium correlation; L = Low correlation

	PO1	PO2	PO3	PO4	PO5
CO1	L				
CO2				H	
CO3			H		

Syllabus
Seismic performance of structures and structural components during earthquakes; ground motion parameters; response spectrum, design spectrum.
Concept of strength, overstrength and ductility, Concept of equal displacement and equal energy principles, Capacity Design; Seismic design consideration in buildings with irregularities.
Equivalent static analysis, response spectrum analysis.
Seismic Design of Building Components: Seismic resistant properties of reinforced concrete; Seismic Behaviour and design of linear reinforced concrete elements; Seismic behavior of planer reinforced concrete elements (beam, column, shear walls and joints), codal provisions
Seismic Provisions for Structural Steel Buildings – Materials, connections, joints and Fasters; Columns, ordinary, intermediate and special moment resisting frame; Concentrically and eccentrically braced frames.
Introduction to Non-Structural Elements, Conceptual Earthquake Behaviour of NSEs, Behaviour of NSEs in Earthquake, Performance Expectation from NSEs during Earthquake, International Code Provisions for Seismic Protection of NSEs,

Reference Books/Material

1. PaulayT. & Priestley, M.J.N. (1992). *Seismic Design of Reinforced Concrete and Masonry Buildings*, John-Wiley & Sons, Inc.
2. Agarwal, P.&Shrikhande, M. (2006). *Earthquake Resistant Design of Structures*, PHI Learning Pvt. Ltd, Eastern Economy Edition.
3. Kramer S. L. (1996).*Geotechnical Earthquake Engineering.* Low Priced Edition, First Indian Reprint, Prentice-Hall International Series in Civil Engineering and Engineering Mechanics, Pearson Education Pvt. Ltd .
4. Penelis, G. G., &Kappos, A. J. (1997), *Earthquake Resistant Concrete Structures* E & FN Spon
5. Englekirk R. E. (2003).*Seismic Design of Reinforced and Precast Concrete Buildings*, John-Wiley & Sons Inc, Priestley.

AML NUMERICAL METHODS FOR DYNAMIC SYSTEMS (DE) (Odd Semester)

Credit:	**4**
Contact hours (L-T-P):	**3-0-2**
Pre-requisites:	**Nil**
Overlaps with:	**Nil**
Course Assessment Method:	**As per Academic Rule Book**

Course Objectives

To course will provide insight into design of structures to withstand earthquake forces and related seismic safety issues.

Course Outcomes

CO1. Students will be capable of using basic matrix methods for solving dynamic problems.

CO2. Students will be capable of selecting appropriate methods for solving complex problem of dynamic systems.

Relationship of Course Objective to Program Outcome
H = High correlation; M = Medium correlation; L = Low correlation

	PO1	PO2	PO3	PO4	PO5
CO1	H				
CO2				H	

Syllabus

Elementary concepts of vector spaces, subspaces; Column and row space of a matrix; Range, null space, and rank of a matrix, ortho-normal bases, vector and matrix norms, testing for convergence, errors in floating point arithmetic.

Computer implementation of matrix and vector operations, operation counting, structures of matrices and their storage, block algorithms, vector processing and parallel processing.

Computational aspects of elimination and in-situ factorisation methods for solution of large system of equations for dynamic problems; Implementation details for band and/or skyline solvers.

Problems associated with choice and implementation of solution techniques in the eigen solution of large problems arising in dynamic systems.

Application of Interpolation and extrapolation, numerical differentiation and quadrature methods.

Response evaluation by the Integration of ordinary differential equations with emphasis on accuracy and stability considerations, integration of stiff ordinary differential equations, concepts of A-stability and stiff-stability.

Reference Books/Material

1. Wilkinson J. H., (1965). *The Algebraic Eigenvalue Problem,* Oxford University Press
2. Wilkinson J. H., Springer, V. and Reinsch, C. (1971).*Linear Algebra*, vol. II of Handbook of Automatic Computation.
3. Dahlquist G. and Bjorck A. (1974)*Numerical Methods*, Prentice Hall.
4. Pariett B. N. (1980) *The Symmetric Eigenvalue Problem,* Prentice-Hall.

5. George A. & Liu J.W.H. (1981) *Computer Solution of Large Sparse Positive Definite Systems*, Prentice Hall.
6. Hager W. W. (1988)*Applied Numerical Linear Algebra*, Prentice-Hall.
7. Press, W. H., Teukolsky, S. A., Flannery, B. P., &Vetterling, W. T. (1992). *Numerical recipes in Fortran 77: volume 1, volume 1 of Fortran numerical recipes: the art of scientific computing*. Cambridge university press.
8. Clough R. W. &Penzien J. (1993) *Dynamics of Structures,* Second Edition, McGraw-Hill.
9. Golub G. H. & Van Loan C.F., (1996) *Matrix Computations,* Third Edition, The Johns Hopkins University Press.
10. Bathe K.J. (1996) *Finite Element Procedures*, Prentice Hall.
11. Hughes, T. J. (2012)*The finite element method: linear static and dynamic finite element analysis,* Courier Corporation..

AML EARTHQUAKE-RESISTANT DESIGN OF CONCRETE BUILDINGS (DC)

(Even Semester)

Credit:	**4**
Contact hours (L-T-P):	**3-0-2**
Pre-requisites:	**Nil**
Overlaps with:	**Nil**
Course Assessment Method:	**As per Academic Rule Book**

Course Objective

To introduce method for design of RC members/building with loading standards

Course Outcomes

CO1. Students will develop ability to carry out research in RC design and development work.

CO2. Students will be capable of developing design report and structural drawings.

CO3. Students will be capable of designing RC members considering ductility concept.

CO4. Student should be able to understand complex behavior of RC buildings and select appropriate modern tool to solve it.

Relationship of Course Objective to Program Outcome
H = High correlation; M = Medium correlation; L = Low correlation

	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO 1	M				
CO 2		M			
CO 3			H		
CO 4				L	

Syllabus

Review of Limit State Method (LSM), Introduction to various loading and design Codes, Seismic Hazard Estimation, Effect of stiffness, strength and ductility on seismic performance of structures, Design and detailing of RC framed building elements (beam, column, shear wall, diaphragm and beam-column joint) as per IS 456 and IS 13920, Analysis, design and detailing of simple buildings (Low Rise Building) including report and structural drawings (as per IS 875, IS1893, IS 456, IS 13920), Development of P-M interaction curves, Effect of slenderness effect, Development of Moment Curvature curve for beam and Columns, Pushover analysis, Concept of Performance based design

Reference Books / Material

1. Park, R. &Paulay, T. (1975). *Reinforced concrete structures.* John Wiley & Sons.
2. Penelis, G. G.&Kappos, A. J. (1997). *Earthquake Resistant Concrete Structures,* E & FN Spon
3. Paulay, T., & Priestly, M. J. N. (2009). *Seismic design of RC and masonry buildings*. John Wiley & Sons, Inc.

4. Moehle, J., (2014). *Seismic design of reinforced concrete buildings*. McGraw Hill Professional.
5. Darwin, D., Dolan, C.W. &Nilson, A.H.(2016). *Design of concrete structures*. McGraw-Hill Education.
6. Booth, E. D. (1994). *Concrete structures in earthquake regions: design and analysis*. Longman Scientific & Technical; Co published in the US with J. Wiley.
7. Reynolds, C. E., Steedman, J. C., &Threlfall, A. J. (2007). *Reinforced concrete designer's handbook*. CRC Press.
8. Reynolds, C. E. (1962). *Basic Reinforced Concrete Design: Elementary* (Vol. 1). Concrete Publications.
9. Fintel, M. (Ed.). (1974). *Handbook of concrete engineering* (p. 801). New York: Van Nostrand Reinhold.
10. Gaylord, E. H., Gaylord, C. N., &Stallmeyer, J. E. (1997). *Structural engineering handbook*.
11. Nilson, A. (1997). *Design of concrete structures* (No. 12th Edition).
12. Agarwal, P. and Shrikhande, M. (2006). *Earthquake Resistant Design of Structures*, PHI Learning Pvt. Ltd, Eastern Economy Edition.

AML EARTHQUAKE-RESISTANT DESIGN OF STEEL BUILDINGS (DC) (Even Semester)

Credit:	**4**
Contact hours (L-T-P):	**3-0-2**
Pre-requisites:	**Nil**
Overlaps with:	**Nil**
Course Assessment Method:	**As per Academic Rule Book**

Course Objectives

To introduce method for design of steel structures with loading standards as per code provisions

Course Outcomes

CO1. Students will develop ability to carry out research in steel design and development work

CO2. Students will be capable of developing design report and structural drawings.

CO3. Students will be capable of designing steel members considering ductility concept.

