Post Graduate Course Structure
For
STRUCTURAL ENGINEERING
(Applicable for batches admitted from 2018-2019)

S No	Programme Code	Programme Name	Branch	No. of Sections	No. of Students	Page
1	SE	M.Tech.	Structural Engineering	01	24	1-3

Autonomous Regulations – R18

Amrita Sai Institute of Science & Technology

Approved by AICTE, New Delhi; Permanently Affiliated to JNTUK, Kakinada
ISO 9001:2015 Certified Institution; Accredited by NAAC with "A" grade
Recognized by UGC under 2(f) and 12(B) of UGC 1956 Act

Amrita Sai Nagar, Paritala, Krishna District
Andhra pradesh – 521 180
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M. Tech. Course Structure – Structural Engineering

I Semester

S. No	Course Code	Course	L	T	P	C
1	18SE1T1	Advanced Mathematics	4	--	--	3
2	18SE1T2	Theory of Elasticity	4	--	--	3
3	18SE1T3	Matrix Analysis of Structures	4	--	--	3
4	18SE1T4	Structural Dynamics	4	--	--	3
5	18SE1T5A 18SE1T5B 18SE1T5C	**Elective - I** i. Experimental Stress Analysis ii. Sub Structure Design iii. Structural Optimization	4	--	--	3
6	18SE1T6A 18SE1T6B 18SE1T6C	**Elective - II** i. Repair and Rehabilitation of Structures ii. Analysis and Design of Tall Buildings iii. Plastic Analysis and Design	4	--	--	3
7	18SE1L1	Advanced Structural Engineering Laboratory	--	--	4	2
8	18SE1G1	Green Buildings (GRIHA – Criterion 1-31)	1	--	--	--
		Total Credits	**20**			

II Semester

S. No	Course Code	Course	L	T	P	C
1	18SE2T1	Finite Element Methods	4	--	--	3
2	18SE2T2	Earthquake Resistant Design	4	--	--	3
3	18SE2T3	Stability of Structures	4	--	--	3
4	18SE2T4	Theory of Plates and Shells	4	--	--	3
5	18SE2T5A 18SE2T5B 18SE2T5C	**Elective – III** i. Pre-Stressed Concrete ii. Mechanics of Composite Materials iii. Fracture Mechanics	4	--	--	3
6	18SE2T6A 18SE2T6B 18SE2T6C	**Elective – IV** i. Industrial Structures ii. Bridge Engineering iii. Earth Retaining Structures	4	--	--	3
7	18SE2L1	CAD & GIS Laboratory	--	--	4	2
		Total Credits	**20**			

III Semester

S. No	Course Code	Course	L	T	P	C
1	18SE3S1	Seminar	--	--	--	3
2	18SE3J1	Thesis-Part-I	--	--	--	7
3	18SE3R1	Research Methodologies	1	--	--	--
		Total Credits	**10**			

IV Semester

S. No	Course Code	Course	L	T	P	C
1	18SE4P1	Project Work & Thesis Part-II	--	--	--	10
		Total Credits	**10**			

L-Lecture; T-Tutorial; P-Practical; C-Credits

Total Course Credits →20+20+10+10 = 60

(BOS CHAIRMAN)

KVSG 16818

[K.V.S.G. MURALI KRISHNA
UNIVERSITY NOMINEE]

[Dr. I.V. MURALI KRISHNA
SUBJECT EXPERT]

[G. M. SUMANTH
INDUSTRY EXPERT]

Subject Code **18SE1T1**	**ADVANCED MATHEMATICS**

UNIT I: Applied partial Differential Equations: One-dimensional Heat equation Cartesian, cylindrical and spherical coordinates (problems having axi-symmetry). Two-dimensional Laplace Equation in Cartesian, cylindrical and spherical coordinates (problems having axi-symmetry) – Analytical solution by separation of variables technique.

UNIT II: Numerical solutions to Heat and Laplace Equations in Cartesian coordinates using finite – differences. Implicit methods, Crank Nicholsen Method, Jacobi Method, Guass Seidal method.

UNIT III: Applied Statistics: Regression and correlation analysis – Method of Least squares – Curve fitting – Curvilinear Regression – Non-linear curves – correlation coefficient – Correlation of grouped bi-variate data – coefficient of determination Multiple Regression – partial Regression coefficients.

UNIT IV: Tests of significance – Analysis of variance for regression – Multiple correlation coefficients – Multiple linear regression with two independent variables.

UNITV: Linear Programming Problem Formation, Graphical Method, Simplex method, artificial variable method-Big-M method-Two Phase Method. Non Linear Programming Problem Gradient method, Steepest Ascent Descent Methods.

TEXT BOOKS:

1. Solutions of Partial Differential Equations" – Duffy, D.G. CBS Publishers, 1988
2. Introductory Methods of Numerical Analysis – Sastry, S.S. Prentice-Hall, 2nd Edition, 1992
3. Basic Statistics – Agarval, B.L., Wiley 1991, 2nd edition.
4.Operations Research – Hamdy A, Taha.Optimization Techniques.-S.S.Rao:.

Subject Code **18SE1T2**	**THEORY OF ELASTICITY**

UNIT I: Elasticity – Notation for forces and stresses – components of stresses and strains – Hooke's Law - Plane Stress – Plane strain – Differential Equations of equilibrium – Boundary conditions – Compatibility equations - Stress function – Boundary Conditions.

UNIT II: Two dimensional problems in rectangular co-ordinates – Solution by polynomials – Saint Venant's principle – Determination of displacements – Bending of simple beams – Application of Fourier series for two dimensional problems for gravity loading

UNIT III: Two dimensional problems in polar co-ordinates - General equations in polar co-ordinates – Stress distribution for problems having symmetrical about an axis - Strain components in polar co-ordinates – Displacements for symmetrical stress distributions - Stresses for plates with circular holes subjected to far field tension – stress concentration factor.

UNIT IV: Analysis of stress and strain in three dimension - Principal stresses – Stress ellipsoid and stress director surface – Determination of principal stresses - Maximum shear stress – Homogeneous Deformation – General Theorems - Differential equations of equilibrium – Conditions of compatibility – Equations of equilibrium in terms of displacements – Principle of superposition – Uniqueness of solution –Reciprocal theorem.

UNIT V: Torsion of prismatical bars – Bars with elliptical cross section – Other elementary solution – Membrane analogy – Torsion of rectangular bars – Solution of torsional problems by energy method.

REFERENCES

1. Theory of Elasticity- Timoshenko & Goodier
2. Elasticity: Theory, Applications and Numeric- Martin H. Sadd

Subject Code **18SE1T3**	**MATRIX ANALYSIS OF STRUCTURES**

UNIT I: Introduction of matrix methods of analysis – Static and kinematic indeterminacy – Degree of freedom – Structure idealization-stiffness and flexibility methods – Suitability: Element stiffness matrix for truss element, beam element and Torsional element- Element force - displacement equations

UNTI II: Stiffness method – Element and global stiffness equation – coordinate transformation and global assembly – structure stiffness matrix equation – analysis of simple pin jointed trusses – continuous beams – rigid jointed plane frames

UNIT III: Stiffness method for Grid elements – development of stiffness matrix – coordinate transformation. Examples of grid problems – tapered and curved beams

UNIT IV: Additional topics in stiffness methods – discussion of band width – semi band width – static condensation – sub structuring –Loads between joints-Support displacements- inertial and thermal stresses-Beams on elastic foundation by stiffness method.

UNIT V: Space trusses and frames - Member stiffness for space truss and space frame– Transformation matrix from Local to Global – Analysis of simple trusses, beams and frames

REFERENCES:

1. Matrix analysis of structures- Robert E Sennet- Prentice Hall-Englewood cliffs-New Jercy
2. Advanced structural analysis-Dr. P. Dayaratnam- Tata McGraw hill publishing company limited.
3. Indeterminate Structural analysis- C K Wang
4. Analysis of tall buildings by force – displacement – Method M. Smolira – Mc. Graw Hill.
5. Foundation Analysis and design – J.E. Bowls

Subject Code **18SE1T4**	**STRUCTURAL DYNAMICS**

UNIT–I: Introduction to Structural Dynamics: Fundamental objective of Dynamic analysis – Types of prescribed loadings – methods of Discretization – Formulation of the Equations of Motion.

