**SYLLABUS**

**FOR**

**TWO-YEAR M. TECH. PROGRAMME**

**IN**

**GEOTECHNICAL ENGINEERING**



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| **NAAC – A Grade** |

**DEPARTMENT OF CIVIL ENGINEERING**

**COLLEGE OF ENGINEERING & TECHNOLOGY**

**(An Autonomous and Constituent College of BPUT, Odisha)**

**Techno Campus, Mahalaxmi Vihar, Ghatikia,**

**Bhubaneswar-751029, Odisha, INDIA**

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**COURSE: M. Tech. (CE - Geotechnical Engineering), Duration: 2 years (Four Semesters)**

**Abbreviations Used: U= UG, I= Integrated, P= PG**

**PC= Professional Core PE= Professional Elective OE= Open Elective**

**LC= Lab Course MC= Mandatory Course AC= Audit Course**

**L= Lectures P= Practical/Laboratory IA\*= Internal Assessment**

**T= Tutorial PA= Practical Assessment EA=End-Semester Assessment**

**\*Internal Assessment Max. Mark (30 marks) consists of Mid Semester (20 marks) and Quiz+Assignment (10 marks)**

**Subject Code Format:**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| **Prog (U/I/P)** | **Type (PC/PE/OE/LC/MC/AC)** | | **Department (CE/EE/IE/ME/…)** | | **Semester (1/2/…/0)** | **Serial No. (1/2/3/…/99)** | |

**1st SEMESTER**

|  |  |  |  |  |  |  |  |  |  |  |  |
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| **Sl. No.** | **Subject**  **Type** | **Subject Code** | **Subject**  **Name** | **Teaching Hours** | | | **Credit** | **Maximum Marks** | | | |
| **L** | **T** | **P** | **IA** | **EA** | **PA** | **Total** |
| 1 | Core 1 | PPCCE103 | Advanced Geo-mechanics | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| 2 | Core 2 | PPCCE104 | Ground Improvement Techniques | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| 3 | Professional Elective 1  (Any One) | PPECE104 | Advanced Numerical Methods | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| PPECE106 | Optimization Methods and its Application in Civil Engineering |
| PPECE107 | Theory of Elasticity and Plasticity |
| 4 | Professional Elective 2 | PPECE108 | Earth Retaining Structures | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| PPECE109 | Transportation Geo-technics |
| PPECE110 | Rock Mechanics |
| 5 | Mandatory | PMCMH101 | Research Methodology & IPR | 2 | 0 | 0 | 2 | 30 | 70 | - | 100 |
| 6 | Lab 1 | PLCCE103 | Geotechnical Engineering Lab | 0 | 0 | 4 | 2 | - | - | 100 | 100 |
| 7 | Lab 2 | PLCCE104 | Computational Geo-techniques Lab | 0 | 0 | 4 | 2 | - | - | 100 | 100 |
| **Total** | | | | **14** | **0** | **8** | **18** | **150** | **350** | **200** | **700** |
| 8 | Audit 1 | Any one subject from Appendix-I | | | | | | | | | 100 |
| **Grand Total** | | | | | | | | | | | **800** |

**2nd SEMESTER**

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| **Sl. No.** | **Subject**  **Type** | **Subject Code** | **Subject**  **Name** | **Teaching Hours** | | | **Credit** | **Maximum Marks** | | | |
| **L** | **T** | **P** | **IA** | **EA** | **PA** | **Total** |
| 1 | Core 3 | PPCCE203 | Advanced Foundation Engineering | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| 2 | Core 4 | PPCCE204 | Dynamics of Soils and Foundation | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| 3 | Professional Elective 3  (Any One) | PPECE206 | Soil Structure Interaction | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| PPECE207 | Subsoil Exploration & Soil Testing |
| PPECE208 | Geo-environmental Engineering |
| 4 | Professional Elective 4  (Any One) | PPECE209 | Finite Elements in Geo-mechanics | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| PPECE210 | Geo-synthetics and Reinforced Soil Structures |
| PPECE211 | Offshore Geo-mechanics |
| 5 | Practical 1 | PPRCE201 | Minor Project & Seminar | 0 | 0 | 4 | 2 | - | - | 100 | 100 |
| 6 | Lab 3 | PLCCE203 | Advanced Geo-tech Engg Lab | 0 | 0 | 4 | 2 | - | - | 100 | 100 |
| 7 | Lab 4 | PLCCE204 | Geo-technical Engg Design Practice | 0 | 0 | 4 | 2 | - | - | 100 | 100 |
| **Total** | | | | **12** | **0** | **12** | **18** | **120** | **280** | **300** | **700** |
| 8 | Audit 2 | Any one subject from Appendix-II | | | | | | | | | 100 |
| **Grand Total** | | | | | | | | | | | **800** |

**3rdSEMESTER**

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| **Sl. No.** | **Subject Type** | **Subject Code** | **Subject**  **Name** | **Teaching Hours** | | | **Credit** | **Maximum Marks** | | | |
| **L** | **T** | **P** | **IA** | **EA** | **PA** | **Total** |
| 1 | Professional  Elective 5  (Any One) | PPECE304 | Ground Water and Flow through Porous Media | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| PPECE305 | Geotechnical Earthquake Engineering |
| PPECE306 | Stability analysis of Slopes, Embankments and Dams |
| 2 | Open Elective | Any one subject from Appendix-III | | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| 3 | Project 1 | PPRCE301 | Phase-I Dissertation | 0 | 0 | 20 | 10 | - | - | 100 | 100 |
| **Total** | | | | **6** | **0** | **20** | **16** | **60** | **140** | **100** | **300** |

**4thSEMESTER**

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| **Sl. No.** | **Subject**  **Type** | **Subject Code** | **Subject**  **Name** | **Teaching Hours** | | | **Credit** | **Maximum Marks** | | | |
| **L** | **T** | **P** | **IA** | **EA** | **PA** | **Total** |
| 1 | Project 2 | PPRCE401 | Phase-II Dissertation | 0 | 0 | 32 | 16 | - | - | 100 | 100 |
| **Total** | | | | **0** | **0** | **32** | **16** | **-** | **-** | **100** | **100** |

**Abstract of Credit and Marks Distribution**

|  |  |  |  |
| --- | --- | --- | --- |
| **Sl. No.** | **Semester** | **Maximum Credits** | **Maximum Marks** |
| 1 | 1st Semester | 18 | 800 |
| 2 | 2nd Semester | 18 | 800 |
| 3 | 3rd Semester | 16 | 300 |
| 4 | 4th Semester | 16 | 100 |
| **Total** | | **68** | **2000** |

