CIVIL ENGINEERING

Scheme of Instruction for M Tech Civil Engineering program (2025-26)

M Tech Program in Civil Engineering

Semester 1 Common to all students
Core: 15 Credits
CE 201 3:0 Basic Geomechanics
CE 263 3:0 Modelling Transport and Traffic
CE 217 3:0 Fluid Mechanics
CE 204 3:0 Solid Mechanics
CE 211 3:0 Mathematics for Engineers

a) To complete the M Tech degree students shall complete 42 credits of coursework, with fulfilling the requirement of one Major, and 22 credits of project.
b) **To fulfill Major requirement in an Area,** students shall complete minimum 21 course credits (15 core + 6 elective on offer) and 22 Dissertation project credits in the said Area.
c) **For optional Minor in one of the other four Areas**, a student must complete minimum of 12 credits in the said Area. A course can be counted only once for determining the major or minor. For a minor in Dam Engineering, only the * marked courses qualify.

Major in Dam Engineering

Core: 15 Credits
CE 285 3:0 Disaster Management for Dams
CE 201A 3:0 Dam Safety Surveillance, Instrumentation and Monitoring
CE 260 3:0 Rock mechanics
CE 202A 2:1 Integrated Investigation of Dams
CE 211A 3:0 Concrete Durability and Repair
CE 299 0:22 Dissertation Project

Major in Geotechnical Engineering

Core: 12 Credits (+ 3 credits from term 1)
CE 202 3:0 Foundation Engineering
CE 295 3:0 Earth Retaining Structures and Earthen Dams
CE 208 3:0 Ground Improvement and Geosynthetics
CE 260 3:0 Rock mechanics
CE 299 0:22 Dissertation Project

Major in Structural Engineering

Core: 12 Credits (+ 3 credits from term 1)
CE 205 3:0 Finite Element Method
CE 209 3:0 Mechanics of Structural Concrete
CE 210 3:0 Structural Dynamics
CE 228 3:0 Continuum Plasticity
CE 299 0:22 Dissertation Project

Major in Water Resources Engineering

Core: 12 Credits (+ 3 credits from term 1)
CE 203 3:0 Surface Water Hydrology
CE 277 3:0 Remote Sensing in Ecohydrology
CE 214 3:0 Ground Water Hydrology
CE 215 3:0 Stochastic Hydrology
CE 299 0:22 Dissertation Project

Major in Transportation Systems Engineering

Core: 12 Credits (+ 3 credits from term 1)
CE 204A 2:0 Pavement Engineering
SL 224 3:1 Network Science & Optimization
CE 271 3:0 Choice Modelling
CE 235 3:0 Optimization Methods
CE 299 0:22 Dissertation Project

Electives in Each Program

Electives in Dam Engineering

CE 203A 3:0 Hydrologic Safety Evaluation of Dams
CE 295 3:0 Earth Retaining Structures and Earthen Dams
CE 208 3:0 Ground Improvement and Geosynthetics
CE 221 3:0 Earthquake Geotechnical Engineering
CE 227 3:0 Engineering Seismology
CE 279 3:0 Computational Geotechnics
ST 222 3:0 Basic Concepts of Planning & Design of Hydro-Mechanical Components in Dams
CE 208A 3:0 Flood Resilient Transport System
CE 240 3:0 Uncertainty Modeling and Analysis

Electives in Geotechnical Engineering

CE 220 3:0 Design of Substructures
CE 221 3:0 Earthquake Geotechnical Engineering
CE 227 3:0 Engineering Seismology
CE 279 3:0 Computational Geotechnics
CE 209A 3:0 Elastic Wave Propagation and Applications in NDE
CE 202A 2:1 Integrated Investigation of Dams

Electives in Structural Engineering

CE 228N 3:0 Introduction to the Theory of Plasticity
CE 229 3:0 Non-Destructive Evaluation Methods for Concrete Structures
CE 235 3:0 Optimization Methods

CE 236 3:0 Fracture Mechanics
CE 243 3:0 Bridge Engineering
CE 250 3:0 Stability and Design of Steel Structures
CE 274 3:0 Earthquake Resistant Design
CE 210A 3:0 Thermodynamic Modelling of Cementitious Systems
CE 211A 3:0 Concrete Durability and Repair
CE 240 3:0 Uncertainty Modeling and Analysis

Electives in Water Resources Engineering
CE 213 3:0 Systems Techniques in Water Resources Engineering
CE 247 3:0 Remote Sensing and GIS for Water Resources Engineering
CE 249 3:0 Water Quality Modelling
CE 203A 3:0 Hydrologic Safety Evaluation of Dams
WR201 3:0 Watershed Modeling (from Aug 2023)
AS 216 3:0 Introduction to Climate Systems