UNIT-II Theory of Vibrations: Introduction – Elements of a Vibratory system– Degrees of Freedom of continuous systems – Oscillatory motion – Simple Harmonic Motion– Free Vibrations of Single Degree of Freedom (SDOF) systems – Undamped and Damped –Critical damping – Logarithmic decrement – Forced vibrations of SDOF systems – Harmonicexcitation – Dynamic magnification factor – Band width.

UNIT-III Single Degree of Freedom System: Formulation and Solution of the equation of Motion – Free vibration response – Response to Harmonic, Periodic, Impulsive and general dynamic loadings – Duhamel integral.

UNIT-IV Multi Degree of Freedom System: Selection of the Degrees of Freedom– Evaluation of Structural Property Matrices – Formulation of the MDOF equations of motion- Undamped free vibrations – Solution of Eigen value problem for natural frequencies and mode shapes – Analysis of dynamic response – Normal coordinates.

UNIT-V Continuous Systems: Introduction – Flexural vibrations of beams – Elementary case – Equation of motion – Analysis of undamped free vibration of beams in flexure – Natural frequencies and mode shapes of simple beams with different end conditions.

REFERENCES:

1. Dynamics of Structures by Clough & Penzien.
2. Structural Dynamics A K Chopra

Subject Code **18SE1T5A**	**EXPERIMENTAL STRESS ANALYSIS**

UNIT I : Introduction and Strain measurement methods – Model & Prototype – Dimensional analysis-Factors influencing model design – Scale factors and Model material properties – Methods of model design. Definition of strain and its relation to experimental determinations - properties of strain gauge systems – Mechanical, Optical, Acoustic and Pneumatic types.

UNIT- II Electrical resistance strain gages: Introduction – gauge construction– strain gauge adhesives - mounting methods – gauge sensitivities and gage factor – performance characteristics of wire and foil strain gauges – environmental effects. Analysis of strain gauge data – the three element rectangular rosette – the delta rosette – correction for transverse sensitivity.

UNIT III Non – destructive testing: Introduction – objectives of non destructive testing. Ultrasonic pulse velocity method – Rebound Hammer method (Concrete hammer) – Acoustic Emission application to assessment of concrete quality.

UNIT IV Theory of photo elasticity: Introduction – temporary double refraction – Index ellipsoid and stress ellipsoid – the stress optic law – effects of stressed model in a polariscope for various arrangements - fringe sharpening.

UNIT V Two dimensional photo elasticity: Introduction – iso-chromatic fringe patterns – isoclinic
fringe patterns – compensation techniques – calibration methods – separation methods – materials for photo- elasticity – properties of photo-elastic materials.

REFERENCES:

1. Experimental Stress Analysis- Riley and Dally
2. Experimental Stress Analysis - L.S. Srinath
3. Experimental Stress Analysis – Lee
4. Experimental Stress Analysis- Sadhu Singh

Subject Code **18SE1T5B**	**SUB-STRUCTURE DESIGN**

UNIT I: Soil Exploration – Importance, Terminology, planning - Geophysical methods. Borings, location, spacing and depth, methods of boring including drilling, stabilization of boreholes, boring records.

UNIT II Soil sampling – Methods of sampling -Types of samples and samplers-cleaning of bore holes, preservation, labeling and shipment of samples - Design considerations of open drive samplers.

UNIT III Shallow Foundations –Bearing capacity – General bearing capacity equation, Meyerhof's, Hansen's and Vesic's bearing capacity factors - Bearing capacity of stratified soils – Bearing capacity based on penetration resistance- safe bearing capacity and allowable bearing pressure. (Ref: IS -2131 & IS 6403)

UNIT IV Types and choice of type. Design considerations including location and depth, Proportioning of shallow foundations- isolated and combined footings and mats - Design procedure for mats. Floating foundation- Fundamentals of beams on Elastic foundations. .(Ref: IS -456 & N.B.C. relevant volume).

UNIT V Pile foundations-Classification of piles-factors influencing choice-Load -carrying capacity of single piles in clays and sands using static pile formulae- á - â - and λ - methods –Dynamic pile formulae-limitations-Monotonic and cyclic pile load tests – Under reamed piles. Pile groups - Efficiency of pile groups- Different formulae-load carrying capacity of pile groups in clays and sands – settlement of pile groups in clays and sands – Computation of load on each pile in a group.

REFERENCES:

1. Principles of Foundation Engineering by Braja M. Das.
2. Soil Mechanics in Engineering Practice by Terzagi and Peck
3. Foundation Design by Wayne C. Teng, John Wiley & Co.,
4. Foundation Analysis and Design by J.E. Bowles McGraw Hill Publishing Co.,
5. Analysis and Design of sub structures by Swami Saran
6. Design Aids in Soil Mechanics and Foundation Engineering by Shanbaga R. Kaniraj,Tata Mc. Graw Hill.
7. Foundation Design and Construction by MJ Tomlinson – Longman Scientific
8. A short course in Foundation Engineering by Simmons and Menzes – ELBS.

Subject Code **18SE1T5C**	**STRUCTURAL OPTMIZATION**

UNIT I: Introduction: Need and scope for optimization – statements of optimization problems- Objective function and its surface design variables- constraints and constraint surface- Classification of optimization problems (various functions continuous, discontinuous and discrete) and function behavior (monotonic and unimodal)

UNIT II Classical optimization techniques: Differential calculus method, multi variable optimization by method of constrained variation and Lagrange multipliers (generalized problem) Khun-Tucker conditions of optimality -Fully stressed design and optimality criterion based algorithms introduction, characteristics of fully stressed design theoretical basis-examples

UNIT III Non-Liner programming: Unconstrained minimization- Fibonacci, golden search, Quadratic and cubic interpolation methods for a one dimensional minimization and univariate method, Powel's method, Newton's method and Davidon Fletcher Powell's method for multivariable optimization- Constrained minimization- Cutting plane method- Zoutendjik's method- penalty function methods

UNIT IV Linear programming: Definitions and theorems- Simplex method-Duality in Linear programming- Plastic analysis and Minimum weight design and rigid frame

UNIT V Introduction to quadratic programming: Geometric programming- and dynamic programming- Design of beams and frames using dynamic programming technique

REFERENCES

1. Optimization Theory and Applications – S.S. Rao, Wiley Eastern Limited, New Delh.
2. Optimization Concepts and Application in Engineering- Belegundu A.D. and Chandrupatla T.R

Subject Code **18SE1T6A**	**REPAIR AND REHABILITATION OF STRUCTURES**

UNIT I Materials for repair and rehabilitation -Admixtures- types of admixtures-purposes of using admixtures- chemical composition- Natural admixtures- Fibres- wraps- Glass and Carbon fibre wraps- Steel Plates-Non destructive evaluation: Importance- Concrete behavior under corrosion, disintegrated mechanisms- moisture effects and thermal effects – Visual investigation- Acoustical emission methods- Corrosion activity measurement- chloride content – Depth of carbonation- Impact echo methods- Ultrasound pulse velocity methods- Pull out tests.

UNIT II Strengthening and stabilization- Techniques- design considerations-Beam shear capacity strengthening- Shear Transfer strengthening-stress reduction techniques- Column strengthening-flexural strengthening- Connection stabilization and strengthening, Crack stabilization.

UNIT III Bonded installation techniques- Externally bonded FRP- Wet layup sheet, bolted plate, near surface mounted FRP, fundamental debonding mechanisms-intermediate crack debonding-CDC debonding- plate end debonding- strengthening of floor of structures.

UNIT IV Fibre reinforced concrete- Properties of constituent materials- Mix proportions, mixing and casting methods-Mechanical properties of fiber reinforced concrete- applications of fibre reinforced concretes-Light weight concrete- properties of light weight concrete- No fines concrete- design of light weight concrete- Flyash concrete-Introduction- classification of flyash-properties and reaction mechanism of flyash- Properties of flyash concrete in fresh state and hardened state- Durability of flyash concretes.

UNIT V High performance concretes- Introduction- Development of high performance concretes- Materials of high performance concretes- Properties of high performance concretes-Self Consolidating concrete-properties qualifications.

REFERENCE:

1. Concrete technology- Neville & Brooks
2. Special Structural concrete- Rafat Siddique
3. Concrete repair and maintenance illustrated- Peter H Emmons
4. Concrete technology-M S Shetty

Subject Code **18SE1T6B**	**ANALYSIS AND DESIGN OF TALL BUILDINGS**

UNIT I Design Criteria Philosophy, Materials – Modern concepts – High Performance Concrete, Fibre Reinforced Concrete, Light weight concrete, Self Compacting Concrete.