Relationship of Course Objective to Program Outcome
H = High correlation; M = Medium correlation; L = Low correlation

	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO 1	L				
CO 2		M			
CO 3			H		

Syllabus

Basics of Steel Design (IS 800), Introduction to plastic analysis and design, Design philosophy for steel structures, review of design of members i.e. tension, compression and flexural members, Beam-Column Members

Design and detailing for Earthquake loads, Load and load combinations, Response Reduction Factor, Panel Zones and Connections, joints and Fasteners, Columns, Storey Drift, Ordinary Concentrically Braced Frames (OCBF), Special Concentrically Braced Frames (SCBF), Eccentrically Braced Frames (EBF), Ordinary Moment Frames (OMF), Special Moments Frames (SMF), Column Bases, Special Truss Moment Frames (STMFs)

Analysis, design and detailing of Multistory steel building (Maximum 2 bay and four storey)

Concepts of: Nonlinear analysis of steel buildings, Capacity Design Philosophy

Reference Books/Material

1. Subramanian, S. (2010). *Steel structures design and practice,* Oxford.
2. Johnson, R. P. (2008). *Composite structures of steel and concrete: beams, slabs, columns, and frames for buildings*. John Wiley & Sons.
3. Owens, G. W., & Knowles, P. R. (1992). *Steel designer's manual.*
4. Faella, C., Piluso, V., &Rizzano, G. (1999). *Structural steel semirigid connections: theory, design, and software (Vol. 21)*, CRC press.

5. Trahair, N. S., Bradford, M. A., Nethercot, D., & Gardner, L. (2007). *The behaviour and design of steel structures to EC3*. CRC Press.
6. Englekirk, R. E. (1994). *Steel structures: Controlling behavior through design*.
7. Johnson, R. P. (2008). *Composite structures of steel and concrete: beams, slabs, columns, and frames for buildings*. John Wiley & Sons.
8. Oehlers, D. J., & Bradford, M. A. (2013). *Composite Steel and Concrete Structures: Fundamental Behaviour: Fundamental Behaviour*. Elsevier.
9. Manual, C. F. S. D. (2002). *American Iron and Steel Institute. Washington, DC*.
10. Yu, W. W., &LaBoube, R. A. (2010). *Cold-formed steel design*. John Wiley & Sons.
11. Brockenbrough, R. L., & Johnston, B. G. (1974). *Steel design manual*. United States Steel Corporation.
12. Schafer, B. W. (2002). *Design Manual for Direct Strength Method of Cold-Formed Steel Design. Report to the American Iron and Steel Institute*, Washington, DC (available online www. ce. jhu. edu/bschafer/direct_strength).
13. Brockenbrough, R. L., & Johnston, B. G. (1968). *USS Steel design manual*. United States Steel Corporation.
14. Chen, W. F., & Kim, S. E. (1997). *LRFD steel design using advanced analysis* (Vol. 13). CRC press.
15. Owens, G. W., & Knowles, P. R. (1992). *Steel designer's manual*.
16. Manual, A. S. D. (1988). Rev. 2. *American Iron and Steel Institute*, Washington DC, USA, 1-4.
17. Packer, J. A., & Henderson, J. E. (1997). *Hollow structural section connections and trusses: a design guide*. Willowdale, Ont.: Canadian Institute of Steel Construction

AML543 EARTHQUAKE DYNAMICS (DC) (Even Semester)

Credit:	**3**
Contact hours (L-T-P):	**2-0-2**
Pre-requisites:	**AML522**
Overlaps with:	**Nil**
Course Assessment Method:	**As per Academic Rule Book**

Course Objective

To impart knowledge of advance concepts and methods for earthquake analysis and design of structures

Course Outcome

At the completion of this course, the student shall acquire knowledge and ability

CO1. to apply codal provisions for seismic resistant structural design,
CO2. to perform linear and nonlinear earthquake analysis of structures,
CO3. to assess the seismic safety of structures,
CO4. to impart changes in the structure to enhance its seismic resistance.

Relationship of Course Outcomes to Program Outcomes
H = High correlation; M = Medium correlation; L = Low correlation

POs → / COs ↓	PO1	PO2	PO3	PO4	PO5
CO1	M	L	H	M	M
CO2	M	L	H	H	M
CO3	H	L	H	M	H
CO4	M	L	H	H	H

Syllabus

Equation of Motion for SDOF and MDOF system subjected to base excitation, Response spectrum analysis and Time history analysis
Modal superposition and Step by step integration for MDOF system, Numerical evaluation of dynamic response, Computer implementation
Response spectrum analysis, Modal participation factor, Mass Participation factor, Modal combination rules, missing mass correction.
Analysis of Secondary systems
Evaluation of floor response spectra
Response of elasto-plastic system, Effect of over strength and ductility, Use of NONLIN software.
Earthquake response of multistory buildings, Torsional response of buildings.
Frequency domain analysis of SDOF system, Introduction to Random Vibration

Reference Books/Material

1. Chopra, A. K. (1995). *Dynamics of structures* (Vol. 3). New Jersey: Prentice Hall.
2. Clough, R. W., &Penzien, J. (1993). *Dynamics of structures*, 2nd edition, McGraw□Hill, New York.

3. Humar, J. L. (1990). *Dynamics of Structures*, Prentice-Hall, Englewood Cliffs, NJ.
4. Paz, M. (2012). *Structural dynamics: theory and computation*. Springer Science & Business Media.
5. Timoshenko, S. P., & Young, D. H. (1948). *Advanced dynamics*.McGraw□Hill Book Company
6. D'Souza, A. F., & Garg, V. K. (1984). *Advanced dynamics: modeling and analysis*. Prentice Hall.
7. Gupta, P. K. (2012). *Advanced dynamics of rolling elements*. Springer Science & Business Media.
8. Greenwood, D. T. (2006). *Advanced dynamics*. Cambridge University Press.
9. Meirovitch, L. (1990). *Dynamics and control of structures*. John Wiley & Sons.

AMP RESEARCH METHODOLOGY AND PRESENTATION (DC) (Even Semester)

Credit:	**1**
Contact hours (L-T-P):	**0-0-2**
Pre-requisites:	**Nil**
Overlaps with:	**Nil**

Course Objective

The objective is to develop habit for understanding the state of art of research on given subject area and develop skill of good report writing and presentation.

Course Outcome

CO1. The Student will learn techniques and method of analyzing a research problem, technical report writing and presentation.

Relationship of Course Objective to Program Outcome
H = High correlation; M = Medium correlation; L = Low correlation

POs → / COs ↓	PO1	PO2	PO3	PO4	PO5
CO1	M	H	L	M	M

Content

The seminar will be on the project allotted at the end of 1st semester.

AML EXPERIMENTAL STRESS ANALYSIS AND INSTRUMENTATION (DE)

(Even Semester)

Credit: **3**
Contact hours (L-T-P): **2-0-2**
Pre-requisites: **Nil**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective
To impart knowledge on laboratory / field testing of civil engineering structures

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability

- **CO1.** to know various devices and instruments and their applications for testing of civil engineering structures,
- **CO2.** to have hands on experience and practical training on measurement of stress-strain, load, deflection etc. for structural elements,
- **CO3.** to be able to correlate and compare the results of laboratory/ field tests with theoretical value,
- **CO4.** to have a knowledge of modelling of structures and the accuracy of various testing methods.

Relationship of Course Objective to Program Outcome
H = High correlation; M = Medium correlation; L = Low correlation

POs → / COs ↓	PO1	PO2	PO3	PO4	PO5
CO1	L	H	H	L	L
CO2	M	H	H	L	M
CO3	H	H	H	L	M
CO4	M	M	H	L	L

Syllabus
Elementary Elasticity and fracture mechanics, Introduction to strain measurements, Study of various types of strain gauges, static and dynamic strain gauge, Recording instruments, calculation of stresses and loads from measurements of strains and deflections, Proof Load testing, Study of various transducers, Principle of their working, displacement, velocity, acceleration etc, strain gauge & piezoelectric type of transducers.
Cracks in buildings: causes and remedial measures, Non-destructive testing of concrete and steel structures, Various NDT tests, codal provisions, Assessment and evaluation for structural stability of existing structures
Corrosion of steel and concrete: Theory and prevention.
Prototype and modelling of structures
Statistical Analysis of experimental data

Reference Books / Material

1. Singh, S.(2009). *Experimental Stress Analysis*. Khanna publishers.
2. Srinivas J. (2011).*Stress Analysis and Experimental Techniques: An Introduction.*Alpha ScienceISBN9788184871616
3. Soisson, H. E. (1975) *Instrumentation in industry*. John Wiley & Sons, Inc.
4. Boomfield, J.P. (1997).*Corrosion of Steel in Concre*te; E& FN SPON; 1997
   SP: 25;1984,*Causes and Prevention of Cracks in Buildings*; Bureau of Indian Standard; New Delhi.

AML BRIDGES (DE) (Even Semester)

Credit: **4**
Contact hours (L-T-P): **3-0-2**
Pre-requisites: **Nil**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective
To understand the planning, behavior, analysis and design of bridges and its components

Course Objectives
At the completion of this course, the student shall acquire knowledge and ability to plan, analyze and design various components of bridges

- **CO1.** Students will develop ability to carry out research in analysis and design of bridge structures.
- **CO2.** Students will be capable of developing design report and structural drawings.
- **CO3.** Students will be capable of planning proper and economical bridge structures including appropriate mathematical modelling.