Electives in Transportation Systems Engineering
CE 262 3:0 Public Transportation Systems Planning
CE 207A 3:0 Characterization of Bituminous Materials
CE 269 3:0 Traffic Engineering
CE 207A 3:0 Characterization of Bituminous Materials
SL 222 3:1 Transportation Demand and Supply Modeling
DS 290 3:0 Modelling and Simulation
ST 203 3:0 Technology and Sustainability
MG 219 3:0 Introductory Probability
MG220 3:0 Introductory Statistics
CP 318 2:1 Data Science for Smart City Applications
CP 218 2:1 Theory and Applications of Bayesian Learning

<u>Semester 1 (mandatory for all MTech Civil Engineering students)</u>

CE 201 (AUG) 3:0
Basic Geo-mechanics

Introduction to genesis of soils, basic clay mineralogy; Principle of effective stress, permeability and flow; Fundamentals of Tensors, Introduction to stresses and deformation measures; Mohr-Coulomb failure criteria, soil laboratory tests; Critical state and stress paths. Shear Strength and Stiffness of Sands; Consolidation, shear strength and stiffness of clays

Tejas G Murthy

Wood, D.M., Soil Behaviour and Critical State Soil Mechanics, Cambridge University Press, 1991.
Bolton, M.D. A Guide to Soil Mechanics, Cambridge University Press, 1991.
Salgado, R., The Engineering of Foundations, McGraw Hill, 2008.

CE 263 (AUG) 3-0
Modelling Transport and Traffic

Approaches to travel demand modelling; trip-based modelling approach, activity based travel demand modelling, land use-transport models; traffic flow theory; deterministic and stochastic models of traffic flows; delay and saturation flow models; pedestrian flow modeling; optimization of public transport system

Ashish Verma

J. de D. Ortuzar and L.G. Willumsen, Modelling Transport, John Wiley and Sons, 2001.
A. D. May, *Traffic Flow Fundamentals*, Prentice–Hall, 1990
A. Verma and T. V. Ramanayya, Public Transport Planning and Management in Developing Countries, CRC Press, 2014 (in press)
Vuchic Vukan R., Urban Transit: Operations, Planning and Economics, Prentice Hall, 2005.

CE 217 (AUG) 3:0
Fluid Mechanics

Vectors and tensors, divergence theorem, pressure, Archimedes principle, fluid mass conservation, heat and contaminant conservation, momentum conservation and Cauchy equation, stress tensor, constitutive relation for Newtonian fluids, Navier-Stokes equations, vorticity, laminar plane couette and open channel flow, Euler equations, potential flow approximation, simple solutions of potential flows, laminar flow in pipes and channels, transition to turbulence Reynolds stress and fluxes, laminar boundary layer, laminar bottom dense flows.

Debsunder Dutta

Kundu, Cohen and Dowling Fluid Mechanics, Sixth Ed., Academic Press, 2016.White, F.M. Fluid Mechanics, F.M., Eighth Edition, McGraw Hill, 2016.

CE 204 (AUG) 3:0
Solid Mechanics

Introduction to tensor algebra and calculus, indicial notation, matrices of tensor components, change of basis formulae, eigenvalues, Divergence theorem. Elementary measures of strain. Lagrangian and Eulerian description of deformation. Deformation gradient, Polar decomposition theorem, Cauchy-Green and Lagrangian strain tensors. Deformation of lines, areas and volumes. Infinitesimal strains. Infinitesimal strain-displacement relations in cylindrical and spherical coordinates. Compatibility. Tractions, body forces, stress at a point, Cauchy's theorem. Piola-Kirchhoff stress tensors. Momentum balance. Symmetry of the Cauchy stress tensor. St. Venant's Principle. Virtual Work. Green's solids, elastic strain energy, generalized Hooke's Law, material symmetry, isotropic linear elasticity in Cartesian, cylindrical and spherical coordinates, elastic moduli, plane stress, plane strain,. Navier's formulation. Airy stress functions. Selected problems in elasticity. Kirchhoff's uniqueness theorem, Betti-Maxwell reciprocal theorem, Principle of stationary potential energy, Torsion in circular and non-circular shafts and thin-walled tubes, warping.