UNIT II Gravity Loading – Dead load, Live load, Impact load, Construction load, Sequential loading. Wind Loading – Static and Dynamic Approach, Analytical method, Wind Tunnel Experimental methods. Earthquake Loading – Equivalent lateral Load analysis, Response Spectrum Method, Combination of Loads.

UNIT III Behavior of Structural Systems- Factors affecting the growth, height and structural form, Behaviour of Braced frames, Rigid Frames, In-filled frames, Shear walls, Coupled Shear walls, Wall–Frames, Tubular, Outrigger braced, Hybrid systems.

UNIT IV Analysis and Design- Modeling for approximate analysis, Accurate analysis and reduction techniques, Analysis of structures as an integral unit, Analysis for member forces, drift and twist. Computerized 3D analysis. Design for differential movement, Creep and Shrinkage effects, Temperature Effects and Fire Resistance.

UNIT V Stability Analysis- Overall buckling analysis of frames, wall–frames, Approximate methods, Second order effect of gravity loading, P–Delta Effects, Simultaneous first order and P-Delta analysis, Translational instability, Torsional Instability, Out of plumb effects, Effect of stiffness of members and foundation rotation in stability of structures.

TEXT BOOKS:

1. Bryan Stafford Smith and Alex Coull, "Tall Building Structures - Analysis and Design", John Wiley and Sons, Inc., 1991.
2. Taranath B.S, "Structural Analysis and Design of Tall Buildings", McGraw-Hill, 1988.

Subject Code **18SE1T6C**	**PLASTIC ANALYSIS AND DESIGN**

UNIT I Introduction and basic hypothesis: Concepts of stress and strain – relation of steel Moment curvature relation- basic difference between elastic and plastic analysis with examples- Yield condition, idealizations, collapse criteria- Virtual work in the elastic-plastic state- Evaluation of fully plastic moment and shape factors for the various practical sections.

UNIT II Method of Limit Analysis: Introduction to limit analysis of simply supported fixed beams and continuous beams, Effect of partial fixity and end, invariance of collapse loads, basic theorems of limit analysis, rectangular portal frames, gable frames, grids, superposition of mechanisms, drawing statistical bending moment diagrams for checks.

UNIT III Limit design Principles: Basic principles, limit design theorems, application of limit design theorems, trial and error method, method of combining mechanisms, plastic moment distribution method, load replacement method, continuous beams and simple frames designs using above principles.

UNIT IV Deflection in Plastic beams and frames: Load deflection relations for simply supported beams, deflection of simple pin based and fixed based portal frames, method of computing deflections.

UNIT V Minimum weight Design: Introduction to minimum Weight and linear Weight functions- Foulkes theorems and its geometrical analogue and absolute minimum weight design.

REFERENCES:

1. Plastic Methods of Structural analysis- B G Neal, Chapman and Rall publications
2. Plastic analysis and Design – C E Messennet, M A Seve

Subject Code **18SE1L1**	**ADVANCED STRUCTURAL ENGINEERING LABORATORY**

LIST OF EXPERIMENTS

1. Strain measurement - Electrical resistance strain gauges
2. Non destructive testing- Impact Hammer test, UPV test
3. Qualifications tests on Self compaction concrete- L Box test, J Box test, U box test, Slump test
4. Tests on Buckling of columns – Southwell plot
5. Repair and rehabilitation of concrete beams
6. Chemical Analysis of water for suitability in concreting with and without Reinforcement.
7. Chemical Analysis of sand and Aggregate for Suitability in Construction.

NOTE: A minimum of five experiments from the above set have to be conducted.

Subject Code **18SE1A1**	**GREEN BUILDINGS (GREEN RATING FOR INTEGRATED HABITAT ASSESSMENT. GRIHA)**

Criterion	
Criterion 1	Site Selection
Criterion 2	Low-impact design
Criterion 3	Design to mitigate UHIE
Criterion 4	Site Imperviousness Factor
Criterion 5	Air and water pollution control
Criterion 6	Preserve and protect landscape during construction
Criterion 7	Construction Management Practices
Criterion 8	Energy efficiency
Criterion 9	Renewable energy utilization
Criterion 10	Zero ODP materials
Criterion 11	Achieving indoor comfort requirements (visual/thermal/acoustic)
Criterion 12	Maintaining good IAQ
Criterion 13	Use of low-VOC paints and other compounds in building interiors
Criterion 14	Use of low-flow fixtures and systems
Criterion 15	Reducing landscape water demand
Criterion 16	Water Quality
Criterion 17	On-site water reuse
Criterion 18	Rainwater Recharge
Criterion 19	Utilization of BIS recommended waste materials in building structure
Criterion 20	Reduction in embodied energy of building structure
Criterion 21	Use of low-environmental impact materials in building interiors
Criterion 22	Avoided post-construction landfill
Criterion 23	Treat organic waste on site
Criterion 24	Labour safety and sanitation
Criterion 25	Design for Universal Accessibility
Criterion 26	Dedicated facilities for service staff
Criterion 27	Increase in environmental awareness
Criterion 28	Smart metering and monitoring
Criterion 29	Operation, Maintenance Protocols
Criterion 30	Performance Assessment for Final Rating
Criterion 31	Innovation

Criterion 1: SITE SELECTION

Mandatory clause

The site plan must be in conformity with the development plan/master plan/UDPFI guidelines (mandatory). This should comply with the provisions of eco-sensitive zone regulations, coastal zone regulations, heritage areas (identified in the master plan or issued separately as specific guidelines), water body zones (in such zones, no construction is permitted in the water-spread and buffer belt of 30 metre minimum around the FTL), various hazard prone area regulations, and others if the site falls under any such area **(mandatory with no point allocation).**

Responsibility: Project Manager, Architect

Optional clause

The site should be located within ½ km radius of an existing bus stop, commuter rail, light rail or metro station and/or the proposed site must be a Brownfield site (to rehabilitate damaged sites where development is hindered by environmental contamination, thereby reducing pressure on undeveloped land) **(1 point)**

Responsibility: Project Manager, Architect

Criterion 2: PRESERVE AND PROTECT LANDSCAPE DURING CONSTRUCTION (selectively applicable)

Commitment

Proper timing of the construction, preserve topsoil and existing vegetation, staging and spill prevention, and erosion and sedimentation control. Replant on-site trees in the ratio of 3:1 to those removed during construction, for every removal one tree plant 3 saplings.

Mandatory clause

Preserve existing vegetation by means of non-disturbance or damage to trees and other forms of vegetation, as per GRIHA

OR

Trees/plants replanted within site premises in ratio of 3:1, as per GRIHA **(1 point – mandatory, if applicable).**
Responsibility: Landscape Architect

Non-Mandatory/Optional clause

Ensure proper timing of construction with respect to rain as per GRIHA
Responsibility: Architect, Project Manager
and Confine construction activity to pre-designated areas, as per GRIHA **(1 point).**
Responsibility: Landscape Architect, Proper implementation of staging and spill prevention plan

Effective erosion and sedimentation control to prevent erosion, as per GRIHA **(1 point)**.
Responsibility: Landscape Architect

Preserve topsoil by employing measures as per GRIHA **(1 point, if applicable).**
Responsibility: Project Manager and Architect

Non applicability condition proposed *(for top soil preservation only)*: Contaminated sites/sites that do not have good quality top soil (as per soil test report) that is considered worth storing for reuse. Soil test has to be carried out as per criteria 3 and the test report has to be endorsed by the landscape architect. The landscape architect has to provide certificate that the top soil is not worth storing for landscaping purposes and cannot be restored to applicable standard.

Trees/plants replanted within site premises in excess of 25% than minimum requirement, as per GRIHA **(1 point).**
Responsibility: Landscape Architect

Non applicability condition proposed (for tree preservation and protection clause only): Sites that are devoid of trees.

Criterion 3: SOIL CONSERVATION (till post-construction) 2 points

Commitment

Proper topsoil laying, stabilization of the soil, and maintenance of adequate fertility of the soil to support vegetative growth.

Optional clause

Proper topsoil laying for vegetative growth, as per GRIHA **(1 point).**
Responsibility: Landscape Architect

Proper stabilization of soil, as per GRIHA **(1 point).**
Responsibility: Landscape Architect

Non applicability condition proposed: For sites in which top soil could not be stored for reasons as sited in Criteria 2 above.