Relationship of Course Outcomes to Program Outcomes
H = High correlation; M = Medium correlation; L = Low correlation

PO, CO	PO1	PO2	PO3	PO4	PO5
CO1	H				
CO2				H	
CO3			H		

Syllabus
Types of RC bridge superstructure and introduction to their design, sub-structure, bearings, IRC / IRS codes bridge loadings and other code recommendations, Performance of bridges in past earthquakes.
Design philosophy for bridges(Deck slab, beam-slab and box), State of art modelling of bridges, Design of Substructures including ductile detailing, Design of well and pile foundations, Modelling soil flexibility, stability analysis, Computer application using FEM
Abutments, dirt wall, pedestals and returns
Bearings (Free, Guided and Restrained)
Introduction of integrated bridges, skew bridges, curved bridges and deck continuous bridges.

Reference Books/Material

1. Chen, W. F., &Duan, L. (Eds.). (2014). *Bridge Engineering Handbook: Construction and Maintenance*. CRC press.
2. Branco, F. A., & De Brito, J. (2004). *Handbook of concrete bridge management*.
3. Smith, J. W. (1994). *Theory and design of bridges: by Petros P. Xanthakos*, Wiley Interscience, New York, 1994, ISBN 0-471-57097-4

4. Tonias, D. E., & Zhao, J. J. (1995). *Bridge engineering: design, rehabilitation, and maintenance of modern highway bridg*es. McGraw-Hill, New York.
5. Hambly, E. C. (1991). *Bridge Deck Behavior.*E & FN Spon, New York.
6. O'Brien, E.J., Keogh, D. L. &O'Connor, A J. (1995).*Bridge Deck Analysis*,*CRC Press,*BrocaRaton.
7. Baidar, B. &, Aftab, M. (2015). *Bridges – Analysis, design, structural health monitoring and rehabilitation*, Springer.
8. Baidar,B. & Leslie, G.J. (1985).*Bridge analysis simplified*, McGraw-Hill Book Company.
9. Hambly, E. C. (1991).*Bridge deck behavior.* E & FN Spon.
10. Cusens, A. R. &Pama, R. P. (1975).*Bridge Deck Analysis*, John Wiley & Sons, 1975
11. Collings D. (2005).*Steel-Concrete Composite Bridges – designing with Euro codes*, ICE Publishings.
12. Reis, A. J., Jose, J.&Oliveira, P. (2019). *Bridge Design Concepts and Analysis*, Wiley.
13. Ellobody, E. (2014). *Finite element analysis and design of steel and concrete composite bridges*, Elsevier B-H.
14. Vayas, I., & Iliopoulos, A. (2013). *Design of steel-concrete composite bridges to Eurocodes*. CRC Press.
15. Clark, L. A. (1983). *Concrete bridge design to BS 5400* (No. Monograph).Construction press.
16. Raina, D. V. (2007). *Raina's Concrete Bridge Practice Analysis, Design &Economics*. Shro Publishers and Distributors Pvt. Ltd. Delhi.

AML INDUSTRIAL STEEL STRUCTURES (DE) (Even Semester)

Credit:	**4**
Contact hours (L-T-P):	**3-0-2**
Pre-requisites:	**Nil**
Overlaps with:	**Nil**
Course Assessment Method:	**As per Academic Rule Book**

Course Objective

To introduce method for design of Industrial steel structures with loading and design standards

Course Outcomes

- **CO1.** CO-1 Students will develop ability to carry out research in Steel design and development work.
- **CO2.** CO-2 Students will be capable of designing advanced steel structures.

Relationship of Course Objective to Program Outcome
H = High correlation; M = Medium correlation; L = Low correlation

	PO1	PO2	PO3	PO4	PO5
CO 1	M				
CO 2			H		

Syllabus

Design of Industrial building, Crane, Gantry Girder, North Light and Lattice girder structure
Multistory steel building (Maximum 2 bay and four storey), including composite construction
Design of Bunker and Silo (Rectangular or Circular), including supporting systems.
Design of Pressure vessels and storage tanks (Circular)
Introduction to IS 1893 Part IV
Design of PEB structures

Reference Books / Material

1. Subramanian, S. (2010). *Steel structures design and practice,* Oxford.
2. Reimbert, M. L., &Reimbert, A. M. (1987). *Silos. Theory and practice. Vertical silos, horizontal silos (retaining walls) (No. Ed. 2)*. Lavoisier Publishing.
3. Johnson, R. P. (2008). *Composite structures of steel and concrete: beams, slabs, columns, and frames for buildings*. John Wiley & Sons.
4. Owens, G. W.& Knowles, P. R. (1992). *Steel designers manual*. London: Blackwell Scientific Publications
5. Faella, C., Piluso, V., &Rizzano, G. (1999). *Structural steel semirigid connections: theory, design, and software (Vol. 21)*. CRC press.

AML WATER RETAINING STRUCTURES (DE) (Even Semester)

Credit: **4**
Contact hours (L-T-P): **3-0-2**
Pre-requisites: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective
To understand the planning, behavior, analysis and design of water retaining structures

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to

- **CO1.** design and detailing of circular GSR and underground tank,
- **CO2.** design and detailing of rectangular GSR and underground tank,
- **CO3.** design and detailing of Elevated Service Reservoir of various capacities and column configurations,
- **CO4.** design and detailing of various units of water treatment plant such as clarrifloculator, Aeration fountain, chemical house etc,
- **CO5.** design and detailing of Approach Bridge, Jack well.

Relationship of Course Outcomes to Program Outcomes
H = High correlation; M = Medium correlation; L = Low correlation

POs → COs ↓	PO1	PO2	PO3	PO4	PO5
CO1	H	H	H	L	M
CO2	H	H	H	L	M
CO3	H	H	H	L	M
CO4	H	H	H	L	M
CO5	H	H	H	L	M

Syllabus
Analysis of circular water tanks with various boundary conditions at base slab, variation of hoop tension, moment and deflection of wall with various H/T ratios, deep and shallow tanks.
Analysis of tanks using beam on elastic foundation analogy
Analysis of rectangular water tanks with various boundary conditions at base slab, variation of moments with respect to height/span ratio.,
Design (un-cracked and cracked design) of water tank sections subjected to moment, Moment and compression, moment and tension.
Earthquake Analysis of water tanks on ground and over head tanks (SDOF and MDOF model)
Analysis and design of jack well, approach bridge and WTP (clarifloculator, FM, aeration fountain, chemical house, flash mixer etc.) units etc.
Analysis and design of ESR (container and staging)

Reference Books/Material

1. Jaiswal, O. R., Rai, D. C., & Jain, S. K. (2007). *Review of seismic codes on liquid-containing tanks*. Earthquake Spectra, 23(1), 239-260.
2. BIS IS 1893-2(2014) *Criteria for Earthquake Resistant Design of Structures – Part 2: Liquid retaining tanks*, Bureau of Indian Standards, New Delhi, India, (2014).
3. BIS IS 1168 (2011)*Criteria for design of RCC staging for overhead water tanks*, Bureau of Indian Standards, New Delhi, India, (2011)
4. Anchor, R. D. (1981). *Design of liquid-retaining concrete structures*. Halsted Press.
5. IS 3370(Part-I). (2009). *Concrete structures for storage of liquids - code of pra*ctice.
6. IS 3370(Part-II). (2009). *Concrete structures for storage of liquids - code of practice*.
7. IS 3370(Part-III). (1967). *Code of practice for concrete structures for the storage of liquids*.
8. IS 3370(Part-IV). (1967). *Code of practice for concrete structures for the storage of liquids. Design –Tables*.
9. IS BIS IS 13920 (2016). *Ductile design and detailing of reinforced concrete structures subjected to seismic forces – code of practice (first revision)*, Bureau of Indian Standards, New Delhi, India.
10. Ghali, A. (2014). *Circular storage tanks and silos*. CRC Press.

AML MULTISTORIED BUILDINGS (DE) (Even Semester)

Credit:	**4**
Contact hours (L-T-P):	**3-0-2**
Pre-requisites:	**Nil**
Overlaps with:	**Nil**
Course Assessment Method:	**As per Academic Rule Book**

Course Objective

To impart knowledge of analysis and design of multistoried buildings for static and dynamic loading

Course Outcomes

- **CO1.** Students will develop ability to carry out research in analysis and design of multistoried buildings.
- **CO2.** Students will be capable of developing design report and structural drawings.
- **CO3.** Students will be capable of planning proper and economical multistoried buildings including appropriate mathematical modelling.