**NB:**

* **Any one of the Courses in Appendix-I is to be Decided by the Concerned Department for Audit-1 (1st Sem)**
* **Any one of the Courses in Appendix-II is to be Decided by the Concerned Department for Audit-2 (2nd Sem)**
* **Any one of the Courses in Appendix-III is to be Decided by the Concerned Department for Open Elective (3rd Sem)**

**Semester-1**

Core 1: Advanced Geo-mechanics (PPCCE103)

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| **COURSE OBJECTIVE:**   1. To go deeper into various aspects of soil mechanics and to gain practical knowledge of geotechnical engineering. 2. To understand each topic in logical progression with reference to recent developments in geotechnical engineering. 3. To develop understanding in geology, genesis of soil formation, soil compaction, consolidation and shear strength of soil. 4. To understand the stress strain relationship of sand and clay with reference to critical soil mechanics, constitutive relationship and failure theories.   **COURSE CONTENTS:**  **Module I**  Soils, rocks and groundwater*:* Geology and genesis of soils and Soil formation- Types of soils and their characteristics; Particle sizes and shapes, their impact on engineering properties, Soil-air-water interaction; Concept of effective stress principle of effective stress, indices and phase relationships, soil-water behaviour.  Compressibility of soils: consolidation theory (one, two, and three-dimensional consolidation theories), consolidation in layered soil and consolidation for time dependent loading, determination of coefficient of consolidation (Casagrande method and Taylors method)  **Module II**  Strength behavior of soils; Mohr Circle of Stress; UU, CU, CD tests, drained and undrained behavior of sand and clay, significance of pore pressure parameters; determination of shear strength of soil; Interpretation of triaxial test results. Stress path; Drained and undrained stress path; Stress path with respect to different initial state of the soil; Stress path for different practical situations.  **Module III**  Theories Of failure: Critical state soil mechanics; Critical state parameters; Critical state for normally consolidated and over consolidated soil; Significance of Roscoe and Hvorslev state boundary surface; drained and undrained plane. critical void ratio; effect of dilation in sands; different dilation models. Elastic and plastic deformations: elastic wall; introduction to yielding and hardening; yield curve and yield surface, associated and non-associated flow rule.  **Text Books**  1.B M Das, Advanced Soil Mechanics, Taylor and Francis  **References Books:**   1. Wood, D.M., Soil Behaviour and Critical State Soil Mechanics, Cambridge University Press, 1991. 2. Bolton, M.D., A Guide to Soil Mechanics, Cambridge University Press, 1991. 3. Salgado, R., The Engineering of Foundations, McGraw Hill, 2008. 4. Atkinson, ‘Critical State Soil Mechanics’ 5. McCarthy D.F., Essentials of Soil Mechanics & Foundations, Prentice-Hall, 2002.   COURSE OUTCOME:   1. Ability to understand various aspects of soil mechanics and to gain practical knowledge of geotechnical engineering. 2. Ability to understand the compressibility of soils and strength behavior of soil. 3. Ability to understand the various theories of failure and critical state. |

**Core 2: Ground Improvement Techniques (PPCCE104)**

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| **COURSE OBJECTIVES:**  1.To know about Necessity of ground improvement  2. To explain the various methods of ground improvement technique.  3.To explain the Field compaction and its control.  4. To explain about soil stabilisation  5. To explain the Use of geo-synthetics and geo-cells in construction work**.**  **COURSE CONTENTS:**  **Module – I**  Introduction: Engineering properties of soft, weak and compressible deposits; Role of Ground Improvement in Foundation Engineering, Methods Of Ground Improvement: Selection of Suitable ground improvement techniques  **Module – II**  Mechanical Stabilization: Suitability of soil, blending of borrow materials, method of compaction, effect of compaction on various soil parameters, field compaction and its control  ChemicalStabilization: using lime, cement, bitumen, salt, disperse sand  In-place Stabilization Techniques: Vibro-Compaction, Blasting, Compaction Pile, Heavy Tamping, Dynamic Compaction, De-Watering, Preload and Consolidation, Electro-Osmosis, Thermal Stabilization, Grouting, Soil Nailing, Stone Columns, Chemical Columns  **Module – III**  Reinforced Soil: Mechanical Reinforced Material, Reinforced Soil Interaction, Geosynthetics, Principles, Analysis & Design of Reinforced Retaining Structure, Embankment & Slopes: Ground Improvement Techniques for Geotechnical Earthquake Engineering, Case Studies For GIT  **Text/Reference Books**   1. Hausmann, M.R., Engineering Principles of Ground Modification, McGraw-Hill International Editions, 1990. 2. Yonekura, R., Terashi, M. and Shibazaki, M. (Eds.), Grouting and Deep Mixing, A.A. Balkema, 1966. 3. Moseley, M.P., Ground Improvement, Blackie Academic & Professional, 1993. 4. Xanthakos, P.P., Abramson, L.W. and Bruce, D.A., Ground Control and Improvement, John Wiley & Sons, 1994. 5. Koerner, R. M., Designing with Geosynthetics, Prentice Hall Inc. 1998. 6. Shukla, S.K., Yin, Jian-Hua, “Fundamentals of Geosynthetic Engineering”, Taylor & Francis. 7. NV NAAYAK: Foundation Design Manual, Dhanpat Rai & Sons   **COURSE OUTCOMES:**  After completion of the course, the students will be able to:  1 Analyze and able to find various engineering properties of soil.  2 Analyze and design of dewatering systems  3 Analyze and design the Stone columns  4 Analyze and design the Reinforced earth |