Criterion 4: DESIGN TO INCLUDE EXISTING SITE FEATURES

Commitment

Minimize the disruption of the natural ecosystem and design to harness maximum benefits of the prevailing micro-climate.

Non mandatory/optional clause

If all compliances are fulfilled, as per GRIHA. **(4 points)**

Criterion 5: REDUCE HARD PAVING ON-SITE AND/OR PROVIDE SHADED HARD-PAVED SURFACES

Commitment

Minimize storm water run-off by reducing hard paving on-site. **(2 points)**

Non mandatory/optional clause

Net paved area of site under parking, roads, paths or any other use not to exceed 25% of site area or net imperviousness of site should not exceed the imperviousness factor, as prescribed by NBC 2005

(BIS 2005b), whichever is more stringent, as per clause Equations 1 and 4 (reference documents: 5.2.1 and 5.2.2 in GRIHA). **(1 point)**
Responsibility: Landscape Architect

Mandatory clause

Total surface parking not to exceed as permitted by local by-law **(mandatory)**

Responsibility: Architect

AND

More than 50% of the total paved area to have pervious paving/open-grid pavement/grass pavers**.**
Responsibility: Landscape Architect

OR

Minimum 50% of the total paved area (including parking) to have shading by vegetated roof/ pergola with plants**.**
Responsibility: Landscape Architect

OR

Minimum 50% of the total paved area (including parking) to be topped with solar reflectance of 0.5 or higher.

or

Minimum 50% of the total paved area (including parking) to have any combination of the above mention strategies where common areas having two or more strategies shall be calculated only once. **(1 point)**
Responsibility: Landscape Architect

Criterion 6: ENHANCE OUTDOOR LIGHTING SYSTEM EFFICIENCY AND USE RENEWABLE ENERGY SYSTEM FOR MEETING OUTDOOR LIGHTING REQUIREMENTS

Commitment

Meet minimum allowable luminous efficacy (as per lamp type) and make progressive use of a renewable-energy-based lighting system. **(3 points)**

Optional clause

Luminous efficacy of 100% of lamps used in outdoor lighting to meet the corresponding lamp luminous efficacy as mentioned in Table 6.1, as per GRIHA **(1 point).**
Responsibility: Electrical Consultant

Automatic controls for 100% of outdoor lights, as per GRIHA **(1 point).**
Responsibility: Electrical Consultant

Percentage of total outdoor lighting fixtures with solar lighting system, as per GRIHA (a minimum of 25% of total number or 15% of total connected load, whichever is higher) **(1 point)**
Responsibility: Electrical Consultant

Criterion 7: PLAN UTILITIES EFFICIENTLY AND OPTIMIZE ON-SITE CIRCULATION EFFICIENCY

Commitment

Minimize road and pedestrian walkway length by appropriate planning and provide aggregate corridors for utility lines.

Optional clause

Demonstrated use of minimization and consolidation of transportation/service corridors and shading of pedestrian roads, as per GRIHA **(1 point).**
Responsibility: Architect

Use of aggregate utility corridors, as per GRIHA **(1 point).**
Responsibility: Architect

Consolidation of utility corridors along the previously disturbed areas or along new roads in order to minimize unnecessary cutting and trenching and ensure easy maintenance, as per GRIHA **(1 point).**
Responsibility: Architect

Health and well-being

Objective

To protect the health of construction workers and prevent pollution.

Criterion 8: PROVIDE MINIMUM LEVEL OF SANITATION/SAFETY FACILITIES FOR CONSTRUCTION WORKERS

Commitment

Ensure cleanliness of workplace with regard to the disposal of waste and effluent, provide clean drinking water and latrines and urinals as per applicable standard. **(2 points)**

Mandatory clause

Compliance with National Building Code norms on construction safety for ensuring safety during construction **(1 point),** as per GRIHA
Responsibility: Project Manager

Provision for health and sanitation facilities as specified above **(1 point),** as per GRIHA
Responsibility: Project Manager

Criterion 9: REDUCE AIR POLLUTION DURING CONSTRUCTION

Commitment

Ensure proper screening, covering stockpiles, covering brick and loads of dusty materials, wheel washing facility, and water spraying facility.

Mandatory clause

Demonstrated use of air pollution preventive measures, as per clauses in GRIHA **(2 points).**
Responsibility: Project Manager

Building planning and construction

Conservation and efficient utilization of resources

Objectives

To maximize resource (water, energy, and materials) conservation and enhance efficiency of the system and operations.

Criterion 10: REDUCE LANDSCAPE WATER REQUIREMENT

Commitment

Landscape using native species and reduce lawn areas while enhancing the irrigation efficiency and reducing the water requirement for landscaping purposes. **(3 points)**

Optional clause

Reduction in water consumption by 30%, as per GRIHA **(1 point).**
Responsibility: Landscape Consultant and Water Consultant

Reduction in water consumption by 40%, as per GRIHA **(additional 1 point).**
Responsibility: Landscape Consultant and Water Consultant

Reduction in water consumption by 50%, as per GRIHA **(additional 1 point).**
Responsibility: Landscape Consultant and Water Consultant

Criterion 11: REDUCE WATER USE IN THE BUILDING

Commitment

Reduce building water use by applying low-flow fixtures and other similar tools. **(2 points)**

Optional clause

Reduction in water consumption by 25%. For calculation, refer to Table 11.1 as per GRIHA **(1 point).**
Responsibility: Plumbing Consultant and Water Consultant

Water-use reduction by 50%. For calculation, refer to Table 11.1 as per GRIHA **(additional 1point).**
Responsibility: Plumbing Consultant and Water Consultant

Criterion 12: EFFICIENT WATER USE DURING CONSTRUCTION

Commitment

Use materials such as pre-mixed concrete for preventing loss during mixing. Use recycled treated water and control the waste of curing water.

Optional clause

Efforts to minimize potable water use for construction, as per GRIHA **(1 point).**

Responsibility: Project Manager and Architect

Energy: end use

Criterion 13: OPTIMIZE BUILDING DESIGN TO REDUCE CONVENTIONAL ENERGY DEMAND

Commitment

Plan appropriately to reflect climate responsiveness, including adequate day lighting as well as efficient artificial lighting. **(8 points)**

Mandatory clause

Appropriate planning which reflects climate responsiveness, as per GRIHA **(2 points).**
Responsibility: Architect and Energy Consultant

Adequate day lighting is provided, as per GRIHA **(2 points).**
Responsibility: Architect and Energy Consultant

Over-design of lighting system is avoided, as per GRIHA **(2 points).**
Responsibility: Architect and Energy Consultant

Optional clause

Increase in day lighted area as per GRIHA **(2points)**

Criterion 14: OPTIMIZE ENERGY PERFORMANCE OF BUILDING WITHIN SPECIFIED COMFORT LIMITS

Commitment

Ensure that the building complies with the mandatory compliance requirement of ECBC 2007 and meet thermal comfort conditions as per NBC 2005 as well as minimum benchmark for EPI as per GRIHA. Ensure reduction in EPI up to 40% under a specified category.

Meet thermal comfort conditions as per National Building Code 2005 and, minimum benchmark for energy performance index as per GRIHA

Ensure that energy consumption in building under a specified category is 10%–40% less than that benchmarked through a simulation exercise. **(16 points)**

Mandatory Clause

Compliance with Energy Conservation Building Code 2007. **(6 points)**.