Ananth Ramaswamy

Fung, Y. C. and Pin Tong, Classical and Computational Solid Mechanics, World Scientific, 2001
Boresi, A.P., and Lynn P.P., Elasticity in Engineering Mechanics, Prentice Hall 1974.
Malvern L., Introduction to the Mechanics of a Continuous Medium, Prentice Hall, 1969

CE 205 (JAN) 3:0
Finite Element Method

Calculus of variations; Variational principles: Principle of virtual work; PSPE; Cycle of FE using 1D elements: Rod elements; Lagrange interpolation and shape functions; stiffness matrix; assembly; boundary conditions; singularities; Coordinate transformations; Plane truss elements; Beam elements; Symmetry; Consistent nodal loads; plane frame elements; Constraints in FE; Lagrange multipliers; penalty method FE formulation for planar elasticity and 2D Continuum Elements; Constant Strain Triangle and Q4 bilinear rectangle; Isoparametric formulation; mapped domain; element stiffnesses; Higher-order (LST, serendipity Q8, Q9) elements; compatibility; Gauss quadrature and reduced integration. Element pathologies: parasitic shear, locking, hour-glassing; Error estimates, convergence. Superconvergence and Barlow points; a posteriori (Zienkiewicz-Zhu) error estimates;

Foundations of FE: Sobolev and Hilbert spaces; weak derivatives; weak and strong forms; abstract form; Riesz representation theorem; Lax-Milgram theorem; Ritz-Galerkin approximation; Galerkin orthogonality;

Computational aspects: Sparse linear systems, ill-conditioning; other topics as time permits

Narayan K Sundaram

Zienkiewicz, O.C. and Taylor, R.L., The Finite Element Method: Vol. 1 (The Basis), Butterworth-Heinemann, 2000.
Cook R.D.. Malkus, D. S., Plesha and Witt, R.J., Concepts and Applications of Finite Element Analysis, Fourth edition, John
Wiley and Sons.
J N Reddy, An Introduction to the Finite Element Method, Second Edition, McGraw Hill Inc, 1993.

CE 211 (AUG) 3:0

Mathematics for Engineers

Revision of ordinary linear ODEs, Formal operators, Adjoint operator, Sturm-Liouville theory, eigenvalue problems, Classification of PDEs, Characteristics / first order PDEs, Laplace equation / potential theory, Separation of variables (cartesian, polar), Eigenfunction expansions, Green's functions, Introduction to boundary value problems
Probability space and axioms of probability. Conditional probability. Total probability and Bayes theorems. Scalar and vector random variables. Probability distribution and density functions. Expectation operator. Functions of random variables.
Vector spaces and subspaces, solution of linear systems, Linear independence, basis, and dimension, The four fundamental subspaces, Linear transformations, Orthogonal vectors and subspaces, Cosines and projections onto lines, Projections and least squares, The fast Fourier transform, Eigenvalues and eigenvectors, Diagonalization of a matrix, Difference equations and powers of matrices, Similarity transformations.

Debraj Ghosh and J M Chandra Kishen

Michael Stone, Paul Goldbart, 2009, Mathematics for Physics: A Guided Tour for

Graduate Students, Cambridge University Press
Papoulis A and Pillai, S U., 2002, Probability, random variables and stochastic processes, Mc Graw-Hill, Boston
Strang Gilbert, 2013, Linear Algebra and Its Applications, India Edition (4th), CENGAGE LEARNING

Major in Dam Engineering

CE 285 (JAN) 3:0
Disaster Management for Dams

Overview of disaster management and flood mapping, Flood risk associated with various types of dams, Dam hazard classification systems, Dam failure modes and assessment of consequences, Dam breach modelling, Hydrologic, Hydraulic and breach outflow routing, Remote Sensing and Geographic Information Systems (GIS) applications for emergency preparedness and flood mapping, Dam hazard classification framework in India, Emergency action plans preparation and implementation.

D Nagesh Kumar, V V Srinivas

Guidelines for Developing Emergency Action Plans for Dams, Dam Safety Rehabilitation Directorate (DSRD), Central Water Commission (CWC), 2016.
Guidelines for Mapping Flood Risks Associated with Dams, DSRD, CWC, 2018.
Heywood, I., Cornelius, S., and Carver, S. An Introduction to Geographical Information Systems, Pearson Education, 1998.
Lillesand T.M. and Kiefer R.W. Remote Sensing and Image Interpretation, John Wiley & Sons, 2000.
Singh, V. P. Dam Breach Modeling Technology, Springer Science & Business Media, 2013.

CE 201A (AUG) 3:0
Dam Safety Surveillance, Instrumentation and Monitoring

Dam safety: Overview of dam inspection for dam safety; Dam safety inspection program; Inspecting embankment dams, concrete & masonry dams; Inspecting spillways, outlets and mechanical equipment; Inspection using ROVs.
Instrumentation & Monitoring: Instrument types and their uses; Instrumentation system planning- Embankment, concrete and masonry dams, seismic monitoring; Hydrometeorological instrumentation – data collection and management, data organization & analysis, automation

J M Chandra Kishen, Debsunder Dutta

Guide to Hydrological Practices, Volume I, Hydrology – From Measurement to Hydrological Information, WMO-No. 168.
Technical Specifications of Hydro-meteorological, Geodetic, Geotechnical and Seismic Instruments, Dam Safety Rehabilitation Directorate, Central Water Commission,2018.
Guidelines for Safety Inspection of Dams (2018), DRIP, Central Water Commission, Government of India, New Delhi.
Guidelines for Instrumentation of Large Dams (2018), DRIP, Central Water Commission, Government of India, New Delhi.