**PE 1: Advanced Numerical Methods (PPECE104)**

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| **COURSE OBJECTIVES:**  1. To apply Computer oriented methods for solving numerical problems in science and engineering  2. To solve Numerically systems of simultaneous linear equations, nonlinear algebraic equations (root solving), differentiation and integration, ordinary differential equations, interpolation.  **Module I:**  *Introduction:* Introduction to numerical methods and analysis and computer programming; *Error Analysis:* Approximations; Round off and Truncation errors; Error Analysis. *Roots of Equations (single variable)*: Method of Bisection, Regula Falsi, Secant Method, Fixed point Method, Newton Raphson method, Multiple roots. Analysis and order of convergence. *Polynomials:* Mueller’s method, Bairstow’s method.  *Solution of Linear System of Equations*: Dense, Sparse and Banded systems, Direct Methods -Gauss Elimination, Gauss-Jordan, LU decomposition, Thomas Algorithm. Condition number of matrix, effect of round-off errors. Iterative improvement of solution by direct methods. Iterative methods: Jacobi and GaussSeidel iteration, rate of convergence of iterative methods. Successive over Relaxation. *Solution of Nonlinear System of Equations*: Iterative methods, Fixed Point iteration, Newton-Raphson method.  **Module II:**  *Approximation Theory*: Approximation of Continuous functions -basis functions, norms and semi-norms, inner product, formulation of least square problem, derivation of normal equations, orthogonal basis functions. TchebycheffandLegendre polynomials. Interpolating polynomials: Newton’s divided difference polynomial, Lagrange polynomials. Interpolation using spline functions: linear, quadratic and cubic splines. *Polynomial regression* of discrete data. Transformation of nonlinear problems to linear approximation problems. *Eigenvalues and Eigenvectors*: Power method, inverse power method. *Fadeev-Leverrier method* for formulation of the Characteristic polynomials, QR decomposition.  **Module III:**  *Numerical Differentiation:* Introduction to finite difference approximations, truncation error analysis. Finite difference approximations on irregular grid. Richardson’s extrapolation. *Numerical Integration*: Rectangular rule, Trapezoidal Rule and Simpson's rule. Local and global error analysis. Romberg Integartion. Gauss Quardrature, Improper Integrals. *ODE, Initial Value Problems*: Euler's method, improvement of Euler's method, Runge -Kutta Methods, MultiSteps Methods. Predictor Corrector Methods. *ODE, Boundary Value Problems*: Decomposition into Linear System of ODEs, Shooting Method, Direct Method. *Partial Differential Equations*: Elliptic, Parabolic and Hyperbolic Equations, Explicit and Implicit Methods, Crank Nicholson Method.  **References**   1. Jain M.K, SRK Iyenge and RK Jain.”Numerical Methods for Scientific &Engg. Computation”. 2. Mathews J. H “Numerical Methods for Mathematics, Science and Engineering”. 3. Gerald C.F and PO Wheatley “Applied Numerical Analysis”. 4. Gupta S.C and V. K. Kapoor “Fundamentals of Applied Statistic”, Sultan Chand &Sons. 5. Johnson R.A “Probability and Statistics for Engineers.” 6. Rajeshwaran S, “Numerical Methods in Science & Engineering (A Practical Approach)”, Willey Publication.   **COURSE OUTCOMES:**  After the completion of the course the students will be able to  **1:** Familiarize with finite precision computation, numerical solutions of nonlinear equations in a single variable.  **2:** Familiarize with numerical interpolation and approximation of functions, numerical integration and differentiation.  **3:** Familiarize with numerical solution of ordinary differential equations.  **4:** Familiarize with calculation and interpretation of errors in numerical methods |

**PE 1: Optimization Methods and its Applications in Civil Engineering (PPECE106)**

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| **COURSE OBJECTIVES:**  **Module I**  Introduction: Need for engineering optimal design, Optimum design formulation: Design variable, objective function and constraints;  Unconstrained optimization methods Single variable optimization methods: Region elimination method – Golden section search, Interval halving method; Gradient based method – Newton-Raphson, bisection and secant method. Multi variable optimization methods: Direct search method: Hooke-Jeeve pattern search, simplex reflection search, Powell’s conjugate direction search. Gradient Based methods: Cauchy’s steeped descent, Newton’s method, Levenberg-Marquardt’s method, Fletcher- Reeve method; Constrained optimization methods  **Module II**  Kuhn Tucker condition, Penalty function method, Augmented Lagrangian method, sequential unconstrained minimization, cutting plane method; Introduction to Evolutionary algorithms: Need for evolutionary algorithms, Type of evolutionary methods, Introduction to Genetic algorithm (GA), Difference and similarities between GA and traditional methods. Basic operations of GA: reproduction, crossover, mutation and elitism.  **Module III**  Binary coded and Real coded GA; Application of Optimization techniques: Water resource planning management, Structural Optimization, Transportation planning and Management, Slope stability and optimal dimensioning of foundations. multi-objective optimization models.  **Text/Reference Books**  1. J.S. Arora, *Introduction to Optimum Design*, Elsevier, 2nd Edition, 2004.  2. K. Deb, *Optimization for Engineering. Design: Algorithms & Examples*, Prentice Hall India, 2006  3. S.S. Rao, *Engineering Optimization: Theory & Practice,* New Age International (P) Ltd, 3rd Edition, 1996, Reprint: June, 2008  4. K. Deb, *Multi-Objective Optimization Using Evolutionary Algorithms*, John Wiley, 2003  **COURSE OUTCOMES:**  After the completion of the course the students will be able to |

**PE 1: Theory of Elasticity and Plasticity (PPECE107)**

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| **COURSE OBJECTIVES:**  1. To make the students understand the concepts of elasticity and equip them with the knowledge to independently handle the problems of elasticity.  2. To make the students understand the concepts behind bending of different types of beam.  3. To make the students understand the concepts Torsion of rectangular bars.  4. To understand the concepts of plasticity, yield criteria, plastic flow etc.,  **Module I**  Linear elasticity; stress, strain, constitutive relations, strain displacement relations, three dimensional stress and strain analysis, compatibility, stress and displacement functions.  **Module II**  Two dimensional problems in Cartesian and polar coordinates, description of an elasticity problem as a boundary value problem, bending of beams-cantilever and simply supported beam.  Torsion of rectangular bars including hollow sections, torsion of a circular and a rectangular section  **Module III**  Elements of plasticity, failure & yield criterion, Equations of plasticity, plastic stress-strain relations, flow rule, velocity field, slip lines and plastic flow, incremental plasticity.  **Text/Reference Books**  1. S.P.Timoshenko& J.N.Goodier,"Theory of Elasticity", McGraw Hill-1970.  2. M.Kachanov, "Theory of Plasticity", MIR Publication.  3. C.R.Calladine, "Plasticity for Engineers", Ellis Horwood, Chichester,U.K.,1985  **COURSE OUTCOMES:**  After the completion of the course the students will be able to  1. Able to solve the problems of 3-D elasticity with confidence.  2. Can independently work with the problems of 2-D & 3D elasticity in Cartesian/Polar Coordinates.  3. Familiarized with the use of airy’s stress function in 2-D & 3D problems of elasticity in Cartesian/Polar Coordinates.  4. Equipped with the knowledge of various theories of torsion of prismatic bars of various cross sections and can solve the problems of torsion. |