Compliance with thermal comfort condition as per National Building Code 2005 and minimum benchmark index as per GRIHA. **(2 points)**
Responsibility: Mechanical Consultant, Electrical Consultant, Plumbing Consultant and Energy Consultant

Non-mandatory/optional clause

Every 10% reduction in EPI after building under a specified category shall fatch additional 2 points to a maximum of 8 points. **(2–8 points)**
Responsibility: Mechanical Consultant, Electrical Consultant, and Energy Consultant

Energy: embodied and construction

Criterion 15: UTILIZATION OF FLY-ASH IN BUILDING STRUCTURE

Commitment

Use of fly-ash for RCC (reinforced cement concrete) structures with in-fill walls and load bearing structures, mortar, and binders. **(6 points)**

Optional clause

Minimum 15% replacement of Portland cements with fly-ash (by weight of cement used) in structural concrete, as per GRIHA — **1 point (additional 1 point if more than 30%).**
Responsibility: Architect, Project Manager and Structural Consultant

Minimum 40% usage of fly-ash (by volume of materials used), for 100% load-bearing and no-load bearing walls, as per GRIHA — **2 points**.
Responsibility: Architect, Project Manager and Structural Consultant

Minimum 30% replacement of Portland cements with fly-ash (by weight of cement used) in plaster/ masonry mortar, as per GRIHA — **2 points**.
Responsibility: Architect, Project Manager and Structural Consultant

Criterion 16: REDUCE VOLUME, WEIGHT, AND CONSTRUCTION TIME BY ADOPTING EFFICIENT TECHNOLOGIES (such as pre-cast systems)

Commitment

Replace a part of the energy-intensive materials with less energy-intensive materials and/or utilize regionally available materials, which use low-energy/energy-efficient technologies. **(4 points)**

Optional clause

Structural application: Use of low-energy materials/efficient technologies in structural application clearly demonstrating a minimum 5% reduction in the embodied energy, when compared with equivalent products for the same application, for 100% structural system used in a building, meeting the equivalent strength requirements, as per all compliance clauses (2 points)
Responsibility: Architect/project manager and structural consultant

Non-structural application: Use of low-energy materials/efficient technologies (not based on the utilization of industrial waste), which are used for non-structural applications such as infill wall system and cause a minimum five per cent reduction in the embodied energy, when compared with equivalent products for the same application, for 100% infill wall system used in a building, meeting the equivalent strength requirements, as per all the compliance clauses (2 points).
Responsibility: Architect/project manager and structural consultant

Criterion 17: USE LOW-ENERGY MATERIAL IN INTERIORS

Commitment

Minimum 70% in each of the three categories of interiors (internal partitions, panelling/false ceiling/ interior wood finishes/in-built furniture door/window frames, flooring) from low-energy materials/ finishes to minimize the usage of wood. **(4 points)**

Optional clause

A minimum of 70% of the total quantity (gross area) of all interior finishes and products used for each of the category, as applicable, to be low-energy finishes, for each of the following category.

Sub-assembly/internal partitions/panelling/false ceiling/in-built furniture **(2 points),** as per GRIHA.
Responsibility: Architect

Flooring **(1 point),** as per GRIHA.
Responsibility: Architect

Doors/windows and frames **(1 point),** as per GRIHA.
Responsibility: Architect

Energy: Renewable

Criterion 18: RENEWABLE ENERGY UTILIZATION

Commitment

Rated capacity of proposed renewable energy systems is equal to or more than 1% of internal lighting and space conditioning connected loads and meets energy requirements for a minimum of 5% of the internal lighting consumption (for general lighting or its equivalent from renewable energy sources[solar, wind, biomass, fuel cell and others]). Energy requirements will be calculated based on realistic assumptions which will be subject to verification during appraisal. **(5 points)**

Mandatory clause

Rated capacity of proposed renewable energy system is equal to or more than 1% of internal lighting and space conditioning connected loads or its equivalent in the building **(1 point–mandatory),** as per all compliance clauses.
Responsibility: Electrical Consultant

Optional clause

Rated capacity of proposed renewable energy system meets annual energy requirements of equal to or more than 5% of internal lighting consumption or its equivalent in the building **(1 point),** as per all compliance clauses.
Responsibility: Energy Consultant

Rated capacity of proposed renewable energy system meets annual energy requirements of equal to or more than 10% of internal lighting consumption or its equivalent in the building **(2 point),** as per all compliance clauses.

Responsibility: Energy Consultant

Rated capacity of proposed renewable energy system meets annual energy requirements of equal to or more than 20% of internal lighting consumption or its equivalent in the building, as per all compliance clauses **(3 points).**

Responsibility: Energy Consultant

Rated capacity of proposed renewable energy system meets annual energy requirements of equal to or more than 30% of internal lighting consumption or its equivalent in the building, as per all compliance clauses **(4 points).**

Responsibility: Energy Consultant

Note: Lighting design shall be based on minimum requirements as per NBC 2005 (BIS 2005d) (criterion 13.1.5).

Criterion 19: RENEWABLE-ENERGY-BASED HOT WATER SYSTEM

Commitment

Meet 20% or more of the annual energy required for heating water through renewable energy based water-heating systems. **(3 points)**

Non applicability condition proposed: This criteria shall not apply to projects that have hot water demand (minimum) of less than 500 litres per day

Optional clause

Annual energy saved by proposed renewable energy system is 20% to 50% of annual energy required for water heating to meet the hot water requirements of the occupants in the building, as per all compliance clauses **(1 point).**

Responsibility: Energy Consultant and Plumbing Consultant

Annual energy saved by proposed renewable energy system is 50% to 70% of annual energy required for water heating to meet the hot water requirement of the occupants in the building, as per all compliance clauses **(2 points).**

Responsibility: Energy Consultant and Plumbing Consultant

Annual energy saved by proposed renewable energy system is more than 70% of annual energy required for water heating to meet the hot water requirements of the occupants in the building, as per all compliance clauses **(3 points).**
Responsibility: Energy Consultant and Plumbing Consultant

Recycle, recharge, and reuse of water

Objective

To promote the recycle and reuse of water.

Criterion 20: WASTE WATER TREATMENT

Commitment

Provide necessary treatment of water for achieving the desired concentration of effluents. **(2 points)**

This criteria shall not apply to projects that have waste water generation on site less than 10 kL/day

Optional Clause

Treated water should meet the disposal/reuse application standards **(2 points).**
Responsibility: Project Manager and Plumbing Consultant

Criterion 21: WATER RECYCLE AND REUSE (including rainwater)

Commitment

Provide on-site waste water treatment for achieving prescribed concentration, rainwater harvesting, reuse of treated waste water and rainwater for meeting the building's water and irrigation demands.

(5 points)

Non applicability condition proposed: The first three appraisal points shall not apply to projects that have waste water generation on site less than 10 kL/day and the fourth and fifth appraisal points shall not apply to projects in which the ground water table is high and recharge of rain water into ground is not advisable as per Central Ground Water Board norms.

Mandatory clause (if applicable)

Details of filtration system to show that adequate preventative measures are being taken to avoid contamination of aquifer by the recharged rainwater **(mandatory).**
Responsibility: Water Consultant and Plumbing Consultant

Optional clause

Annual water reuse of 25%, as per clause 21.2.5 **(1 point)**
Responsibility: Water Consultant and Plumbing Consultant

Annual water reuse of 50%, as per clause 21.2.5 **(additional 1 point).**
Responsibility: Water Consultant and Plumbing Consultant

Annual water reuse of 75%, as per clause 21.2.5 **(additional 1 point).**
Responsibility: Water Consultant and Plumbing Consultant

Recharge of surplus rainwater into aquifer, as per Table 21.2 of GRIHA **(2 points).**
Responsibility: Water Consultant and Plumbing Consultant

Waste management

Objective

To minimize waste generation; streamline waste segregation, storage, and disposal; and promote resource recovery from waste.

Criterion 22: REDUCTION IN WASTE DURING CONSTRUCTION

Commitment

Ensure maximum resource recovery and safe disposal of wastes generated during construction and reduce the burden on landfill. **(1 point)**

Optional clause

Segregation of inert and hazardous wastes, as per GRIHA

Responsibility: Architect and Project Manager

and

Recycling and safe disposal of segregated wastes, as per GRIHA **(1 point).**
Responsibility: Architect and Project Manager

Criterion 23: EFFICIENT WASTE SEGREGATION

Commitment

Use different coloured bins for collecting different categories of waste from the building. **(1 point)**

Optional clause

Provision of multi-coloured bins for waste segregation at source **(1 point).**
Responsibility: Architect and Project Manager

Criterion 24: STORAGE AND DISPOSAL OF WASTES

Commitment

Allocate separate space for the collected waste before transferring it to the recycling/disposal stations.

(1 point)

Non applicability condition proposed: This criteria shall not apply to projects that have organic solid waste generation on site less than 100 kg/day

Optional clause

Provision of space for hygienic storage of segregated waste, as per GRIHA **(1 point).**
Responsibility: Architect and Project Manager

Criterion 25: RESOURCE RECOVERY FROM WASTE

Commitment

Employ resource recovery systems for biodegradable waste as per the *Solid Waste Management and Handling Rules, 2000 of the MoEF*. Make arrangements for recycling of waste through local dealers. **(2 points)**

Optional clause

Zero waste generation through appropriate resource recovery measures as per GRIHA **(2 points).**
Responsibility: Project Manager

Health and well-being

Objective

To ensure healthy indoor air quality, water quality, and noise levels, and to reduce the global warming potential.