CE 260 (AUG) 3:0
Rock Mechanics

Physical properties of intact rocks, stresses and strains, engineering properties of rocks and rock masses, theory of elasticity, rock discontinuities, in situ stresses, structural geology, strike, dip, bedding plane, types of fractures: joints, faults, folds, unconformity, formation and classification of joints, faults and folds, effects of joints, faulting, folding, geological exploration - bore holes, methods of drilling, rock strength and rock mass strength, rock failure criteria, rock mass classification: rock mass rating, geophysical methods, geology of dam sites and reservoirs, Importance of geology in dam construction, rock slope stability. numerical and computer methods in rock mechanics and under-ground excavations.

Jyant Kumar, Swetha Veeraraghavan

John A. Hudson and John P. Harrison. Engineering Rock Mechanics
John Jaeger, N. G. Cook, and Robert Zimmerman. Fundamentals of Rock Mechanics
Goodman, R. E. Introduction to Rock Mechanics. John Wiley & Sons.
Ömer Aydan. Rock Mechanics and Rock Engineering.

CE 202A (JAN) 2:1
Integrated Investigation of Dams – Laboratory Course

Introductions to Geotechnical field investigations, laboratory experiments and relevant IS codes; Geotechnical and Geophysical investigation of Dams; Theory and demonstration of Ground Penetrating Radar

testing: Multichannel Analysis of Surface Testing: Seismic borehole tests, Down/Up and Cross hole testing; Electric Resistivity testing; Planning of Integrated Investigation. Field experimental case studies of Dam investigations.

P Anbazhagan & P Raghuveer Rao

An-Bin Huang, Paul W Mayne, Geotechnical and Geophysical Site Characterization, CRC Press, 2008.
Head, K.H., Manual of Soil Laboratory Testing. Vols. 1 to 3, 1981.
Compendium of Indian Standards on Soil Engineering Parts 1 and II, 1987 - 1988.

Major in Geotechnical Engineering

CE 202 (JAN) 3:0
Foundation Engineering

Subsurface investigations, Bearing capacity of shallow foundations, penetration tests, plate load tests. Settlement of shallow foundations, elastic and consolidation settlements; settlement, estimates from penetration tests, settlement tolerance. Allowable bearing pressure. Foundations on problematic soils. Principles of foundation design. Introduction of deep foundations. Bearing capacity and settlement of piles and pile groups in soils. Machine foundations. Reinforced soil beds.

Tejas G Murthy

Bowles, J.W., Foundation Analysis and Design, 5th Edn., McGraw-Hill, 1996.
Das, M. B., Principles of Foundation Engineering, Brooks/Cale Engineering Division, 1984.

CE 295 (JAN) 3:0
Earth Retaining Structures and Earthen Dams

Earth retaining structures, lateral earth pressure coefficients, Rankine and Coulomb theories, passive earth pressure computation with curved rupture surfaces, stability of gravity and cantilever retaining walls, stability of vertical cuts, braced excavations, cantilever and anchored sheet piles, stability of infinite slopes and finite slopes, different methods of slices for the analysis of finite slopes and embankments, stability analysis of earth and rock dams, forces/loads to be considered, different load cases, factors of safety in different conditions, filters for earthen dams, seepage analysis, software application.

Jyant Kumar

Terzaghi, K., Theoretical Soil Mechanics, John Wiley, 1965.
Taylor, D.W., Fundamentals of Soil Mechanics, John Wiley, 1948.
Bowles, J.W., Analysis and Design of Foundations, 4th and 5th Ed., McGraw-Hill, 1988 & 1996.
Lambe, T.W. and Whitman, R.V., Soil Mechanics, Wiley Eastern Limited, 1976.
Earth and earth-rock dams: Engineering problems of design and construction. James L. Sherard, Wiley, 1963.

CE 208 (JAN) 3:0
Ground Improvement and Geosynthetics

Principles of ground improvement, mechanical modification. Properties of compacted soil. Hydraulic modification, dewatering systems, preloading and vertical drains, electro-kinetic dewatering, chemical modification, modification by admixtures, stabilization using industrial wastes, grouting, cutoff walls, underpinning, soil nailing, soil reinforcement principles, properties of geo-synthetics, applications of geo-synthetics in bearing capacity improvement, slope stability, retaining walls, embankments on soft soils and dams, filtration, drainage and seepage control with geo-synthetics, landfills and other applications of geo-synthetics, case studies.