Relationship of Course Objective to Program Outcome
H = High correlation; M = Medium correlation; L = Low correlation

	PO1	PO2	PO3	PO4	PO5
CO 1	L				
CO 2		M			
CO 3			H		

Syllabus

Building frames, frame-shear wall buildings, Braced Buildings, Mathematical modeling of buildings with different structural systems with and without diaphragms.
Earthquake, wind and other (i.e. seismic,blast, snow) load calculations along with dead load and live loads and their combinations, Seismic analysis using equivalent static, response spectrum and time history analysis using software.
Special aspects in Multi-storeyed buildings: Effect of torsion, flexible first story, various methods for P-delta analysis, soil-structure interaction on building response, drift limitation.
Analysis and Design of multi-storeyed buildings with masonry infills, Sequential analysis for multistoried buildings.
Design for Fire Resistant, Creep, Shrinkage and Thermal stresses.

Reference Books / Material

1. IS: 16700 – (2017), *Criteria for structural safety of tall concrete building,* BIS New Delhi
2. Naeim, F. (1989). *The seismic design handbook*. Springer Science & Business Media.
3. Paulay, T., & Priestly, M. J. N. (2009). *Seismic design of RC and masonry buildings*. John Wiley & Sons, Inc..

4. Booth, E. D. (1994). *Concrete structures in earthquake regions: design and analysis*. Longman Scientific & Technical; Co-published in the US with J. Wiley.
5. Park, R., &Paulay, T. (1975). *Reinforced concrete structures*. John Wiley & Sons.
6. Fintel, M. (Ed.). (1974). *Handbook of concrete engineering* (p. 801). New York: Van Nostrand Reinhold
7. Taranath, B. S. (2009). *Reinforced concrete design of tall buildings*. CRC press.
8. Taranath, B. S. (1998). *Steel, concrete, and composite design of tall buildings*. McGraw-Hill Professional.

AML BLAST LOADING ON STRUCTURES (DE) (Even Semester)

Credit: 4
Contact hours (L-T-P): 4-0-0
Pre-requisites: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective

The main objective of this course is to expose the students to the basic concepts of blast and ballistic loading of structures and to acquaint analysis procedures used nationally and internationally so as to evaluate the structures subjected to blast/explosions.

Course Outcomes (COs)

- **CO1.** Students will be able to understand basic concepts of blast and ballistic loading.
- **CO2.** Students will be able to understand and analyze behavior of such structures under blast loading.
- **CO3.** Students will be able to analyze and design the simple structures subjected to blast loading using standard code of practice.

Relationship of Course Outcomes to Program Outcomes
H = High correlation; M = Medium correlation; L = Low correlation

POs → / COs ↓	PO1	PO2	PO3	PO4	PO5
CO1	H	M	H	H	L
CO2	H	M	H	H	L
CO3	H	H	H	H	L

Syllabus

Basic Concepts of Blast Engineering: Blast waves and blast loading, Mach stem formation, blast wave front parameters, blast wave pressure profile

Blast Analysis: External blast wave loading on structures, Internal blast loading, Underwater blast, Ground shock loading of structures

Stress Wave: Reflection and transmission of stress waves, X-T diagrams, Analysis of multi-layered structure under stress wave

Structural Response: Analytical, energy and numerical method based analysis of simple structures under blast loading, Development of pressure-impulse diagrams/Iso-damage curves under blast loading

Protective Design: Protection against ballistic attack, analysis of sacrificial structures under blast loading

Dynamic Material Properties: One-dimensional wave propagation in long rod,Strain rate based material characterization, Basic understanding of Split Hopkinson Bar for high strain rate characterization, materials behavior under blast loading and their application in blast analysis

Design of Structures Against Blast: Introduction to various standards (IS and DoD) and their application, Design of steel and reinforced concrete structures/components against blast

Reference Books/Material

1. Smith, P. D. & Hetherington, J. G. (1994), *Blast and Ballistic Loading of Structures*, Butterworth-Heinemann Ltd. Boston, USA.
2. Dusenberry, D. O. (2010),*Handbook for Blast-Resistant Design of Buildings*, John-Wiley & Sons, Inc., Hoboken, New Jersey, USA.
3. Bangash, M.Y.H. (1993), *Impact and Explosion Analysis and Design*, Boca Raton, FL: CRC Press, Inc.
4. Bangash, M.Y.H. &Bangash, T. (2006), *Explosion-Resistant Buildings Design, Analysis and Case Studies*, Springer, Berlin, Germany.
5. ASCE Standard (2009), *Blast Protection of Buildings*, American Society of Civil Engineers, Reston, VA, USA.
6. Henrych, J. (1979), *The Dynamics of Explosion and Its Use*, Elsevier, Amsterdam, Netherlands.
7. Kinney, G.F. & Graham, K.J. (1985), *Explosive Shocks in Air,* Springer, Berlin, Germany.
8. Krauthammer, T. (2008), *Modern Protective Structures*, CRC Press, Boca Raton, FL, USA.
9. Mays G.C. & Smith, P.D. (1995), *Blast Effects on Buildings*, Thomas Telford Publications, London, UK.
10. Meyers, M.A. (1994), *Dynamic Behavior of Materials*, Wiley, New York, USA.
11. Cole, R. H.(1948), *Underwater Explosions*, Princeton University Press, Princeton, New Jersey, USA.
12. IS: 4991-1968, *Criteria for Blast Resistant Design of Structures for Explosions above Ground, Bureau of Indian Standards (BIS)*, New Delhi, India.
13. IS 6922-1973,*Criteria for Safety and Design of Structures Subject to Underground Blasts*, Bureau of Indian Standards (BIS), New Delhi, India.
14. UFC 3-340-02 (2014), *Structures to Resist the Effects of Accidental Explosions*, DoD, USA.
15. FEMA-426 (2003), *Reference Manual to Mitigate Potential Terrorist Attacks against Buildings*, Federal Emergency Management Agency, Washington, DC, USA.
16. FEMA-427 (2003),*Primer for Design of Commercial Buildings to Mitigate Terrorist Attacks*, Federal Emergency Management Agency, Washington, DC, USA.

AML ADVANCED FINITE ELEMENTANALYSIS (DE) (Even Semester)

Credit: 4
Contact hours (L-T-P): 3-0-2
Pre-requisites: FEA
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective
The objectives of this course are to introduce concepts of finite element method for analysis of structures

Course Outcomes (COs)
After completion of this course, the student shall acquire
- **CO1.** knowledge of the formulation of plate and shell element,
- **CO2.** knowledge of formulation of non-linear, dynamic problems using finite element,
- **CO3.** knowledge of Preparing mathematical model of structure,
- **CO4.** perform static, dynamic and nonlinear analysis and interpret the results.

Relationship of Course Outcomes to Program Outcomes
H = High correlation; M = Medium correlation; L = Low correlation

PO, CO	PO1	PO2	PO3	PO4	PO5
CO1	H				
CO2		H			
CO3			H	H	
CO4					H

Syllabus
Plate elements (Kirchoff theory, Mindlin plate element, triangular and rectangular),

Shell elements (flat faced triangular and rectangular elements), Axi-symmetric elements, Ring elements. BRICK / Solid Element

Introduction to advanced elements-Mixed formulation, Infinite elements, Element with drilling DoF and incompatible modes,

Formulation for Nonlinear problems. Formulation of Dynamic problems, Consistent and lumped mass matrices.

Mathematical modeling of structures, analysis of problems using plate, shell elements.

Non-linear analysis of structure, dynamics analysis of structure using finite element method.

Reference Books / Material
1. Dhatt, G., Lefrançois, E., &Touzot, G. (2012). *Finite element method.* John Wiley & Sons
2. Bathe, K. J. (2008). *Finite element method.* John Wiley & Sons, Inc.

3. Zienkiewicz, O. C., Taylor, R. L., Zienkiewicz, O. C., & Taylor, R. L. (1977).*The finite element method* (Vol. 3). London: McGraw-hill.
4. Hughes, T. J. (2012). *The finite element method: linear static and dynamic finite element analysis*. Courier Corporation.
5. Reddy, J. N. (1993). *An introduction to the finite element method* (Vol. 2, No. 2.2). New York: McGraw-Hill.
6. Cook, R. D. (2007). *Concepts and applications of finite element analysis*. John Wiley & Sons.
7. Cook, R. D. (1994). *Finite element modeling for stress analysis*. Wiley.
8. Chandrupatla, T. R., Belegundu, A. D., Ramesh, T., & Ray, C. (1997). *Introduction to finite elements in engineering* (pp. 279-300). Upper Saddle River: Prentice Hall.
9. Strang, G., & Fix, G. J. (1973). *An analysis of the finite element method* (Vol. 212). Englewood Cliffs, NJ: Prentice-Hall
10. Prathap, G. (2013). *The finite element method in structural mechanics: principles and practice of design of field-consistent elements for structural and solid mechanics (Vol. 24)*. Springer Science & Business Media.
11. Rao, S. S. (2005). *The finite element method in engineering*. Butterworth-heinemann

AML MACHINE FOUNDATIONS (DE) (Even Semester)

Credit: 4
Contact hours (L-T-P): 4-0-0
Pre-requisites: AML522
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective

To understand the behaviour and basic concepts for the design of foundation subjected to machine vibrations.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability

- **CO1.** to understand static and dynamic properties of soil,
- **CO2.** to understand wave propagation in soil,
- **CO3.** to develop mathematical models of Machine foundation systems,
- **CO4.** to develop mathematical solution techniques to calculate the response and design of foundations.