**PE 2: Earth Retaining Structures (PPECE108)**

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| **COURSE OBJECTIVE:**  1 To make students understand Pressures in soils  2 To provide brief explanation on Design of retaining walls  3. To explain in detail Design of sheet pile wall, shoring and bracing coffer dams  4. To explain in detail Design of earthen dam.  **Module I**  Earth pressure, introduction, earth pressure as a stability problem, concept of strain dependence of developed stresses, active, at rest and passive conditions, plastic equilibrium, various theories related with E.P. Distillation, Rankine, Coulomb and Hansen theoretical derivation and graphical construction with different geometric and boundary conditions.  **Module II**  Types of retaining walls. Gravity, Cantilever, Counter fort. Basement or foundation retaining walls. Design principles of retaining walls, abutments and wing walls; allowable bearing capacity settlement tilting. Safety against general slip failure.  Sheet pile and Cofferdam. Type, material, method of construction, distribution of earth pressure and related approximation. Distinction between Sheet Pile and Retaining wall, analysis and design; Deep Excavation and Braced -Cuts  **Module III**  Earth - structure - Definition features of an earth dam, stability analysis of slope, total - vs. - effective stress analysis. Stability of earth dams during different stages - during and at end of construction, steady seepage, and sudden draw down, estimation of pore water pressure - use of stability charts. Seismic Stability of Earth Retaining Structure  **Text/Reference Books**:  1. J.L.Sherard, R.J.Woodward, S.F.Gizienski, and W.A. Clevenger, Earth and Earth –Rock Dams Engineering Problems of Design and Construction, John Wiley and Sons, New York, 1963.  2. R F Craig, Soil Mechanics, Chapman and Hall(ELBS)  3. C. Justin and Hinds, Engineering for Dams Vol. 2 & 3.  4. S. Leliavsky, ‘Design of Dams for Percolation and Erosion’, Chapman and Hall.  **COURSE OUTCOME:**  After the completion of the course the students will be able to  1.Ability to understand Theories of earth pressure:  2. Ability to Design the retaining wall.  3. Ability to understand and analyze Sheet pile and cofferdam.  4. Ability to understand and analyze stability of the earth dam |

**PE 2: Transportation Geo-Techniques (PPECE109)**

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| **Module I**  Introduction: Aspects of geotechnics for roads, highways, railways and airfields; Geotechnical properties of geomaterials (soils, rocks, soil and rock mixtures, and recycled and alternative materials) for rational and sustainable design and construction.  **Module II**  Behaviour of compacted geomaterials, behaviour of stabilized geomaterials (mixtures of soils with - cement, lime, fly ash, polymers and other kind of geomaterials), geosynthetics and reinforcement of constructed layers and interlayers.  Compaction technology, compaction management, maintenance technology, climatic effects such as freezing and thawing, embankments for highways and railways, transition zones, dredging, underwater geotechnics for infrastructure purposes.  **Module III:**  Modeling of multi-layered structures and supporting ground under dynamic and repeated loads. Case studies applicable to sustainable transportation infrastructure construction.  **References:**   1. Advances in Transportation Geotechnics: Proceedings of the International Conference held in Nottingham, UK, 25-27 August 2008. 2. Advances in Transportation Geotechnics II - Proceedings of the 2nd International Conference on Transportation Geotechnics, ICTG 2012. 3. TeruoNakai, Constitutive Modeling of Geomaterials: Principles and Applications |

**PE 2: Rock Mechanics (PPECE110)**

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| **Course Objective:**  1.To make students understand Importance and application of rock mechanics to engineering problems.  2.Toexplain the determination of rock properties using different laboratory and field test .  3. To explain in detail tunnel design  **Module I**  Introduction, Importance and application of rock mechanics to engineering problems; Classification, Lithological classification of rocks, Engineering classification of intact and fissured rocks, Classification of fissures, joints and faults; Engineering properties of rocks.  **Module II**  Rock Testing: Laboratory and Field tests; Simple methods of determining in-situ stresses, Borehole over covering technique, Bore hole deformation gauges, Evaluation of rock stresses and deformation around tunnels;  Strength Behaviour: Compression, Tension and Shear, Stress-Strain relationships, Rheological behavior; Strength/ Failure  **Module III:**  Criterion: Coulomb, Mohr, Griffith theory of brittle strength and other strength criteria. Stresses in rock near underground openings; Application of rock mechanics in Civil Engineering: Rock tunneling, Rock slope stability, bolting, blasting, grouting and rock foundation design.  **Text/Reference Books**  1. W. Farmer, *Engineering Behavior of Rocks*, Chapman and Hall Ltd.  2. R. E. Goodman, *Introduction to Rock Mechanics*  3. P.R. Sheorey, *Empirical Rock Failure Criteria*, Balkema, Rotterdam, 1997  4. V.S. Vutukuri and R D Lama, *Hand Book on Mechanical Properties*  **COURSE OUTCOME:**  After the completion of the course the students will be able to  1.Ability to understand Engineering properties of rocks.  2. Ability to evaluate rock stresses and deformation around tunnels.  3. Ability to understand application of rock mechanics in civil engineering |

**MC: Research Methodology & IPR (PMCMH101)**

**Module I: (10 Hours)**

Introduction to RM: Meaning and significance of research. Importance of scientific research in decision making. Types of research and research process. Identification of research problem and formulation of hypothesis. Research Designs.

Types of Data: Primary data Secondary data, Design of questionnaire; Sampling fundamentals ad sample designs, Methods of data collection, Measurements and Scaling Techniques, Validity & Reliability Test.

**Module II: (10 Hours)**

Data Processing and Data Analysis-I, Data editing, Coding, Classification and Tabulation, Descriptive and Inferential Analysis, Hypothesis Testing- Parametric Test (z test, t test, F test) and non-parametric test (Chi square Test, sign test, Run test, Krushall-wallis test).

**Module III: (10 Hours)**

Data Analysis II: Multivariate Analysis- Factor Analysis, Multiple Regression Analysis. Discriminant Analysis, Use of Statistical Packages.

**Reference Books:**

1. Research Methodology, Chawla and Sondhi, Vikas

2. Research Methodology, Paneerselvam, PHI

**Course Outcomes:**

**CO1:** Understood the Meaning of research problem, Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem.

**CO2:** Got the knowledge of How to get new ideas (Criticizing a paper) through the Literature Survey (i.e. Gap Analysis).

**CO3:** Understood the Filing patent applications- processes, Patent Search, Various tools of IPR, Copyright, Trademarks.

**CO4:** Understood How to apply for Research grants and Significance of Report Writing, Steps in Report Writing, Mechanics and Precautions of Report Writing, Layout of Research Report.

**CO5:** Got the knowledge of How to write scientific paper & Research Proposal - Structure of a conference and journal paper, how (and How Not) to write a Good Systems Paper:

**Lab 1: Geotechnical Engineering Laboratory (PLCCE103)**

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| **COURSE OBJECTIVE:**  To make students understand the concept of various soil parameters  **COURSE CONTENTS:**  Standard and Modified Proctor Compaction Test; Permeability test; Direct Shear Test; Triaxial Test (CU, CD, UU); C.B.R. Test (Un-soaked& soaked); Consolidation Test., Field Density Test, Unconfined Compressive Test, Swelling Pressure Test.  **COURSE OUTCOMES:**  1.Ability to evaluate various soil characteristics  2.Ability to measure shear strength of soil |

**Lab 2: Computational Geo-techniques Laboratory (PLCCE104)**

Introduction to MATLAB and some Geotechnical free softwares (DEEPSOIL, OpenSeesPL, GEO-STUDIO, GEO5, L-PILE, CYCLIC 1D, etc.) to solve problems related to Civil Engineering/Geotechnical Engg.