Criterion 26: USE LOW-VOC PAINTS/ADHESIVES/SEALANTS

Commitment

Use only low VOC paints in the interior of the building. Use water–based rather than solvent-based sealants and adhesives. (**3 points)**

Optional clause

Zero/low-VOC paints: Zero/low-VOC paints for 100% of all paint used in the interior of the building as per GRIHA **(1 point)**,
Responsibility: Architect and Project Manager

Low-VOC sealants and adhesives: 100% of all the sealants and adhesives used are water based rather than solvent oil based/low in oil solvent content, as per GRIHA **(1 point).**
Responsibility: Architect and Project Manager

100% of composite wood products with no urea–formaldehyde resins, as per GRIHA **(1 point).**
Responsibility: Architect and Project Manager

Criterion 27: MINIMIZE OZONE DEPLETING SUBSTANCES

Commitment

Employ 100% zero ODP (ozone depletion potential) insulation, HCFC (hydrochloro-fluorocarbon)/ and CFC (chlorofluorocarbon), free HVAC, and refrigeration equipment/and halon-free fire suppression and fire extinguishing systems. (**1 point)**

Mandatory clause

All the insulation used in building is chloro fluoro carbon (CFCs) and hydro chloro fluoro carbon

(HCFCs) free, as per GRIHA
Responsibility: Mechanical Consultant and Architect

and

All the HVAC and refrigeration equipment are CFCs free, as per GRIHA**.**
Responsibility: Mechanical Consultant

and

The fire suppression systems and fire extinguishers installed in the building are free of halon, as per GRIHA **(1 point).**
Responsibility: Mechanical Consultant, Electrical Consultant, and Plumbing Consultant

Criterion 28: ENSURE WATER QUALITY

Commitment

Ensure water from all sources (such as groundwater, municipal water, treated wastewater)meets the water quality norms as prescribed in the Indian Standards for various applications (Indian

Standards for drinking [IS 10500-1991], irrigation applications [IS 11624-1986]), cooling towers (as given in NBC 2005). In case the water quality cannot be ensured, provide necessary treatment of raw water for achieving the desired concentration for various applications. **(2 points)**

Mandatory clause

Water quality conforming to IS standards, as per GRIHA **(2 points).**
Responsibility: Plumbing Consultant & Project Manager

Criterion 29: ACCEPTABLE OUTDOOR AND INDOOR NOISE LEVELS

Commitment

Ensure outdoor noise level conforms to the CPCB (Central Pollution Control Board)– Environmental

Standards–Noise (ambient standards) and indoor noise level conforms to the *NBC (National Building Code of India) 2005* (BIS 2005a). **(2 points)**

Optional clause

The outdoor noise levels are within the acceptable limits as set in Central Pollution Control Board (CPCB). Environmental Standards–Noise (ambient standards), as per GRIHA **(1 point).**
Responsibility: Project Manager

The indoor noise levels are within the acceptable limits as set in NBC 2005 (BIS 2005a), as per GRIHA **(1 point).**
Responsibility: Architect

Criterion 30: TOBACCO SMOKE CONTROL

Commitment

Zero exposure to tobacco smoke for non-smokers, and exclusive ventilation for smoking rooms.

(1 point)

Mandatory clause

The company policy for ban/prohibition of smoking within the building premises, a signed template by HVAC/ Architect consultant certifying that all compliances are met **(1 point)**
Responsibility: Mechanical consultant/Architect

Criterion 31: PROVIDE AT LEAST THE MINIMUM LEVEL OF ACCESSIBILITY FOR PERSONS WITH DISABILITIES

Commitment

To ensure accessibility and usability of the building and its facilities by employees, visitors, and clients with disabilities **(1 point)**

Optional clause

Compliance with National Building Code norms on requirements for planning of public buildings meant for use of physically challenged, as per GRIHA **(1 point).**

Responsibility: Project Manager and Architect

Building operation and maintenance

Criterion 32: ENERGY AUDIT AND VALIDATION

Commitment

Energy audit report to be prepared by approved auditors of the Bureau of Energy Efficiency (BEE), Government of India. **(0 point)**

Mandatory clause

Energy audit report by an energy auditor approved by the BEE, Government of India.
Responsibility: Project Manager

Criterion 33: OPERATION AND MAINTENANCE

Commitment

Validate and maintain 'green' performance levels/adopt and propagate green practices and concepts.

Ensure the inclusion of a specific clause in the contract document for the commissioning of all electrical and mechanical systems to be maintained by the owner, supplier or operator. Provide a core facility/service management group, if applicable, which will be responsible for the O&M of the building and the electrical and mechanical systems after commissioning. Owner/builder/ occupants/service or facility management group to prepare a fully documented operations and maintenance manual, CD, multimedia or an information brochure listing the best practices/dos and don'ts/maintenance requirements for the building and the electrical and mechanical systems along with the names and addresses of the manufacturers/suppliers of the respective system. **(2 points)**

Mandatory clause

Appendage of specific clause in the contract document for the commissioning of all electrical and mechanical systems to be maintained by the owner, supplier or operator, as per compliance clauses in GRIHA document. Provision of a core facility/service management group, if applicable, or the owners or occupants themselves (in the case of single owner commercial buildings) undertaking the

responsibility for O&M of the building, documentation of the O&M best practices for the building's electrical and mechanical systems. **(2 points)**

Responsibility: Project Manager

Innovation points

Criterion 34: INNOVATION POINTS

Commitment

Four innovation points are available under the rating system for adopting criteria which enhances the green intent of a project, and one can apply for the innovation points. Some of the probable points are as follows.

alternative transportation

environmental education

company policy on green supply chain

life cycle cost analysis

any other criteria proposed by applicant

Subject Code **18SE2T1**	**FINITE ELEMENT METHOD**

UNIT I Introduction: Review of stiffness method- Principle of Stationary potential energy- Potential energy of an elastic body- Rayleigh-Ritz method of functional approximation – variational approaches -weighted residual methods

UNIT II Finite Element formulation of truss element: Stiffness matrix- properties of stiffness matrix – Selection of approximate displacement functions-solution of a plane truss- transformation matrix and stiffness matrix for a 3-D truss- Inclined and skewed supports- Galerkin's method for 1-D truss – Computation of stress in a truss element.

UNIT III Finite element formulation of Beam elements: Beam stiffness-assemblage of beam stiffness matrix- Examples of beam analysis for concentrated and distributed loading- Galerkin's method - 2-D Arbitrarily oriented beam element – inclined and skewed supports – rigid plane frame examples

UNIT IV Finite element formulation for plane stress, plane strain and axisymmetric problems- Derivation of CST and LST stiffness matrix and equations-treatment of body and surface forces- Finite Element solution for plane stress and axisymmetric problems- comparison of CST and LST elements –convergence of solution- interpretation of stresses.

UNIT V Iso-parametric Formulation: An isoparametric bar element- plane bilinear isoparametric element – quadratic plane element - shape functions, evaluation of stiffness matrix, consistent nodal load vector - Gauss quadrature- appropriate order of quadrature – element and mesh instabilities – spurious zero energy modes, stress computation- patch test.

REFERENCES:

1. Concepts and applications of Finite Element Analysis – Robert D. Cook, Michael E Plesha, John Wiley & sons Publications
2. A first course in the Finite Element Method – Daryl L. Logan, Thomson Publications.
3. Introduction to Finite Elements in Engineering- Tirupati R. Chandrupatla, Ashok D. Belgunda, PHI publications.

Subject Code **18SE2T2**	**EARTHQUAKE RESISTANT DESIGN**

UNIT I Engineering seismology – rebound theory – plate tectonics – seismic waves - earthquake size and various scales – local site effects – Indian seismicity – seismic zones of India – theory of vibrations – near ground and far ground rotation and their effects.

UNIT II Seismic design concepts – EQ load on simple building – load path – floor and roof diaphragms – seismic resistant building architecture – plan configuration – vertical configuration – pounding effects – mass and stiffness irregularities – torsion in structural system- Provision of seismic code (IS 1893 & 13920) – Building system – frames – shear wall – braced frames – layout design of Moment Resisting Frames(MRF) – ductility of MRF – Infill wall – Nonstructural elements.