G Madhavi Latha

Hausmann, M.R., Engineering Principles of Ground Modification, McGraw-Hill, 1990.
Jones, C.J.E.P., Reinforcement and Soil Structures, Butterworth Publications, 1996.
Koerner, R. M., Designing with Geosynthetics, Prentice Hall Inc. 1998.

Major in Structural Engineering

CE 209 (JAN) 3:0
Mechanics of Structural Concrete

Introduction, Limit state design philosophy of reinforced concrete, Stress-strain behavior in multi-axial loading, failure theories, plasticity and fracture, ductility, deflections, creep and shrinkage, Strength of RC elements in axial, flexure, shear and torsion, RC columns under axial and eccentric loading, Beam-column joints, Strut and Tie modelling, Yield line theory

of slabs, Seismic resistant design, Methods for predicting the behavior of pre-stressed concrete members and structures.

Ananth Ramaswamy

Nilson, A. H., Darwin, D. and Dolan, C. W., Design of concrete structures, McGraw Hill, 2004
Lin and Burns, Design of Prestressed concrete structures, John Wiley and Sons, 2006
Agarwal and Shrikhande- Earthquake resistant design of structures, Prentice-Hall of India Pvt. Ltd. New Delhi, 2006.

CE 210 (JAN) 3:0
Structural Dynamics

Equations of motion. Degrees of freedom. D' Alembert principle. SDOF approximation to vibrating systems. Energy storage elements: mass, stiffness and damper. Undamped free vibration. Natural frequency. Damped free vibration. Critical damping. Forced response under periodic and aperiodic excitations. Support motions. Resonance. Impulse response and complex frequency response functions. Duhamel integral. Vibration isolation: FTR and DTR. Multi-DOF systems. Normal modes and natural frequencies. Orthogonality of normal modes. Natural coordinates. Uncoupling of equations of motion. Repeated natural frequencies. Proportional and non proportional damping. Damped normal modes. Principle of vibration absorber. Continuous systems. Vibration of beams. Forced response analysis by eigenfunction expansion. Moving loads and support motions. Effect of axial loads. Approximate methods for vibration analysis. Rayleigh's quotient. Rayleigh-Ritz method. Method of weighted residual. Method of collocation. Galerkin's method.

J M Chandra Kishen

Meirovich, L., 1984, Elements of vibration analysis, McGraw-Hill, NY
Clough R W and J Penzien, 1993, Dynamics of structures, McGraw-Hill, NY
Rao,S S 2004, Mechanical Vibrations, 4th Edition, Pearson Education, New Delhi.

CE 228 (JAN) 3:0
Continuum Plasticity

Brief reviews of finite deformation kinematics and constitutive closure; introduction to rational thermodynamics and formulation of constitutive theories; internal variables; dissipation inequality; physics of yielding; plastic flow and hardening; notion of yield surface; classical models for yielding; plastic flow and hardening; additive and multiplicative splitting of kinematic quantities; solutions of simple BVPs; FEM for small deformation plasticity; yield free plasticity models; linearization and computational schemes; introduction to damage mechanics

Prerequisite: This is a graduate-level course designed for masters and doctoral students with a fair background in solid mechanics. The pre-requisite is a graduate level course in solid mechanics or continuum mechanics. We essentially assume the definition of strain and equations of mechanical equilibrium.

Debasish Roy

A S Khan, S Huang, 1995, Continuum Theory of Plasticity, John Wiley, NY
J Lubliner, 2008. Plasticity theory. Courier Corporation.
M E Gurtin, L Anand, 2012, The Mechanics and Thermodynamics of Continua, Cambridge University Press, UK
Simo, J. C., & Hughes, T. J., 2006, Computational inelasticity, Springer Science & Business Media.

Major in Water Resources Engineering

CE 203 (JAN) 3:0
Surface Water Hydrology

Review of basic hydrology, hydrometeorology, infiltration, evapotranspiration, runoff and hydrograph analysis. Flood routing – lumped, distributed and dynamic approaches, `hydrologic statistics, frequency analysis and probability, introduction to environmental hydrology, urban hydrology. Design issues in hydrology.

V V Srinivas

Bedient, P. B., and Huber, W. C., Hydrology and Floodplain Analysis, Prentice Hall, 2002.
Chow, V.T., Maidment, D.R. and Mays, L.W,. Applied Hydrology, McGraw-Hill 1988.
Linsley, R.K., Kohler, M.A. and Paulhus, J.L.H., Hydrology for Engineers, McGraw Hill, 1985.