**Audit-1**

**[To be decided by the Department]: Refer Appendix-I**

**Semester-2**

**Core 3: Advanced Foundation Engineering (PPCCE203)**

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| **COURSE OBJECTIVE:**   1. To make students understand Allowable total and differential settlement of structures. 2. To explain in detail of shallow foundation, deep foundations, Caission foundation.   3. To analyze foundations on problematic soils  **COURSE CONTENTS**:  **Module I**  Shallow foundation: Requirements for satisfactory performance of foundations, method of estimating bearing capacity Effect of eccentricity,inclined load, layered soil interface, foundation in slope, settlement of footing and rafts, proportion using field test data, IS Code  **Module II**  Pile foundations, methods of estimating load transfer of piles, settlements of pile foundations, pile group capacity and settlement, negative skin friction of piles, laterally loaded piles, pile load tests, analytical estimation of load- settlement behavior of piles, proportioning of pile foundations, lateral and uplift capacity of piles, IS Code Methods  **Module III**  Caission foundation: IS and IRC codal provisions, elastic theory and ultimate resistance methods, Shrinking, Method of Construction  Foundations on problematic soils: Foundations for collapsible and expansive soil  **References:**   * Bowles. J.E., Foundation Analysis and Design, Tata McGraw-Hill International Edition, 5th Edn, 1997. * Das B.M., Shallow Foundations: Bearing capacity and settlement, CRC Press, 1999. * Tomlinson M.J., Pile design and construction Practice, Chapman and Hall Publication, 1994. * Poulos, H. G. and Davis, F. H., “Pile Foundation Analysis and Design”, Wiley and Sons. 1980   **COURSE OUTCOMES:**   * 1 Ability to evaluate Bearing capacity factors and settlement. * 2. Ability to design shallow and deep foundation as per IS Code * 3.Ability to understand Caission foundation. * 4. Ability to analyze foundations on problematic soils |

**Core 4: Dynamics of Soils and Foundation (PPCCE204)**

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| **COURSE OBJECTIVE:**  1. To understand deep into various aspects of soil dynamics and gain practical knowledge of machine foundation design.  2. To develop each topic in logical progression with reference to recent developments in structure-soil-structure dynamics.  3. To understand and applythe theories of wavepropagation in elastic media, evaluate dynamic properties of soil by various lab and field-testing methods.  **CONTENTS:**  **Module I**  Soil Dynamics: Introduction: Soil mechanics and soil dynamics, problems of dynamic loading on soil structure. Theory of vibrations: Introduction, definitions, properties of simple harmonic motion, free vibrations of spring-mass system, Equations for free and forced vibrations with and without viscous damping.  **Module II**  Wave Propagation: Waves in semi-infinite body; Waves in layered medium; Earthquake waves – P-wave, S-wave, Rayleigh wave and Love wave. Dynamic Soil Properties: Introduction, measurement of dynamic soil properties (Stress and strain controlled cyclic tri-axial tests, stress-strain behavior of cyclically loaded soils, strength of cyclically loaded soils.  *Introduction to Liquefaction of soils:* Liquefaction mechanism, factors affecting liquefaction, assessment of liquefaction potential. Machine Foundations: Types of machines; Basic design criteria; Methods of analysis; Mass-Spring-Dashpot model; Elastic-Half-Space theory; Tschebotarioff’s reduced natural frequency method; Types of foundations; Modes of vibrations; Vertical, sliding, torsional (yawing) and rocking (and pitching) modes of oscillations;  **Module III**  Design guidelines of Machine Foundations as per codes; Typical design problems for reciprocating, Impact and rotary machine foundations.*Vibration isolation and screening*: force isolation, motion isolation, active and passive screening.  **Text/Reference Books:**   1. Geotechnical Earthquake Engineering by Steven L. Kramer, Low Price Edition, Pearson Education, [www.pearsoned.co.in](http://www.pearsoned.co.in) 2. Geotechnical Earthquake Engineering ByIkuoTowhata, Springer.   3. Soil Dynamics by ShamsherPrakash, McGraw-Hill Book Company  4. Soil Behaviour in Earthquake Geo-technics by Kenji Ishihara, Clarendon Press, Oxford  5. Theory of Vibrations with Applications by W. T. Thomson and M. D. Dahleh, Low Price Edition, Pearson Education, [www.pearsoned.co.in](http://www.pearsoned.co.in)  **COURSE OUTCOME:**  After the completion of the course the students will be able to  **1.** Understand soil dynamics and analyse problems of dynamic loading.  2. Understand the aspects of wave propagation in elastic media and apply the same to understand the waves generated during earthquake and locate its epicentre.  3. Understand and evaluate the dynamic soil properties by field and laboratory tests and analyse the stress-strain behaviour and strength of cyclically loaded soils.  4. To analyse and design Machine foundations subjected to different loading types. |