UNIT III Calculation of EQ load – 3D modeling of building systems and analysis (theory only) Design and ductile detailing of Beams and columns of frames Concept of strong column weak beams, Design and ductile detailing of shear walls

UNIT IV Cyclic loading behavior of RC, steel and pre- stressed concrete elements - modern concepts- Base isolation – Adaptive systems – case studies.

UNIT V Retrofitting and restoration of buildings subjected to damage due to earthquakes- effects of earthquakes – factors related to building damages due to earthquake- methods of seismic retrofitting- restoration of buildings

REFERENCES

1. Pankaj Agarwal and Manish ShriKhande, Earthquake Resistant Design of Structures, Prentice – Hall of India, 2007, New Delhi.
2. Bullen K.E., Introduction to the Theory of Seismology, Great Britain at the University Printing houses, Cambridge University Press 1996.
3. Relevant code of practices.

Subject Code **18SE2T3**	**STABILITY OF STRUCTURES**

UNIT I Beam columns: Differential equation for beam columns – Beams column with concentrated loads – continuous lateral load – couples – Beam column with built in ends – continuous beams with axial load – application of Trigonometric series – Determination of allowable stresses.

UNIT II Elastic buckling of bars : Elastic buckling of straight columns – Effect of shear stress on buckling – Eccentrically and laterally loaded columns –Sway & Non Sway mode – Energy methods – Buckling of a bar on elastic foundation – Buckling of bar with intermediate compressive forces and distributed axial loads – Buckling of bars with change in cross section – Effect of shear force on critical load – Built up columns – Effect of Initial curvature on bars – Buckling of frames – Sway & Non Sway mode.

UNIT III In-elastic buckling: Buckling of straight bars – Double modulus theory Tangent modulus theory. Experiments and design formulae: Experiments on columns – Critical stress diagram – Empirical formulae of design – various end conditions – Design of columns based on buckling. Mathematical Treatment of stability problems: Buckling problem orthogonality relation – Ritz method –Stiffness method and formulation of Geometric stiffness matrix- Applications to simple frames

UNIT IV Torsional Buckling: Pure torsion of thin walled bars of open cross section – Non uniform torsion of thin walled bars of open cross section - Torsional buckling – Buckling of Torsion and Flexure.

UNIT V Lateral Buckling of simply supported Beams: Beams of rectangular cross section subjected for pure bending, Buckling of I Section subjected to pure bending.

REFERENCES:

1. Theory of Elastic stability by Timshenko & Gere-Mc Graw Hill
2. Theory of Stability of Structures by Alexander ChaJes.

Subject Code **18SE2T4**	**THEORY OF PLATES AND SHELLS**

UNIT I Derivation of governing differential equation for plate– in plane bending and transverse bending effects- Rectangular plates: Plates under various loading conditions like concentrated, uniformly distributed load and hydrostatic pressure. Navier and Levy's type of solutions for various boundary condition.

UNIT II Circular plates: Symmetrically loaded, circular plates under various loading conditions, Annular plates.

UNIT III Introduction to Shells- Single and double curvature- Equations of Equilibrium of Shells: Derivation of stress resultants, Principles of membrane theory and bending theory.

UNIT IV Cylindrical Shells: Derivation of the governing DKJ equation for bending theory, details of Schorer's theory. Application to the analysis and design of short and long shells. Use of ASCE Manual coefficients for the design.

UNIT V Beam theory of cylindrical shells: Beam and arch action. Design of diaphragms – Geometry analysis and design of elliptic Paraboloid, Conoidal and Hyperbolic Paraboloid shapes by membrane theory.

REFERENCES:

1. Theory of Plates and Shells – Timoshenko and Krieger, McGraw-Hill book company, INC, New york.
2. K. Chandra Sekhara
3. A Text Book of Plate Analysis – Bairagi, K, Khanna Publisher, New Delhi.
4. Design and Construction of Concrete Shell Roofs – Ramaswamy, G.S, Mc Graw – Hill, New York.

Subject Code **18SE2T5A**	**PRESTRESSED CONCRETE (ELECTIVE –III)**

UNIT I General principles of Pre-stressing- Pre-tensioning and Post tensioning - Pre tensioning and Post tensioning methods- Different systems of Pre-stressing- Analysis of prestress and Bending stresses– Resultant – stress at a section – pressure line – concept of load balancing – stresses in tendons.

UNIT II Losses of Pre-stressing- Loss of Pre-stress in pre-tensioned and post tensioned members due to various causes -Elastic shortening of concrete, shrinkage of concrete, creep of concrete, Relaxation of steel, slip in anchorage, differential shrinkage- bending of members and frictional losses- Long term losses

UNIT III Flexural, shear; torsional resistance and design of Prestressed concrete section. Types of flexural failure – code procedures-shear and principal stresses – Prestressed concrete members in torsion – Design of sections for flexure, Axial Tension, Compression and bending, shear, Bond

UNIT IV Analysis of continuous beams –Elastic theory- Linear transformation and Concordant tendons- Deflections of pre-stressed concrete beams: Importance of control of deflections-factors influencing deflections-short term deflections of un-cracked member – prediction of long term deflections

UNIT V Analysis of end blocks: By Guyon's method and Magnel's method, Anchorage zone stresses- Approximate method of design- anchorage zone reinforcement- transfer of pre stresses- pre tensioned members-Composite sections: Introduction-Analysis for stresses-differential shrinkage- general design considerations

REFERENCES:

1. Prestressed Concrete- N. Krishna Raju
2. Prestressed Concrete- S. Ramamrutham
3. Prestressed Concrete- P. Dayaratnam
4. Prestressed Concrete- T.Y.Lin

Subject Code **18SE2T5B**	**MECHANICS OF COMPOSITE MATERIALS (ELECTIVE –III)**

UNIT I Introduction to Composite Materials: Introduction ,Classification: Polymer Matrix Composites, Metal Matrix Composites, Ceramic Matrix Composites, Carbon–Carbon Composites, Fiber-Reinforced Composites and nature-made composites, and application- **Reinforcements:** Fibres- Glass, Silica, Kevlar, carbon, boron, silicon carbide, and born carbide fibres. Particulate composites, Polymer composites, Thermoplastics, Thermosetts, Metal matrix and ceramic composites.**-Manufacturing methods:** Autoclave, tape production, moulding methods, filament winding, man layup, pultrusion, RTM.

UNIT II Macromechanical Analysis of a Lamina: Introduction, Definitions: Stress, Strain, Elastic Moduli, Strain Energy. Hooke's Law for Different Types of Materials, Hooke's Law for a Two-Dimensional Unidirectional Lamina, Plane Stress Assumption, Reduction of Hooke's Law in Three Dimensions to Two Dimensions, Relationship of Compliance and Stiffness Matrix to Engineering Elastic Constants of a Lamina,

UNIT III Hooke's Law for a Two-Dimensional Angle Lamina, Engineering Constants of an Angle Lamina, Invariant Form of Stiffness and Compliance Matrices for an Angle Lamina Strength Failure Theories of an Angle Lamina : Maximum Stress Failure Theory Strength Ratio, Failure Envelopes, Maximum Strain Failure Theory ,Tsai–Hill Failure Theory, Tsai–Wu Failure Theory, Comparison of Experimental Results with Failure Theories. Hygrothermal Stresses and Strains in a Lamina: Hygrothermal Stress–Strain Relationships for a Unidirectional Lamina, Hygrothermal Stress–Strain Relationships for an Angle Lamina

UNIT IV Micromechanical Analysis of a Lamina :Introduction, Volume and Mass Fractions, Density, and Void Content, Evaluation of the Four Elastic Moduli, Strength of Materials Approach, Semi-Empirical Models, Elasticity Approach, Elastic Moduli of Lamina with Transversely Isotropic Fibers, Ultimate Strengths of a Unidirectional Lamina, Coefficients of Thermal Expansion, Coefficients of Moisture Expansion.