CE 214 (JAN) 3:0
Ground Water Hydrology

Ground water and hydrological cycle. Ground water movement and balance. Ground water monitoring. Equations of flow. Well hydraulics - analysis of aquifer tests and models. Regional groundwater resource evaluation and numerical modeling. Groundwater recharge estimation. Base flow analysis and models. Ground water quality. Mass transport in ground water. Tracer tests and scale effects of dispersion. Solute transport modeling.

M Sekhar

Freeze, A. R. And Cherry, J. A. Groundwater, Prentice Hall, 1979.
Fetter, C. W. Applied Hydrogeology, Prentice Hall, 1988.
Domenico, P. A., and Schwartz, F. W. Physical and Chemical Hydrogeology, John Wiley, 1990.
Fetter, C. W. Contaminant Hydrogeology, Prentice Hall, 1993.

CE 215 (JAN) 3:0
Stochastic Hydrology

Introduction to random variables, statistical properties of random variables. Commonly used probability distributions in hydrology. Fitting probability distributions to hydrologic data. Probability plotting and frequency analysis. Data generation. Modeling of hydrologic uncertainty - purely stochastic models, first order Markov processes. Analysis of hydrologic time series – linear and nonlinear correlations, Fourier analysis and spectral density functions, Wavelets. Applications to hydrologic forecasting.

Rajarshi Das Bhowmik

Bras, R.L. and Rodriguez-Iturbe, Random Functions and Hydrology, Dover Publications, New York, USA, 1993.
Hann, C.T., Statistical Methods in Hydrology, First East-West Press Edition, New Delhi, 1995.
Ang, A.H.S. and Tang, W.H., Probabilistic concepts in Engineering Planning Design, Vol. 1, Wiley, New York, 1975.
Clarke, R.T., Statistical Models in Hydrology, John Wiley, Chinchester, 1994

CE 277 (JAN) 3:0

Remote Sensing in Ecohydrology

Introduction to ecohydrology, fundamentals of exchange of energy and water in terrestrial ecosystems, soil temperature and moisture, surface energy fluxes, modeling leaf photosynthesis and stomatal conductance, introduction to plant canopies and radiation regime, soil, plant atmosphere continuum, fundamentals of optical remote sensing, remote sensing of vegetation composition, structure and function, applications of remote sensing to coupled water and carbon cycles in terrestrial ecosystems.

Debsunder Dutta

Ecological Climatology, 3rd Edition, Gordon Bonan, Cambridge University Press. An Introduction to Environmental Biophysics, 1998, G.S. Campbell, J. Norman, Springer. Remote Sensing and Image Interpretation, 2015, Lilliesand, Thomas and Chipman, John Wiley & Sons. Some current and previous literature on remote sensing and modeling.

Major in Transportation Systems Engineering

CE 204A (JAN) 2:0
Pavement Engineering

Introduction to pavement engineering; design of flexible and rigid pavements: selection of pavement design input parameters, traffic loading and volume, material characterization, drainage, failure criteria; pavement design of overlays; pavement performance evaluation; non-destructive tests for pavement; IRC, AASHTO design codes; maintenance and rehabilitation of pavements.

Satyavati Komaragiri

Rajib B Mallick and Tahar El-Korchi, Pavement Engineering, Principles and Practice, CRC Press, 2009.
Y.H. Huang, Pavement Analysis and Design, Prentice-Hall, New Jersey, 1993.
E. J. Yoder, M. W. Witczak, Principles of Pavement Design, Wiley New York, 1975.
C. E. G. Justo, S.K. Khanna, and A. Veeraragavan, Highway engineering, Nem Chand & Bros, 2017.

CE 271 (JAN) 3:0
Choice Modeling

Individual choice theories; Binary choice models; Unordered multinomial choice models (multinomial logit and multinomial probit); Ordered response models (ordered logit, ordered probit, generalized ordered response; rank-ordered data models); Maximum likelihood estimation; Sampling based estimation (choice-

based samples and sampling of alternatives); Multivariate extreme value models (nested logit, cross-nested logit); Mixture models (mixed logit and latent class models); Mixed multinomial probit; Integrated choice and latent variable models; Discrete-continuous choice models with corner solutions; Alternative estimation methods (EM, analytic approximations, simulation); Applications to travel demand analysis.

Abdul R. Pinjari

F. Koppelman & C.R. Bhat. A Self-Instructing Course in Mode Choice Modeling: Multinomial and Nested Logit Models, 2006.
K. Train. Discrete Choice Methods with Simulation (2nd edition), Cambridge University Press, 2009.
M. Ben-Akiva & S.R. Lerman. Discrete Choice Analysis: Theory and Application to Travel Demand, MIT Press, 1985.