**PE 3: Soil Structure Interaction (PPECE206)**

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| **COURSE OBJECTIVE:**  1. To provide an understanding of the relevance and significance of soil-structure interaction in the case of different types of structures  2. Ability to evaluate Numerical analysis of finite plates  3. Ability to understand Beam on Elastic Foundation.  4. Ability to understand Elastic Analysis of Pile.  **CONTENTS**  **Module I:**  Soil-Foundation Interaction: Introduction to soil-foundation interaction problems, Soil behaviour, Foundation behaviour, Interface behaviour, Scope of soil foundation interaction analysis, soil response models, Winkler, Elastic continuum, Two parameter elastic models, Elastic plastic behaviour, Time dependent behavior.  **Module II:**  Beam on Elastic Foundation- Soil Models: Infinite beam, two parameters, Isotropic elastic half space, Analysis of beams of finite length, Classification of finite beams in relation to their stiffness. Plate on Elastic Medium: Thin and thick plates, Analysis of finite plates, Numerical analysis of finite plates, simple solutions.  **Module III:**  Elastic Analysis of Pile: Elastic analysis of single pile, Theoretical solutions for settlement and load distributions, Analysis of pile group, Interaction analysis, Load distribution in groups with rigid cap.  Laterally Loaded Pile: Load deflection prediction for laterally loaded piles, Sub-grade reaction and elastic analysis, Interaction analysis, Pile raft system, Solutions through influence charts.  Introduction to Seismic soil structure interaction, Kinematic interaction, Inertial Interaction  **Text/Reference Books:**  1. Foundation Design by Teng W.C (1969), Prentice Hall, NJ.  2. Tomlinson M.J. (1986), Foundation Design and Construction, 5th edition, John Wiley, Newyork  3. Bowles J.E., Foundation Analysis and Design, 5th edition, Mc-GrawHill, Newyork 4. Tomlinson M. J., Pile Design and Construction Practice, 1977 Viewpoint publications,London 5. Desai, C. S., and Abel, J.F., Introduction to the Finite Element Method: A Numerical Method for Engineering Analysis, Van Nostrand Reinhold Co., New York, 1972. Tenth Reprint. Translated into Japanese and Chinese (Peking). Asian (Indian) Edition, Taiwanese Edition.  6. N.P. Kurien, Design of Foundation Systems : Principles & Practices, Narosa, New Delhi 1992,  7. E.S. Melerski, Design Analysis of Beams, Circular Plates and Cylindrical Tanks on Elastic Foundation, Taylor and Francis, 2006.  8. L.C. Reese, Single piles and pile groups under lateral loading, Taylor & Francis, 2000  9. G. Jones, Analysis of Beams on Elastic foundation, Thomas Telford, 1997  10. Selvadurai, A.P.S.," Elastic analysis of soil foundation interaction. Elsevier Science Ltd.  11. Soil structure interaction: numerical analysis and modelling / edited by John W.  Bull. London; New York: E & FN Spon, 1994.  **COURSE OUTCOME:**  After the completion of the course the students will be able to  1. Analyze and able understand soil-foundation interaction problems.  2. Analyze and able to estimate beams of finite length.  3. Analyze and able to understand Classification of finite beams in relation to their stiffness. |

**PE 3: Subsoil Exploration & Soil Testing (PPECE207)**

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| **COURSE OBJECTIVE:**  1 To make students understand concepts of methods of boring, types of samples & sampling, field tests  2 To provide brief explanation on pile load test  3. To explain in detail Advanced topics on in-situ soil testing  **ModuleI**  Planning of Exploration and experimental programme, investigations, exploration for preliminary design, exploration for detailed design. methods of boring, types of samples & sampling. Preparation of detail borelog profile.  **ModuleII**  Measurement of dynamic soil properties (laboratory and field tests - Stress and strain controlled cyclic tri-axial tests, seismic reflection and refraction test, seismic up-hole/down hole test, dilatometer and pressure meter tests, cone penetration test, dynamic cone penetration test, suspension logging test, in-situ permeability tests, Plate load test and cyclic plate load test; Presentation and processing of soil exploration data and its interpretation;  **ModuleIII**  Rock coring percussion drilling, rock probing, Rock testing (Lab and fiels tests), Electrical resistivity method.  Advanced topics on in-situ soil testing: Spectral analysis of Surface wave, Multichannel analysis of Surface wave, ground penetration radar.  **Text/Reference Books:**  1**.**Head, K.H., Manual of Soil Laboratory Testing, Vols. 1 to 3, 1981.  2.Compendium of Indian Standards on Soil Engineering, Parts 1 and II, 1987–1988.  3.Engineering Principles of Ground Modifications – Hausmann, McGraw Hill  4.Subsurface Exploration and Sampling of Soils for Civil Engg. Purposes – Hvorslev M J |

**PE 3: Geo-environmental Engineering (PPECE208)**

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| **COURSE OBJECTIVES:**  1. To know about waste generation and its impact on environment  2. To explain the engineering properties of various waste.  3. To explain the selection & design of landfill.  4. To explain the concept of ash pond disposal process and stability analysis of ash pond  5. To explain the various concept of waste remedial techniques.  **Module I**  Introduction: Types & forms of waste, engineering properties (determination and typical values), subsurface contamination, Effect of contamination on soil  **Module II**  Selection of waste disposal sites: Site selection – selection criteria and rating; Municipal and hazardous waste landfill: Types- Dry cell, wet cell, bioreactor, Design- clay liners, geosynthetic clay liners for waste containment, cover and gas collection system.  **Module III**  Ash disposal: Ash Disposal facilities- Dry disposal, Wet disposal, Design of ash containment system, Stability of ash dykes;  Contaminant transport through porous media: mechanisms- advective and dispersion  Remediation: Principle- planning, source control, soil washing, bioremediation.  **References:**  1. K. R. Reddy and H D Sharma, “Geoenvironmental Engineering: Site Remediation, waste containment, and emerging waste management technologies”, John Willey, 2004.  2. R N. Yong, “Geo Environmental Engineering: Contaminated Ground: Fate of Pollutions and Remediation”, Thomson Telford, 2000.  3. L N Reddy and H.I. Inyang, “Geoenvironmental Engineering: Principles and Applications”, Marcel Dek, 2000  4. Sharma H.D. and Reddy K.R., Geo-environmental Engineering: Site Remediation, Waste Containment, and Emerging Waste Management Technologies, John Wiley, New Jersey, 2004.  5. Geotechnical Practice for Waste Disposal: D.E. Daniel Chapman and Hall, London (1993)  **COURSE OUTCOME:**  After the completion of the course the students will be able to  1. Analyze and able to find various engineering properties of wastes.  2. Analyze and design engineering landfill.  3. Analyze and design the geosynthetics for waste containment.  4. Analyze and design ash pond dykes |

**PE 4: Finite Elements in Geo-mechanics (PPECE209)**

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| **Module I**  Basic concepts - Discretization of continuum, typical elements, the element characteristic matrix, element assembly and solution for unknowns - Applications.    **Module II**  Variational principles, variational formulation of boundary value problems, variational methods approximation such as Ritz and weighted residual (Galerkin) methods, Applications.Displacements based elements, finite elements for axial symmetry. One-dimensional problems of stress, deformation and flow, assembly, convergence requirements, Finite elements analysis of two-dimensional problems. The linear and quadratic triangle, Natural coordinates. Plane strain and axisymmetric models.    **Module III**  Isoparametric formulation – Isoparametric bar element – plane bilinear isoparametric element – refined elements – Numerical integration techniques.  Use of FEM to Problems in soils and rocks, Introduction to non-linearity. Description and application to consolidation, seepage and soil – structure interaction problems.  Text/Reference Books   1. Cook, R.D., Malkus, D.S., and Plesha, M.E., Concepts and Applications of Finite Element Analysis, John Wiley, 1989. 2. Reddy, J.N., An Introduction to the Finite Element Method, McGraw Hill, 1984. 3. Chadrupatla, R.T., and Belegundu. A.D, Introduction to Finite Elements in Engineering, Third Edition, Prentice- Hall, 2006. 4. Rockey, K.C., Erans, H.R., Griffiths, D.W., and Nethercot, D.A., The Finite Element method, Grostry Lockwood Staples, London, 1975. 5. Rajasekaran, S., Finite Element Analysis in Engg Design, Wheller Publishing, Allahabad, 1993. 6. Smith, I.M., Programming the Finite Element Method with Application to Geomechanics, John Wiley and sons, New Delhi, 2000. 7. Gupta, O.P. Finite and Boundary Element Methods in Engineering, Oxford & IBH Publishing Co., Pvt. Ltd., New Delhi, 2000. 8. Rao, S.S. The finite element method in Engg, Butterworth - Heinemann., 1998. 9. Potts, D.M. and Zdramcovic, L., Finite Element analysis in Geotechnical Engineering - Application, Thomas Telford, 2001. 10. Shen, J. and Kushwaha. R.L., Soil-Machine Interaction - A finite element perspective, MoralDikker, Inc. 1998. |