UNIT V Macromechanical Analysis of Laminates: Introduction , Laminate Code , Stress–Strain Relations for a Laminate, In-Plane and Flexural Modulus of a Laminate , Hygrothermal Effects in a Laminate, Warpage of Laminates -**Failure, Analysis, and Design of Laminates** : Introduction, Special Cases of Laminates, Failure Criterion for a Laminate, Design of a Laminated Composite

TEXT BOOKS:

1. Engineering Mechanics of Composite Materials by Isaac and M Daniel, Oxford University Press, 1994.
2. B. D. Agarwal and L. J. Broutman, Analysis and performance of fibre Composites, Wiley-Interscience, New York, 1980.
3. Mechanics of Composite Materials, Second Edition (Mechanical Engineering), By Autar K.Kaw, Publisher: CRC

Subject Code **18SE2T5C**	**FRACTURE MECHANICS (ELECTIVE –III)**

UNIT I Introduction: Fundamentals of elastic and plastic behaviour of materials- stresses in a plate with a hole – Stress Concentration factor-modes of failure- Brittle fracture and ductile fracture history of fracture mechanics-Griffiths criteria for crack propagation cracks- Energy release rate, GI GII and GIII - Critical energy release rate GIc , GIIc and GIIIc – surface energy – R curves – compliance.

UNIT II Principles of Linear Elastic Fracture Mechanics: SOM vs Fracture Mechanics -stressed based Criteria for fracture- Stress Intensity Factors- KI K II and K III – Critical stress Intensity Factors, KIc KIIc and KIIc – crack tip plastic zone – Erwin's plastic zone correction –Critical crack length-Load carrying capacity of a cracked component- Design of components based on fracture mechanics.

UNIT III Mixed mode crack propagation- Maximum tangential stress criterion – crack propagation angle - Material characterisation by Crack Tip Opening Displacements (CTOD)- Crack Mouth Opening Displacement (CMOD)- Critical crack tip opening displacement (CTODc) – critical Crack Mouth Opening Displacement (CMODc).

UNIT IV Fatigue Crack propagation- Fatigue load parameters Fatigue crack growth curve – Threshold stress intensity factor-Paris law- Retardation effects.

UNIT V Applications of fracture Mechanics to concrete- reasons –strain softening behaviour – Bazant's size effect law.

REFERENCES

1. Elementary engineering fracture mechanics – David Broek – Sijthoff & Noordhoff – Netherlands.
1. Elements of Fracture Mechanics – Prasanth Kumar, wiley Eastern Publications
2. Fracture Mechanics: Fundamentals and applications – T. L. Andrason, PhD, CRC publications
3. Fracture Mechanics of Concrete: Applications of fracture mechanics to concrete, Rock, and other quasi-brittle materials, Surendra P. Shah, Stuart E. Swartz, Chengsheng Ouyang, John Wiley & Son publications.

Subject Code **18SE2T6A**	**INDUSTRIAL STRUCTURES (ELECTIVE –IV)**

UNIT I Planning and functional requirements- classification of industries and industrial structures planning for layout- requirements regarding lighting ventilation and fire safety- protection against noise and vibrations

UNIT II Industrial buildings- roofs for industrial buildings (Steel) - design of gantry girder- design of corbels and nibs- machine foundations

UNIT III Design of Folded plates- Design considerations- analysis of folded plates- analysis of multibay folded plates- design of diaphragm beam

UNIT IV Power plant structures- Bunkers and silos- chimney and cooling towers-Nuclear containment structures

UNIT V Power transmission structures- transmission line towers- tower foundations- testing towers

REFERENCES:

1. Advanced reinforced concrete design- N. Krishnam Raju
2. Handbook on machine foundations- P. Srinivasulu and C.V. Vaidyanathan
3. Tall Chimneys- Design and construction – S.N. Manohar
4. Transmission Line Structures- A.R. Santakumar and S.S. Murthy
5. SP 32: 1986, Handbook on functional requirements of Industrial buildings
6. Design of shells- K. Chandrasekhara

Subject Code **18SE2T6B**	**BRIDGE ENGINEERING (ELECTIVE –IV)**

UNIT I Masonry arch Bridge design details- Rise, radius, and thickness of arch- Arch ring- Dimensioning of sub structures- Abutments pier and end connections.(Ref: IRC- SP-13)

UNIT II Super Structure: Slab bridge- Wheel load on slab- effective width method- slabs supported on two edges- cantilever slabs- dispersion length- Design of interior panel of slab- Pigeaud's method- design of longitudinal girders- Guyon-Messonet method- Hendry Jaegar method- Courbon's theory. (Ref: IRC-21), voided slabs, T-Beam bridges.

UNIT III Plate girder bridges- Elements of plate girder and their design-web-flange-intermediate stiffener- vertical stiffeners- bearing stiffener-design problem

UNIT IV Prestressed Concrete and Composite bridges- Preliminary dimensions-flexural and torsional parameters- Courbon's Theory – Distribution coefficients by exact analysis- design of girder section- maximum and minimum prestressing forces- eccentricity- live load and dead load shear forces- cable zone in girder- check for stresses at various sections- check for diagonal tension- diaphragms and end block design- short term and long term deflections- Composite action of composite brides- shear connectors- composite or transformed section-design problem. (Ref: IRC: Section-VI)

UNIT V Sub structure- Abutments- Stability analysis of abutments- piers- loads on piers – Analysis of piers- Design problem(Ref: IRC-13, IRC-21, IRC-78)- Pipe culvert- Flow pattern in pipe culvers- culvert alignment-culvert entrance structure- Hydraulic design and structural design of pipe culverts- reinforcements in pipes .(Ref: IRC: SP-13)

REFERENCES:

1. Design of concrete bridges- Aswini, Vazirani, Ratwani
2. Essentials of bridge engineering- Jhonson Victor D
3. Design of bridges- Krishna Raju

Subject Code **18SE2T6C**	**EARTH RETAINING STRUCTURES (ELECTIVE –IV)**

UNIT I Earth pressures – Different types and their coefficients- Classical Theories of Earth pressure – Rankine's and Coulomb's Theories for Active and Passive earth pressure- Computation of Lateral Earth Pressure in Homogeneous and Layered soils- Graphical solutions for Coulomb's Theory in active and passive conditions.

UNIT II Retaining walls – different types - Type of Failures of Retaining Walls – Stability requirements – Drainage behind Retaining walls – Provision of Joints – Relief Shells.

UNIT III Sheet Pile Structures – Types of Sheet piles – Cantilever sheet piles in sands and clays – Anchored sheet piles – Free earth and Fixed earth support methods – Row's moment reduction method – Location of anchors, Forces in anchors.

UNIT IV Soil reinforcement – Reinforced earth - Different components – their functions – Mechanics of reinforced earth – Failure modes-Failure theories – Design of Embakments on problematic soils.

UNIT V Braced cuts and Cofferdams: Lateral Pressure in Braced cuts – Design of Various Components of a Braced cut – Stability of Braced cuts – Bottom Heave in cuts. – types of cofferdam, suitability, merits and demerits – Design of single – wall cofferdams and their stability aspects – TVA method and Cummins' methods.

REFERENCES

1. Principles of Foundation Engineering by Braja M. Das.
2. Foundation analysis and design – Bowles, JE – McGraw Hill
3. Soil Mechanics in Engineering Practice – Terzaghi, K and Rolph, B. peck 2nd Edn. – John Wiley & Co.,
4. Analysis and Design of Foundations and Retaining Structures, Prakash, S – Saritha Prakashan, Mearut.

Subject Code **18SE2L1**	**CAD & GIS LABORATORY**

Analysis and Design using STADD, STRAP, STRUDS, ANSYS
CADD SOFTWARE:
1. STAAD PRO / Equivalent/
2. STRAAP
3. STUDDS

EXCERCISES IN CADD:
1. Programming for beams subject to different loading (mandatory).
2. Analysis of reinforced concrete multistoried building
3. Analysis of steel transmission line tower
4. Analysis of plane and space truss
5. Analysis of plane and space frame
6. Wind analysis on tall structure
7. Modal Analysis of a Cantilever Beam

GIS SOFTWARES:
1. Arc GIS 9.0
2. ERDAS 8.7
3. Mapinfo 6.5

EXCERCISES IN GIS:
1. Digitization of Map/Toposheet
2. Creation of thematic maps.
3. Estimation of features and interpretation
4. Developing Digital Elevation model
5. Simple applications of GIS in water Resources Engineering & Transportation Engineering.

NOTE: A minimum of eight (including item 1) from the above set have to be conducted.

REFERENCE:
Computer aided design laboratory (Civil Engineering) by Shesha Prakash and Suresh.S