SL 224 (Jan) 3:1 Network Science & Optimization

Introduction to Networks; Shortest paths (Label setting and label correcting methods, A* algorithm, Contraction hierarchies); Max flows and Min cost problems (Augmenting path method, Cycle cancelling and successive shortest path methods); Spanning Trees; Time-dependent graphs; Random networks, Centrality measures (Small worlds, Power laws, Scale-free properties); Evolution of networks; Spreading phenomenon; Introduction to GNNs.

Tarun Rambha

- Ahuja, R. K., Magnanti, T. L., & Orlin, J. B. (1988). *Network flows*. Pearson.
- Newman, M. (2018). *Networks*. Oxford University Press.
- Barabási, A. L. (2016). *Network science*. Cambridge University Press.
- Hamilton, W. L. (2020). *Graph representation learning*. Morgan & Claypool Publishers.

Brief description of lab component: The lab will involve the implementation of algorithms using Python, NetworkX, and PyTorch Geometric. In addition, visualization tools such as Gephi will be covered.

CE 235 (JAN) 3:0
Optimization Methods

Basic concepts, Kuhn-Tucker conditions, linear and nonlinear programming, treatment of discrete variables, stochastic programming, Genetic algorithm, simulated annealing, Ant Colony and Particle Swarm Optimization, Evolutionary algorithms, Applications to various engineering problems.

Ananth Ramaswamy

Arora, J.S. Introduction to Optimization, McGraw-Hill (Int. edition)1989.
Rao, S.S., Optimization: Theory and Applications. Wiley Eastern, 1992
Current Literature.

Electives in Dam Engineering

CE 203A (AUG) 3:0
Hydrologic Safety Evaluation of Dams

Significance of hydrologic safety evaluation and modeling uncertainty in hydro-meteorological processes; Standard project storm and Probable maximum precipitation (PMP); Design flood estimation - Hydro-meteorological approach: unit hydrograph construction, design storm depth estimation from PMP Atlas, storm transposition and adjustment, estimation of loss rate, base flow and time distribution coefficients, HEC-HMS model; Flood frequency analysis approach: At-site and regional frequency

analysis using commonly used probability distributions in hydrology, Probability plotting and Goodness of fit tests; Reservoir sedimentation, Reservoir rule curve.

V V Srinivas

Chow, V.T., Maidment, D.R. and Mays, L.W., Applied Hydrology, McGraw-Hill, 1988.
Handbook for Assessing and Managing Reservoir Sedimentation, Dam Safety Rehabilitation Directorate, Central Water Commission, 2019.
Hosking, J. R. M., and Wallis, J. R., Regional Frequency Analysis: An Approach Based on L-Moments, Cambridge University Press, 1997.
Manual on Estimation of Probable Maximum Precipitation (PMP), World Meteorological Organization, 2009.

ST 222 (JAN) 3:0
Basic Concepts of Planning & Design of Hydro-Mechanical Components in Dams

Introduction and Types of Gates, Selection of Hydraulic gates, Hydraulic gates design & weight estimation, Hydro-dynamic forces, Gate operating systems, Materials, Fabrication, Erection, Testing and Commissioning, Hydraulic Gates for Dam Safety, Social and environment impacts of dam structures, Design of fish pass and alternate gate structures, Dam removal and the sediment effect.

Punit Singh

Design of Small Dams-A Water Resources Technical Publication, United States Department of The Interior, Bureau of Reclamation, Third edition - 1987
Bandyopadhyay, J. (2017). Restoration of ecological status of Himalayan rivers in China and India: The case of the two mother rivers—The Yellow and the Ganges. In Environmental Sustainability from the Himalayas to the Oceans (pp. 69-98). Springer, Cham.
Bandyopadhyay, J. (2018). Why we need a new perspective on rivers. The Third Pole, 25.
Emil Mosonyi, Waterpower development, Hardcover – 2009, ISBN-10: 8185240841
Giesecke, Wasserkraftanlagen, Springer Verlag
Knauss, J. (1987). Swirling flow problems at intakes: Hydraulic structures design manual. Rotterdam, The Netherlands: AA Balkema.
Schwartz, H. I, (1964). Projected Nappes subjected to harmonic pressures. Proceedings of the Institution of Civil Engineers, 28(3), 313-326.

Electives in Geotechnical Engineering

CE 220 (AUG) 3:0
Design of Substructures

Design considerations, field tests for bearing capacity and settlement estimates, selection of design parameters. Structural design considerations. Codes of practice. Design of spread footings, combined footings, strap footings, ring footings, rafts, piles and pile caps and piers.