Relationship of Course Objective to Program Outcome
H = High correlation; M = Medium correlation; L = Low correlation

POs → / COs ↓	PO1	PO2	PO3	PO4	PO5
CO1	H	L	H	H	
CO2	M		H	H	
CO3	H		H	M	
CO4	H		H	H	

Syllabus

Lessons learned from past failure of machine foundations
Theory of Wave propagation in Elastic Homogeneous and Isotropic Materials, Vibration of Elastic Media, Elastic Waves
Dynamic Soil Properties including field and Laboratory tests to find design soil parameters
Bearing Capacity of Shallow Foundation
Pile Foundation under Dynamic Loads
General Principle of Analysis and Design machine Foundation,
Introduction to IS Codes, Analysis and Design of Different Machine Foundations based on IS Code Method, Elastic Half Space Method and coefficient of sub grade reactions
Analysis and design for Impact type machine
Analysis and design of Block type foundation for reciprocating and rotary machines
Analysis and design of Frame type foundation for reciprocating and rotary machines

Reference Books/Material

1. Kramer, S. L. (1996). *Geotechnical earthquake engineering (Vol. 80)*. UpperSaddle River, NJ: Prentice Hall.

2. Bowles, J. E. (1988). *Foundation analysis and design*.McGraw-Hill Company Inc.
3. Richart, F. E., Hall, J. R., & Woods, R. D. (1970). *Vibrations of soils and foundations*.Englewood Cliffs, N.J Prentice-Hall - Prentice-Hall international series in theoretical and applied mechanic
4. Prakash, S. (1981). *Soil dynamics (pp. 361-7)*. New York: McGraw-Hill.
5. Wolf, J. P. (1985). *Dynamic soil-structure interaction.* Prentice Hall int.
6. Saran, S. (2006). *Soil dynamics and machine foundation*.Galgotia Publication, New Delhi
7. Bhatia, K. G. (2008). *Foundations for industrial machines and earthquakeeffects*. ISET Journal of Earthquake Technology, Paper, (495), 1-2.
8. Bhatia, K. G. (2009). *Foundations for Industrial Machines: Handbook for Practising Engineers*. CRC.
9. Major, A. (1962). *Vibration analysis and design of foundations for machines and turbines: dynamical problems in civil engineering*. Collet's Holdings.

AML SEISMIC EVALUATION AND RETROFITTING OF STRUCTURES (DE)

(Even Semester)

Credit:	**3**
Contact hours (L-T-P):	**2-0-2**
Pre-requisites:	**AML522**
Overlaps with:	**Nil**
Course Assessment Method:	**As per Academic Rule Book**

Course Objective

To impart the knowledge for assessing and improving the performance of buildings not designed as per seismic codes of practice.

Course Outcomes

CO1. Students will develop capability to understand state of the art on seismic assessment methods and retrofitting techniques.

CO2. Students will develop capability to understanding the complexity of seismic retrofitting problem and can apply modern retrofitting tools to improve the seismic resistance of structures.

Relationship of Course Objective to Program Outcome
H = High correlation; M = Medium correlation; L = Low correlation

	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	H				
CO2				H	

Syllabus

Introduction: Terminology; Basic principles of seismic evaluation and retrofitting.
Qualitative Methods of Seismic Evaluation: Rapid visual screening procedure (RVSP) and simplified evaluation of buildings; Visual inspection method and non-destructive testing (NDT) method.
Quantitative Methods of Seismic Evaluation: Performance based method using nonlinear static push-over analysis (NSP) and nonlinear dynamic method of analysis (NDP); Estimation of seismic capacity (strength and ductility).
Local and Global Methods of Seismic Retrofitting of RC Buildings: System completion; Strengthening of existing components; RC, Steel and FRP Jacketing; Addition of new components – frames, shear walls and braced frames; Introduction to supplemental energy dissipation and base isolation.
Local and Global Methods of Seismic Retrofitting of Bridges: Seismic evaluation of components of bridges (foundation, pier, deck, bearings), determination of liquefaction potential, modeling issues, strengthening of components.
Re-evaluation of Buildings with Retrofitting Elements: Linear and Non-linear modelling; Modelling of soil and foundations.
Seismic Repair and Retrofitting of Earthquake Damaged RC Buildings: Schemes of temporary shuttering damages; Methods of repair and retrofitting.

Seismic Safety of Equipment and Accessories: Retrofitting solutions against sliding and overturning of equipment and accessories.
Case Studies in Seismic Retrofitting: Case studies RC and masonry buildings.

Reference Books/Material

1. J. H. Bungey , "*The Testing of Concrete in Structures*", Surrey University Press
2. Comartin, C. D., Niewiarowski, R. W., &Rojahn, C. (1996). *Seismic evaluation and retrofit of concrete buildings ATC-40*. Applied Technology Council (ATC).: Report No. SSC, 96-01..
3. Priestley, M. N., Seible, F., &Calvi, G. M. (1996). *Seismic design and retrofit of bridges*. John Wiley & Sons.
4. Paulay, T., & Priestly, M. J. N. (2009). *Seismic design of RC and masonry buildings*. John Wiley & Sons, Inc.
5. Kappos, A., &Penelis, G. G. (2010). *Earthquake resistant concrete structures*. CRC Press.
6. FEMA 310 (1998).*Handbook for the Seismic Evaluation of Buildings – A Prestandard*, Federal Emergency Management Agency, Washington DC, USA.
7. FEMA 154 (1988). *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook*, Federal Emergency Management Agency, Washington DC, USA,.
8. FEMA 273 (1996). *NEHRP Commentary on the guidelines for the rehabilitation of building*. Washington DC: Federal Emergency Management Agency.
9. *FEMA-356*. (2000). *Commentary for the Seismic Rehabilitation of Buildings.,* Federal Emergency Management Agency, Washington, DC.
10. FEMA-440 (2005). *Improvement of nonlinear static seismic analysis procedures*. *FEMA-440, Redwood City.*
11. FEMA, P-695 (2009). *Quantification of Building Seismic Performance Factors*, Federal Emergency Management Agency.
12. ASCE 41. (2013). *Seismic Evaluation and Retrofit of Existing Buildings (ASCE/SEI 41-13)*, Reston, VA..
13. ATC 40 (1996). *Seismic Evaluation and retrofit of concrete building – Vol. I & II*, Applied Technology Council, California

AML ANALYSIS AND DESIGN OF PIPES (DE) (Even Semester)

Credit: 4
Contact hours (L-T-P): 3-0-2
Pre-requisites: Nil
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective

The main objective of this course is to expose the students to the basic concepts of design of piles (Over ground / underground) and to acquaint them with well-established design and analysis procedures used nationally and internationally so as to evaluate the pipe structures.

Course Outcomes

CO1. Students will develop ability to carry out research in analysis and design of pipe structures.
CO2. Students will be capable of developing design report and structural drawings.
CO3. Students will be capable of planning proper and economical pipe structures including appropriate mathematical modelling.

Relationship of Course Objective to Program Outcome
H = High correlation; M = Medium correlation; L = Low correlation

	PO1	PO2	PO3	PO4	PO5
CO 1	L				
CO 2		M			
CO 3			H		

Syllabus

Preliminary Ring design, ring deformation, soil mechanics, pipe mechanics, ring stress and deflation, ring stiffness

External loads, Design of gravity flow pipes, design of pressure pipes

Rigid and flexible pipe, minimum soil cover, longitudinal pipe mechanics, thrust, restraints and embedment, parallel pipe and trenches, special sections, Analysis of burned pipe in FEA

Reference Books/Material

1. American Society of Civil Engineers (1998), *Standard Practice for Direct Design of Buried Precast Concrete Pipe Using Standard Installations* (SIDD), 1998
2. American Concrete Pipe Association (2001), *Concrete pipe Design Manual*, Fourteenth Printing.
3. Heger, Frank J., (1963).*Structural Behavior of Circular Reinforced Concrete Pipe-Development of Theory.* ACI Journal," Proceeding V. 60, No. 11, Nov. 1963, pp. 1567-1614
4. Spangler, M.G. (1 933). *The Supporting Strength of Rigid Pipe Culverts*, Bulletin 112, Iowa State College

5. Tadros, M.K.; Benak, J.V.; Gilliland, M.K. (1989). *Soil Pressure on Box Culverts,* ACI Structural Journal, V. 86, No. 4, July-August 1989, pp. 439-450
6. Moser, A. P. &Folkman, S, (2008). *Buried Pipe Design*, Third Edition, The McGraw-Hill Companies, Inc.

AML COMPOSITE STRUCTURES (DE) (Even Semester)

Credit: 4
Contact hours (L-T-P): 4-0-0
Pre-requisites: Nil
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective

The objective of this course is to familiarize the students with analysis and design of steel-concrete composite structure.