**PE 4: Geo-synthetics and Reinforced Soil Structures (PPECE210)**

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| **COURSE OBJECTIVES: -**  • To understand the emerging trends of Geosynthetics in Geotechnical Engineering  • To evaluate the different properties of including different tests  • To analyze the functions of Geosynthetics and its suitability  • To design different structures using Geosynthetics according to various applications  **Module I:**  **PRINCIPLES AND MECHANISMS OF SOIL REINFORCEMENT**: Historical Background-Initial and Recent developments of Geosynthetics & Reinforced Soil; Principles, Concepts and Mechanisms of reinforced earth soil through Mohr Circle Analysis  **Module II**  **REINFORCING MATERIALS AND THEIR PROPERTIES:** Metallic stips, Natural Fibers, Geocells, Manufacturing Process & Types, Properties-physical properties, mechanical properties, hydraulic properties & endurance properties; Methods of Testing-Techniques for testing of different index properties, strength properties, Apparent Opening Size, In-plane and cross-plane permeability tests, assessment of construction induced damage, extrapolation of long term strength properties from short term tests.  **Module III**  Durability of Reinforced Materials: Corrosion, pH, Temperature; Geo textiles - requirement for design of separation – Filtration – General behavior - filtration behind retaining wall, under drains, erosion control and silt fence – drainage design – Liners for liquid containment – Geo membrane and Geosynthetics clay liners (GCL)- Mining, agriculture and aquaculture applications: containment, filtration; Case studies.  DESIGN OF SOIL REINFORCEMENT**:** Reinforcing the soil-Geo textiles and Geo grids with seismic analysis – Embankments and slopes Internal and Overall Stability Analysis – reinforced walls – Bearing Capacity Improvement in Soft Soil, Modes of Failure– Road Way Reinforcement design following the Giroud and Noiray Approach – Slope Stabilization along with seismic analysis.  **TEXT/REFERENCE BOOKS:** Jewell, R.A., Soil Reinforcement with Geotextile, CIRIA, London, 1996.  1. Jones, C.J.F.P., Earth Reinforcement and Soil Structures, Earthworks, London, 1982. 2. Koerner, R.M., Designing with Geosynthetics, Third Edition, Prentice Hall, 1997.  Muller, W.W. HDPE Geomembrances in Geotechnics, Springer, New York 2007.  1. John, N.W.M., Geotextiles, John Blackie and Sons Ltd., London, 1987. 2. Gray, D.H., and Sotir, R.B., Biotechnical and Soil Engineering Slope Stabilization: A practical Guide for Erosion control, John Wiley & Son Inc., New York, 1996. 3. RamanathaAyyar, T.S., Ramachandran Nair, C.G. and Balakrishna Nair, N., Comprehensive Reference Book on Coir Geotextile, Centre for Development for Coir Technology, 2002. 4. SivakumarBabu, G.L., An Introduction to Soil Reinforcement and Geosynthetics, University Press (India), Pvt. Ltd., Hyderabad, 2006.   **COURSE OUTCOMES: -**  After successful completion of the course it is expected that student will be able to:-  1. Identify the type of Geosynthetics and their relevance in geotechnical field  2. Understand the mechanism of formation of different Geosynthetics  3. Analyse and compute different properties of Geosynthetics  4. Apply the knowledge for designing the structures using Geosynthetics materials. |

**PE 4: Offshore Geo-mechanics (PPECE211)**

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| **COURSE OBJECTIVES: -**  1.To introduce different types of offshore structures & calculation of loads acting on it.  2.To perform fundamental stability checks of various floating and bottom supported offshore structures.  3.To perform static & dynamic analysis of Jacket platforms.  4.To understand the layout of marine structures from functional and safety requirements.  **CONTENTS:**  **Module I:**  Design of offshore platforms: Introduction, fixed and floating platforms, Design principles of Compliant platforms- Tension Leg Platforms and Spar platforms Semisubmersibles, Jack-ups, Concrete Gravity. Case Studies and general features- elements of hydrodynamics and wave theory-fluid structure interaction-Concept of Return waves - Extreme Loads on offshore structures- Morison equation- Maximum wave force on offshore structures-Wave forces on large structures-Linear diffraction theory, steel, concrete and hybrid platforms.  **Module II:**  Design criteria. Environmental loading, Wind, wave, Buoyancy and Current loads after installation- -Stability during towing. Foundations: Site investigations. Piled foundation, Foundations for gravity structures, Sea bed anchors, Dredging methods and equipments. Foundation, renewable energy converters.  **Module III:**  Materials and theirBehaviour under dynamic loading -Static and dynamic analysis of platforms and component- Statutory regulations-Allowable stresses - Regulations and codes of practice- Principles of static and dynamic analysis of jacket platforms- analytical modelling of jacket platforms.  Dynamic response in deterministic and in deterministic environment, codes of practice, analysis of fixed platform and semisubmersible related topics, offshore pipelines and riser geotechnics.  **Text/Reference Books:**  1.T. H. Dawson, Offshore Structural Engineering, Prentice Hall  2.W. J. Graff, Introduction to Offshore Structures, Gulf Publ. Co  3. B. McClelland, M. D. Reifel, Planning & Design of fixed Offshore Platforms, Van Nostrand.  4.API RP 2A, Planning, Designing and Constructing Fixed Offshore Platforms, API  5. Mark Randolph, Susan Gourvenec, Offshore Geotechnical Engineering, Spon Press. |

**Mini Project with Seminar (PPRCE201)**

**[To be decided by the Department]**

**Lab 3: Advanced Geo-Tech. Engg Lab (PLCCE203)**

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| Standard Penetration test; Field vane shear test; Cone penetration tests; Plate load test (both field and laboratory); Pile load tests; Non-destructive testing of piles; Pressure meter test; Dilatometer Test, Static and Cyclic Triaxial Test, Geophysical Exploration; Field Visit |