Course Outcomes

At the completion of this course, the student is expected to acquire

CO1. knowledge of analysis of various engineering properties of composite cross section,
CO2. ability to design steel-concrete composite member,
CO3. ability to analyze and design composite structure.

Relationship of Course Outcomes to Program Outcomes
H = High correlation; M = Medium correlation; L = Low correlation

PO, CO	PO1	PO2	PO3	PO4	PO5
CO1		M			
CO2				M	
CO3			M		

Syllabus

Analysis and design of steel-concrete composite deck floor,
Analysis and design composite beam, composite beams with solid steel beam, composite beams with steel beams with web opening,
Types of shear connectors and its function, analysis and design of shear connection between concrete slab and beam,
Analysis and design steel-concrete composite column, steel section embedded in concrete, concrete in filled steel tubes.
Analysis and design steel frame structure with concrete in-filled.
Advanced topics and detailing in composite structures.

Reference Books/Material

1. Taranath, B. S. (2011). Structural analysis and design of tall buildings: Steel and composite construction. CRC press.
2. Vinson, J. R., & Sierakowski, R. L. (2006). *The behavior of structures composed of composite materials* (Vol. 105). Springer Science & Business Media.
3. Vinson, J. R., &Sierakowski, R. L. (2012). *The behavior of structures composed of composite materials* (Vol. 5). Springer Science & Business Media.
4. Jones, R. M. (1975). *Mechanics of composite materials* (Vol. 1). New York: McGraw-Hill.
5. Christensen, R. M. (2012). *Mechanics of composite materials*. Courier Corporation.

6. Kaw, A. K. (2005). Mechanics of composite materials. CRC press.
7. Daniel, I. M., Ishai, O., Daniel, I. M., & Daniel, I. (1994). *Engineering mechanics of composite materials* (Vol. 3). New York: Oxford university press.
8. Liang, Q. Q. (2014). Analysis and Design of Steel and Composite Structures. CRC Press.
9. IS 11384 (1985). *Code of Practice for Composite Construction in Structural Steel and Concrete*, Indian Standard Institution, New Delhi.
10. IS 3935(1966). *Code of practice for composite construction*, Indian Standard Institution, New Delhi.
11. Narayanan, R. (Ed.). (1988). *Steel-concrete Composite Structures* (Vol. 7). CRC Press.
12. Owens, G. W., & Knowles, P. R. (1992). *Steel designers manual*.
13. Davison, B., & Owens, G. W. (Eds.). (2011). *Steel designers' manual*. John Wiley & Sons.

AML STRUCTURAL HEALTH MONITORING AND REHABILITATION (DE)

(Even Semester)

Credit:	**3**
Contact hours (L-T-P):	**2-0-2**
Pre-requisites:	**Nil**
Course Assessment Method:	**As per Academic Rule Book**

Course Objective
The main objective of studying this course is to learn monitoring, performance evaluation of existing Structures, and to understand causes of distress in structures, their assessment and subsequent repairs.

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to
- **CO1.** understand SHM and its applications to structures,
- **CO2.** identify damages in structures applying different methods,
- **CO3.** strengthen various structural components,
- **CO4.** employ different repair techniques to damaged structures and their maintenance.

Relationship of Course Outcomes to Program Outcomes
H = High correlation; M = Medium correlation; L = Low correlation

	PO1	PO2	PO3	PO4	PO5
CO1	H	L	H	M	H
CO2	H		M	M	H
CO3	H	L	M	M	H
CO4	H	L	M	M	H

Syllabus
Structural health monitoring (SHM):
Introduction:
Definition, Principles, significance of SHM, basic components of SHM and its working mechanism, potential applications in civil, naval, aerospace & manufacturing Engineering, SHM as a tool for proactive maintenance of structures.
Operational Evaluation:
Sensor technology, piezoelectric wafer active sensors, data acquisition and cleaning procedures, elastic waves in solid structures, guided waves
Pattern Recognition:
State-of-Art damage identification and pattern reorganization methods, neural networks & AI
Case studies:
Repair, Rehabilitation and Retrofitting of Structures:
Strengthening of Structural elements, Repair of structures distressed due to corrosion, fire, Leakage, earthquake. Demolition Techniques, Engineered demolition methods & Case studies
Techniques for Repair and Protection Methods:

Non-destructive Testing Techniques, Epoxy injection, Shoring, Underpinning, Corrosion protection techniques – Corrosion inhibitors, Corrosion resistant steels, Coatings to reinforcement, cathodic protection

Strength and Durability of Concrete:

Quality assurance for concrete – Strength, Durability and Thermal properties of concrete – Cracks, different types, causes – Effects due to climate, temperature, Sustained elevated temperature, Corrosion – Effects of cover thickness

Reference Books/Material

1. Daniel, B., Claus-Peter F. & Alfredo, G. (2006).*Structural Health Monitoring*, Wiley-ISTE.
2. Douglas, E. A. (2007).*Health Monitoring of Structural Materials and Components-Methods with Applications*, John Wiley and Sons.
3. Ou,J.P.,Li, H.&Duan,Z.D. (2006)*Structural Health Monitoring and Intelligent Infrastructure*, Vol-1, Taylor and Francis Group, London, U.K, 2006.
4. Giurglutiu, V. (2007). *Structural Health Monitoring with Wafer Active Sensors*, Academic Press Inc.
5. Gandhi, M. V., & Thompson, B. D. (1992). *Smart materials and structures*. Springer Science & Business Media.
6. Chang, F. K. (1998). *Structural health monitoring: current status and perspectives*. CRC Press.
7. Santhakumar, A. R. (2007). *Concrete technology*. Oxford University Press.
8. Bungey, J. H., & Grantham, M. G. (2006). *Testing of concrete in structures*. Crc Press.
9. Emmons, P. H. (1993). *Concrete repair and maintenance illustrated*, RS Means Company. INC. Kingston MA.

AML IRRIGATION STRUCTURES (DE) (Even Semester)

Credit: **4**
Contact hours (L-T-P): **3-0-2**
Pre-requisites: **Nil**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective
To understand the planning, behavior, analysis and design of various Irrigation structures

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to plan, analyze and design various irrigation structures

- **CO1.** Students will develop ability to carry out research in analysis and design of irrigation structures.
- **CO2.** Students will be capable of developing design report and structural drawings.
- **CO3.** Students will be capable of planning proper and economical irrigation structures including appropriate mathematical modelling.

Relationship of Course Objective to Program Outcome
H = High correlation; M = Medium correlation; L = Low correlation

	PO1	PO2	PO3	PO4	PO5
CO1	L				
CO2		M			
CO3			H		

Syllabus
Introduction to Irrigation structures and relevant IS codes
Gravity Dams – Site selection, Forces, Stability analysis.
Analysis and Design of Diversion Works – Bandhara, Weirs and Barrages
Analysis and Design of Head Regulators and Cross regulators
Design of Canals and Canal Falls
Analysis and Design of Cross Drainage Work
Analysis and Design of cut-fill tunnels

Reference Books/Material

1. Novák, P., Moffat, A. I. B., Nalluri, C., & Narayanan, R. (2007). *Hydraulic structures*. CRC Press.
2. Creager, W. P., Justin, J. D. W., & Hinds, J. (1945). *Engineering for dams.*John Wiley & Sons, New York, USA, 3 Volumes
3. Creager, W. P., Justin, J. D., & Hinds, J. (1961). *Engineering for dams: Earth, Rock-fill, Steel and Timber Dams*. John Wiley & Sons.
4. Linsley, R. K., &Franzini, J. B. (1964). *Water Resources Engineering*. *Chap*, *6*, 148-160.
5. Leliavsky, S. (1982). *Design textbooks in civil engineering*. Chapman and Hall
6. Bureau, O. R. (1977). *Design of small dams. Washington. DC: Govt. Print. Off.*
7. Singh, B. (1979). *Fundamentals of Irrigation Engineering,*Nem Chand & Bros.

8. Arora, K. R. (2002). *Irrigation, water power and water Resources Engineering*. Standard Publisher Distributors.
9. Varshney, R. S., Gupta, S. C., & Gupta, R. L. (1979). *Theory & Design of Irrigation Structures,* Nem Chand & Bros.
10. Garg, S. K. (1987). *Irrigation engineering and hydraulic structures*. Khanna publishers.
11. IS 6512 (1984). *Criteria for Design of Solid Gravity Dams*. BIS New Delhi
12. IS 1893 (1984). *Criteria for Earthquake Resistant Design of Structures*, BIS New Delhi
13. IS 4410 (Part-22). (1994). *Glossary of terms relating to river valley projects*, BIS New Delhi
14. IS 6966(Part-I). (1989). *Guidelines for hydraulic design of barrages and weirs*, BIS New Delhi
15. IS 7349(1989). *Guidelines for operation and maintenance of barrages and weirs*, BIS New Delhi
16. IS 7720(1991). *Criteria for Investigation, Planning and Layout for Barrages and Weirs*, BIS New Delhi
17. IS 11130 (1984). *Criteria for Structural Design of Barrages and Weirs*, BIS New Delhi
18. IS14955 (2001). *Guidelines for Hydraulic Model Studies of Barrages and Weirs*, BIS New Delhi
19. Novak, P. (2005). *Developments in hydraulic engineering* (Vol. 5). CRC Press

AML ADVANCED EARTHQUAKE-RESISTANT DESIGN OF STRUCTURES (DE)

(Even Semester)

Credit:	**3**
Contact hours (L-T-P):	**3-0-0**
Pre-requisites:	**Nil**
Overlaps with:	**Nil**
Course Assessment Method:	**As per Academic Rule Book**

Course Objective

To course will provide insight into advanced concepts of analysis and design of structures to withstand earthquake forces and related seismic safety issues.

Course Outcomes

CO1. CO1: Students will be capable to independently carry out research /investigation and development work to solve practical problems of seismic analysis and design.

CO2. CO2: Students will be capable of analyzing and designing various special structures for seismic actions

CO3. CO3: Students will be able to solve complex problem of linear and nonlinear modelling and analysis of structures under seismic excitations by using appropriate modern techniques.

Relationship of Course Objective to Program Outcome
H = High correlation; M = Medium correlation; L = Low correlation

	PO1	**PO2**	**PO3**	**PO4**	PO5
CO1	M				
CO2			H		
CO3				L	

Syllabus

Concepts of Earthquake-Resistant Design – Seismic Input Characteristics and their effect on seismic design, Comparative study of different national codes, Force Based Design, Displacement Based Design, Energy Based Design, Performance Based Design,

Modelling and Analysis of Structures for Displacement Based Design – Back-bone curve, Idealized component models, Estimation and modelling of stiffness, strength and ductility of RC and Steel structures, Nonlinear static (Pushover) and dynamic analyses.

Performance Based Design - Structure Performance Objectives, Performance Levels and Limit States; P-Delta effects; Torsion; Capacity Design for Direct Displacement Based Design.

Performance Based Design- Structural and non-structural performance, quantification of performance, Performance evaluation of structures, services and equipment.

Overhead Water Tanks-Modelling and analysis of overhead water tanks, hydrostatic and hydrodynamic effects, Earthquake-resistant provisions.

Modelling and analysis of special structures i.e. chimneys, cooling towers, bridges, industrial structures.

Acceleration and displacement sensitive Non-structural elements, simplified methods of classifications

Reference Books/Material

1. M.J.N. Priestley, G.M. Calvi and M.J. Kowalsky, (2007), *Displacement-Based Seismic Design of Structures*, IUSS Press.
2. FEMA-356. (2000). *Commentary for the Seismic Rehabilitation of Buildings.,* Federal Emergency Management Agency, Washington, DC.
3. FEMA-440 (2005). *Improvement of nonlinear static seismic analysis procedures*. *FEMA-440, Redwood City.*
4. FEMA, P-695 (2009). *Quantification of Building Seismic Performance Factors*, Federal Emergency Management Agency.
5. ASCE 41. (2013). *Seismic Evaluation and Retrofit of Existing Buildings (ASCE/SEI 41-13)*, Reston, VA.
6. ATC 40 (1996). *Seismic Evaluation and retrofit of concrete building – Vol. I & II*, Applied Technology Council, California
7. FEMA-450 (2003*) NEHRP Recommended provisions for Seismic Regulations for New Buildings and Other Structures*, Federal Emergency management Agency
8. Park, R., &Paulay, T. (1975). *Reinforced concrete structures*. John Wiley & Sons.
9. Penelis, George G., and Kappos, Andreas J. (1997). *Earthquake Resistant Concrete Structures*, E & FN Spon
10. Paulay, T., & Priestly, M. J. N. (2009). *Seismic design of RC and masonry buildings*. John Wiley & Sons, Inc.
11. Moehle, J.(2014). *Seismic design of reinforced concrete buildings*. McGraw Hill Professional.
12. Darwin, D., Dolan, C.W. &Nilson, A.H. (2016).*Design of concrete structures*. McGraw-Hill Education.
13. Skinner,R., Robinson,W.H. &McVerry, G. H. (1996).*An Introduction to Seismic Isolation*, John Wiley and Sons.

AML NONLINEAR STRUCTURAL ANALYSIS (DE) (Even Semester)

Credit: 3
Contact hours (L-T-P): 3-0-0
Pre-requisites: Nil
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective

To course will provide insight into advanced concepts of analysis and design of structures to withstand earthquake forces and related seismic safety issues.

Course Outcomes

- **CO1.** Students will be capable of identifying the sources of nonlinearity in the response of structure.
- **CO2.** Students will be capable of carrying out static non-linear analysis of member.
- **CO3.** Students will be capable to carrying out dynamic non-linear analysis of structure

Relationship of Course Objective to Program Outcome
H = High correlation; M = Medium correlation; L = Low correlation

	PO1	PO2	PO3	PO4	PO5
CO1	M				
CO2			H		
CO3				H	

Syllabus

Introduction to nonlinear structural analysis; Overview, Sources of nonlinearities, types of structural analysis (1st order elastic, 1st order inelastic, 2nd order elastic, and 2nd order inelastic),
Principles of computational plasticity;
overview, yield criterion, flow rule, hardening rule, loading/unloading criterion. Some commonly used uniaxial material models; elastic material, elastic-perfectly plastic material, bilinear steel material with kinematic and isotropic hardening, Ramberg-Osgood steel material model, Giuffre-Menegotto-Pinto model with isotropic strain hardening, Kent-Scott-Park concrete material model, Visco-elastic material model, Bouc-Wen model;
Member section analysis; fiber section discretization; moment-curvature response; force-deformation response; Material nonlinear beam-column element formulation; lumped plasticity models (beam with hinges formulation), distributed nonlinearity models; displacement-based nonlinear beam-column element; force-based nonlinear beam-column element. Geometrically nonlinear analysis; simplified 2nd order P-Δ analysis, co-rotational formulations of truss and beam elements.
Solution strategies for nonlinear system of equations; incremental single-step methods; Euler method, second-order Runge-Kutta methods, incremental-iterative methods, load control, displacement control, work control, arc-length control; Nonlinear structural dynamic analysis; semi-discrete equations, of motion, explicit time integration, implicit time integration, dissipative integration algorithms, stability and accuracy. Application to hybrid

simulation; overview, sub-structuring in hybrid simulation; application to modeling analytical substructures, solution of time discretized equations of motion.

Reference Books/Material

1. Owen, D. R. &Hinton, E. (1980)*Finite Elements in Plasticity (Theory and Practice)*, Pineridge Press Limited, Swansea.
2. Bathe, K. J. (1987)*Finite Element Procedures in Engineering Analysis*, Prentice-Hall, Englewood Cliffs, New Jersey.
3. Crisfield, M. A. (1991)*Non-Linear Finite Element Analysis of Solids and Structures (Vol. 1: Essentials)*, John Wiley & Sons, Chichester.
4. Washizu, K. (1975). *Variational methods in elasticity and plasticity (Vol. 3)*. Oxford: Pergamon press.
5. Crisfield, M. A. (1993). *Non-linear finite element analysis of solids and structures (Vol. 1)*. New York: Wiley.
6. James, F. D. (2010*). Nonlinear analysis of thin-walled structures*. Springer.
7. Denkowski, Z., Migórski, S., &Papageorgiou, N. S. (2013). *An introduction to nonlinear analysis: theory*. Springer Science & Business Media.
8. Li, G., & Wong, K. (2014). *Theory of nonlinear structural analysis: The force analogy method for earthquake engineering*. John Wiley & Sons.
9. Sathyamoorthy, M. (1997). *Nonlinear analysis of structures (Vol. 8)*. CRC Press.

AML PRESTRESSED CONCRETE STRUCTURES (DE)(Even Semester)

Credit: 4
Contact hours (L-T-P): 3-0-2
Pre-requisites: Nil
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objectives
To understand the mechanical behavior, analysis and design of prestressed concrete elements.

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability

CO1. to understand basic properties of pre-stressed concrete structures,
CO2. to analyse and design pre-stressed concrete structures as per IS codes,
CO3. to understand techniques and method of communicating engineering design to industry.

Relationship of Course Objective to Program Outcome
H = High correlation; M = Medium correlation; L = Low correlation

POs → / COs ↓	PO1	PO2	PO3	PO4	PO5
CO1	M	M	H	M	L
CO2	M	M	H	M	L
CO3	M	M	M	M	L

Syllabus
Introduction to basic concepts and general principles of pre-stressed concrete, materials used in prestressed concrete and methods and techniques of prestressing, prestressing systems.
Analysis of prestressed concrete sections for flexure considering loading stages, computation of sectional properties, critical sections under working loads for pretensioned and post tensioned members, load balancing method of analysis of prestressed concrete beams, losses in prestress, application to simply supported beams and slabs
Design philosophy of prestressed concrete sections, permissible stresses in concrete and steel, design approaches using working stress method as per IS 1143 – 1980, limit state of collapse – flexure and shear as applied to prestressed concrete beams, kern points, choice and efficiency of sections, cable profile and layouts, cable zone, deflection of prestressed concrete sections.
End zone stresses in prestresses concrete members, pretension transfer bond, transmission length, end block of post tensioned members.
Design of simply supported pre-tensioned and post tensioned slabs and beams. Design of bridge girders as per IRC.