**Lab 4: Geo-technical Engg Design Practice (PLCCE204)**

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| Design of various types Shallow, Deep Foundations manually, retaining structure, sheet pile wall. Using various available softwares, Field Visits. |

**Audit-2**

**[To be decided by the Department]: Refer Appendix-II**

**Semester-3**

**PE 5: Ground Water and Flow Through Porous Media (PPECE304)**

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| **COURSE OBJECTIVE:**  1.To make students understand concepts of Soil Water  2.To provide brief explanation on consolidation theory  3.To explain in detail Ground water Hydraulics  **CONTENT:**  **Module I**  Soil Water: Modes of occurrence of water in soils. Adsorbed water, capillary water, Capillary potential, capillary tension and soil suction. Effective and Neutral pressures in soil; unsaturated flow  Flow through a porous media: Darcy’s Law, Validity of Darcy’s Law, Permeability, Laboratory and Field Measurement of Permeability; Laplace equation; Flownet; steady radial flow to a well in confined and unconfined aquifer  **ModuleII**  Well Hydraulics: unsteady Radial Flow into confined aquifer, Non equilibrium Theis method of solution, Cooper- Jacob Method, Chow’s method, Recovery of drawdown, unsteady Radial Flow into unconfined aquifer, Multiple well system  **ModuleIII**  Geophysical Exploration: test drilling, surface and sub-surface investigation of groundwater, Artificial Recharge of Groundwater, Ground water Pollution, Ground Water Management  **Text/Reference Books:**  1. D.K.Todd, Groundwater Hydrology, Johnwiley and Sons  2. H. M. Raghunath, Ground Water, Willy Eastern Ltd.  3. C. Fitts, Ground Water Science, Elsevier Publications, U. S. A.  4. P. P. Raj, Geotechnical Engineering, Tata McGraw-Hill  5. A. Jumikis, Soil Mechanics, East West Press Pvt Ltd**.**  **COURSE OUTCOME:**  After the completion of the course the students will be able to   1. Ability to evaluateEffective and Neutral pressures in soil 2. Ability to evaluate the capillarity and permeability characteristics of soil strata 3. Ability to understand consolidation theory and Ground water Hydraulics |

**PE 5: Geotechnical Earthquake Engineering (PPECE305)**

**COURSE OBJECTIVE:**

1. To knowthe theories of formation of Earth, plate tectonics and continental drift.
2. To understand and analyse how and where earthquake occurs and to measure the size of an earthquake.
3. To understand and apply the theories of wave propagation in elastic media, evaluate dynamic properties of soil by various lab and field testing methods.
4. To perform ground response analysis and understand the local site effects.
5. To understand various earthquake induced hazards and different remedial measures (ground improvement methods).

**Module I**

Introduction, Seismic Hazards, seismic waves, internal structure of earth, Continental drift and plate tectonics, faults, elastics rebound theory, geometric notations, location of earthquakes, size of earthquakes. Strong ground motion measurement, ground motion parameters, estimation of ground motion parameters. Seismic Hazard Analysis: Identification and Evaluation of Earthquake Sources, deterministic seismic hazard analysis, probabilistic seismic hazard analysis.

**Module II**

Wave Propagation: Waves in unbounded media, waves in a semi – infinite body, waves in a layered media, attenuation of stress waves. Dynamic soil properties: Measurement of dynamic soil properties using field and laboratory tests (overview), stress strain behavior of cyclically loaded soils, strength of cyclically loaded soils. One – Dimensional Ground response Analysis – Linear and Non-Linear Approaches. Local Site Effects: Effect of local site conditions on ground motion, design parameters, development of design parameters.

**Module III**

Flow liquefaction, cyclic mobility, evaluation of liquefaction hazards, liquefaction susceptibility, initiation of liquefaction, effects of liquefaction. Soil Improvement for Remediation of Seismic Hazards: Densification techniques, Reinforcement Techniques, Grouting and Mixing techniques, Drainage techniques. Dynamic earth pressure and seismic slope stability analysis.

**Text/Reference Books:**

1.Geotechnical Earthquake Engineering by Steven L. Kramer, prentice Hall, 1st edition, 1996.

2.Geotechnical Earthquake Engineering Handbook by Robert W. Day, McGraw-Hill.2nd edition, 2010.

1. Geotechnical Earthquake Engineering ByIkuoTowhata, Springer.

**COURSE OUTCOME:**

After the completion of the course the students will be able to

1. Know the theories of formation of Earth, plate tectonics, continental drift, fault, how earth quake occurs and quantify the size of an earthquake.

2. Measure and estimate ground motion parameters, perform seismic hazard analysis and locate the epicentre of an earthquake.

3. Understand the aspects of wave propagation in elastic media and evaluate the dynamic soil properties by field and laboratory tests and analyse the stress-strain behaviour and strength of cyclically loaded soils.

4. Perform 1D ground response analysis and understand the local site effects due to ground motion.

5. Understand soil liquefaction and its effects and evaluate soil improvement and remediation of liquefaction hazards.

6. Evaluate the dynamic bearing capacity of foundations and perform seismic analysis and design of earth retaining structures and soil slopes.

**PE 5: Stability analysis of Slopes, Embankments and Dams (PPECE306)**

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| **Module I:**  Landslide phenomenon: Types and causes of slope failures, rock falls, deep failure of slopes and shallow debris flows, Practical applications;  **Module II:**  Stability analysis of infinite slopes with or without water pressures;Stability analysis of finite and Infinite slopes: concept of factor of safety, pore pressure coefficients, Mass analysis, Wedge methods, friction circle method; Method of slices, Bishop’s method, Janbu’s method; Effect of seepage, submerged and sudden draw down conditions;  **Module III:**  Design of slopes Short-term and Long-term stability analysis of slopes; Methods for stability analysis of slopes; Methods for enhancing stability of unstable slopes; design of slope in cutting, Embankments and Earth dams;  Site Investigation: Reconnaissance, Preliminary and detailed investigation, Investigation for foundations; Advances in stability analysis of slopes.  **Text/Reference Books**   1. L. W Abramson, T. S Lee, S Sharma and G M Boyce, Slope Stability and Stabilization Methods, Willey Interscience publications 2. B M Das, Principles of Geotechnical Engineering, Thomson Brooks/Cole 3. T W. Lambe and R V Whitman, Soil Mechanics, John Wiley & sons 4. V N S Murthy, Principles of Soil Mechanics and Foundation Engineering, UBS Publishers Private Ltd**.** |

**Open Elective**

**[To be decided by the Department]: Refer Appendix-III**

**Project 1: (PPRCE301)**

**[To be decided by the Department]: Dissertation (Phase-I)**

**Semester-4**

**Project 2: (PPRCE401)**

**[To be decided by the Department]: Dissertation (Phase-II)**