Practical Content

Experimental evaluation of design examples (3 - 4) including report writing and drawing based on syllabus.

Reference Books/Material

1. Raju, N. K. (2006). *Prestressed concrete*. Tata McGraw-Hill Education
2. Lin, T. Y., & Burns, N. H. (1981). *Design of prestressed concrete structures.*
3. Park, R. (1977). *Design of Prestressed Concrete Structures*. University of Canterbury.
4. IS 1343 (2012). Bureau of Indian Standards (BIS), Govt. of India, New Delhi

AML566 RANDOM VIBRATION ANALYSIS (DE) (Even Semester)

Credit:	**3**
Contact hours (L-T-P):	**3-0-0**
Pre-requisites:	**AML522**
Overlaps with:	**Nil**
Course Assessment Method:	**As per Academic Rule Book**

Course Objective

This course covers the basic principles of random variables and stochastic processes and applications to the response of systems subjected to random vibrations.

Course Outcomes

CO1. Student will be learn and understand the non-deterministic nature of loading, material properties, and other parameters.

CO2. Probabilistic / Stochastic description of response and safety assessment will be known.

CO3. Student will be able to extend the concept to stochastic design for various dynamic loads.

Relationship of Course Objective to Program Outcome
H = High correlation; M = Medium correlation; L = Low correlation

POs → / COs ↓	PO1	PO2	PO3	PO4	PO5
CO1	H	H	M	L	M
CO2	H	H	H	M	M
CO3	H	H	L	M	L

Syllabus

Basic Theory: Meaning and axiom of probability, events, random variables, discrete and continuous distribution, some examples; Functions of random variables, expectations, characteristic functions; Orthogonality principles, sequence of random variables.
Stochastic Processes: Counting process, random walk, Markov chain, Gaussian process, filtered point process, Markov process and non-stationary Gaussian process; Stochastic continuity and differentiation, integral, time average, ergodicity; Correlation and power spectrum; Threshold crossing, peak, envelope distribution and first passage problem.
Response of Linear Systems to Random Vibrations: Linear response of single and multiple-degree of freedom systems subjected to random inputs; Linear response of continuous systems.

Reference Books/Material

1. Nigam, N. C., & Saunders, H. (1986). *Introduction to Random Vibration*. MIT Press, Cambridge.

2. Preumont, A. (2013). *Random Vibration and Spectral Analysis/Vibrations aléatoiresetanalyse spectral (Vol. 33)*. Springer Science & Business Media.
3. Lin, Y. K., &Cai, G. Q. (2004). *Probabilistic structural dynamics: advanced theory and applications*. Mcgraw-hill Professional Publishing.
4. C. W. (2011). *Nonlinear random vibration: Analytical techniques and applications*. CRC Press.
5. Wirsching, P. H., Paez, T. L., & Ortiz, K. (2006). *Random vibrations: theory and practice*. Courier Corporation.
6. Robson, J. D. (1964). *An introduction to random vibration,* Edinburgh University Press.

AML CONCRETE STRUCTURES (AU) (Even Semester)

Credit:	**4**
Contact hours (L-T-P):	**3-0-2**
Pre-requisites:	**Nil**
Overlaps with:	**Nil**
Course Assessment Method:	**As per Academic Rule Book**

Course Objective

To introduce method for design of RC structures with loading standards as per codal provisions

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability

- **CO1.** to understand methods of reinforce concrete design,
- **CO2.** to design various types of RC structures,
- **CO3.** to understand techniques and method of communicating engineering design to industry.

Relationship of Course Objective to Program Outcome
H = High correlation; M = Medium correlation; L = Low correlation

POs → / COs ↓	PO1	PO2	PO3	PO4	PO5
CO1	M	H	H	M	L
CO2	M	H	H	M	L
CO3	M	M	M	M	L

Theory Content

Review of limit state design and loadings as per applicable codes.
Analysis, design and detailing of simple buildings
Analysis, design and detailing of folded plates and cylindrical shells (beam and arch theory),
Analysis, design and detailing of deck slab bridges, Analysis, design and detailing cylindrical water tanks resting on ground (fixed and hinged boundary conditions at base),
Analysis, design and detailing of circular silos including foundations,

Practical Content

Study of construction materials and construction technique related to reinforced concrete structural design including site visits / visit to structural design office
Experimental evaluation of design examples (3 - 4) including report writing and drawing based on syllabus.

Reference Books / Material

1. Naeim, F., & Kelly, J. M. (1999). *Design of seismic isolated structures: from theory to practice*. John Wiley & Sons.
2. Paulay, T., & Priestly, M. J. N. (2009). *Seismic design of RC and masonry buildings*. John Wiley & Sons, Inc..

3. Booth, E. D. (1994). *Concrete structures in earthquake regions: design and analysis*. Longman Scientific & Technical; Copublished in the US with J. Wiley.
4. Reynolds, C. E., Steedman, J. C., &Threlfall, A. J. (2007). *Reinforced concrete designer's handbook*. CRC Press.
5. Reynolds, C. E. (1962). *Basic Reinforced Concrete Design: Elementary* (Vol. 1). Concrete Publications.
6. Fintel, M. (Ed.). (1974). *Handbook of concrete engineering* (p. 801). New York: Van Nostrand Reinhold.
7. Chen, W. F., &Duan, L. (Eds.). (2014). *Bridge Engineering Handbook: Construction and Maintenance*. CRC press.
8. Gaylord, E. H., Gaylord, C. N., &Stallmeyer, J. E. (1997). *Structural engineering handbook*.
9. Wai-Fah, C., &Lian, D. (2000). Bridge engineering handbook. *New York: CRC Press.*
10. Nilson, A. (1997). *Design of concrete structures* (No. 12th Edition).

AML STEEL STRUCTURES (AU) (Even Semester)

Credit: **4**
Contact hours (L-T-P): **3-0-2**
Pre-requisites: **Nil**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective
To introduce method for design of steel structures with loading and design standards

Course Outcomes
CO1. Students will develop ability to carry out research in Steel design and development work
CO2. Students will be capable of developing design report and structural drawings.
CO3. Students will be capable of designing steel structures.

Relationship of Course Objective to Program Outcome
H = High correlation; M = Medium correlation; L = Low correlation

	PO1	PO2	PO3	PO4	PO5
CO1	M				
CO2		M			
CO3			H		

Syllabus
Review of allowable stress, plastic design and limit state design and loadings as per applicable codes.
Design of Beams, Beam-column, Plate Girders
Design of open web structures and space structures
Design of bridges and composite structures
Design of industrial buildings including crane/gantry girders
Welded, riveted and bolted connections
Analysis, design and detailing of simple steel structures

Reference Books / Material

1. Trahair, N. S., Bradford, M. A., Nethercot, D., & Gardner, L. (2007). *The behaviour and design of steel structures to EC3*. CRC Press. 21
2. Englekirk, R. E. (1994). *Steel structures: Controlling behavior through design*.
3. Johnson, R. P. (2008). *Composite structures of steel and concrete: beams, slabs, columns, and frames for buildings*. John Wiley & Sons.
4. Oehlers, D. J., & Bradford, M. A. (2013). *Composite Steel and Concrete Structures: Fundamental Behaviour: Fundamental Behaviour*. Elsevier.
5. Manual, C. F. S. D. (2002). *American Iron and Steel Institute*. Washington, DC.
6. Yu, W. W., &LaBoube, R. A. (2010). *Cold-formed steel design*. John Wiley & Sons.

7. Brockenbrough, R. L., & Johnston, B. G. (1974). *Steel design manual*. United States Steel Corporation.
8. Schafer, B. W. (2002). *Design Manual for Direct Strength Method of Cold-Formed Steel Design*. Report to the American Iron and Steel Institute, Washington, DC (available online www. ce. jhu. edu/bschafer/direct_strength).
9. Brockenbrough, R. L., & Johnston, B. G. (1968). *USS Steel design manual*. United States Steel Corporation.
10. Chen, W. F., & Kim, S. E. (1997). *LRFD steel design using advanced analysis (Vol. 13).* CRC press.
11. Owens, G. W., & Knowles, P. R. (1992). *Steel designers manual*.
12. Manual, A. S. D. (1988). *Rev. 2. American Iron and Steel Institute*, Washington DC, USA, 1-4.
13. Packer, J. A., & Henderson, J. E. (1997). *Hollow structural section connections and trusses: a design guide*. Willowdale, Ont.: Canadian Institute of Steel Construction.
14. Subramanium, N. (2018). *Design of Steel Structures – Limit State Method*, Oxford publication