P Raghuveer Rao

Bowles, J.E. Foundation analysis and design. 5th Edn., McGraw Hill, 1996
Indian Standard Codes

CE 221 (AUG) 3:0
Earthquake Geotechnical Engineering

Introduction to engineering seismology, Plate tectonics, Seismic wave propagation, Earthquake magnitude, Ground motion, Seismic hazard analysis, Ground response analysis, Soil-structure interaction, Local site effects, Dynamic properties of soils, Liquefaction phenomena, analysis of pore pressure development. Laboratory and in-situ testing for seismic loading, analysis and design of slopes, foundations, earth retaining structures and dams for seismic loading, Case histories, Earthquake hazard mitigation techniques.

G Madhavi Latha

Geotechnical Earthquake Engineering By Steven L. Kramer, Pearson Education, 2003.
Geotechnical Earthquake Engineering Handbook, Robert W. Day, McGraw-Hill, 2002.

CE 227 (JAN) 3:0
Engineering Seismology

Introduction to earthquake hazards. Strong ground motions, tsunamis, landslides, liquefaction. Overview of plate tectonics and earthquake source mechanisms. Theory of wave propagation. Body waves and surface waves. Concepts of seismic magnitudes and intensity. Seismic station. Sensors and data loggers, mechanical and digital sensors. Interpretation of seismic records – acceleration, velocity and displacement. Regional seismicity and earthquakes in India. Seismic zonation – scales, macro and micro, attenuation,

recurrence relation. Seismic hazard analysis - deterministic and probabilistic. Site characterization – different methods and experiments. Local site effects, ground motion amplifications. Development of response/design spectrum. Liquefaction hazard assessments. Integration of hazards using GIS. risk and vulnerability Studies.

P Anbazhagan

Earthquake Engineering – From Engineering Seismology to Performance Based Engineering, Edited by Bozorgnia, Y. and Bertero, V.V., CRC Press Washington 2004.
Leon Reiter, Earthquake hazard Analysis – Issues and Insights, Columbia University Press New York 1990.
Steven L Kramer, Geotechnical Earthquake Engineering, Pearson Education, 2003.

CE 231 (AUG) 3:0
Forensic Geotechnical Engineering

Introduction, Definition of a Forensic Engineer, Types of Damage, Planning the Investigation, investigation methodology, Collection of Data, Distress Characterization, Development of Failure, Hypothesis, Diagnostic Tests, Back Analysis, Technical Shortcomings, Legal Issues Reliability Aspects, Observation Method of Performance Evaluation, Case Histories related to settlement of Structures, lateral movement, backfill settlements, causes due to soil types such as collapsible soil, expansive soil, soluble soils, slope Failures and landslides, debris flow, slope softening and creep, trench collapses, dam failures, foundation due to earthquakes, erosion, deterioration, tree roots, groundwater and moisture problems, groundwater problems, retaining failures problems, pavement failures and issues, failures in soil reinforcement and geosynthetics, development of codal provisions and performance based analysis procedures.

G L Sivakumar Babu

Bolton M (1991) A Guide to Soil Mechanics, Universities Press
Robert W. Day (2011) Forensic Geotechnical and Foundation Engineering, Second Edition, McGraw-Hill Companies, Inc.
Rao, V.V.S. and Sivakumar Babu, G.L (2016) Forensic Geotechnical Engineering, Springer Nature.

CE 279 (JAN) 3:0
Computational Geotechnics

Introduction to numerical modelling with focus on geotechnical aspects, basics of continuum mechanics, introduction to finite difference and finite element methods, constitutive modelling of linear elastic and elasto-plastic behaviour of soils, static & dynamic loads and boundary conditions applicable to dams and other structures, coding of finite element and finite difference problems using MATLAB, examples of solving for dam's response using the commercial Geotech software FLAC.

Swetha Veeraraghavan

Bathe, K.J., Finite Element Procedures in Engineering Analysis, Prentice-Hall,
Englewood Cliffs, NJ, 1982.
Wood, D.M., Soil Behavior and Critical State Soil Mechanics, Cambridge University
Press, New York, 1990.
Hai-Sui Yu, Plasticity and Geotechnics, Springer, 2006
Desai, C.S. and Christian, J.T. Eds. Numerical Methods in Geotechnical Engineering,
McGraw-Hill, 1977.

CE 209A (AUG) 3:0
Elastic Wave Propagation and Applications in NDE

At the end of the course, students will understand the mechanics of wave propagation including the governing equation for wave propagation in elastic solids in one, two and three dimensions, their solutions and different classifications based on wave types. They will learn the aspects relating reflection and transmission of waves at boundaries and the application of this concept to several Nondestructive test methodologies. They will also be introduced to spectral finite element analysis (SFEM) and modelling of wave propagation through SFEM. On completion of this course, the students will be able to explore, read and understand the literature on wave propagation topics of their interest.

Vivek Samu

Wave propagation in Elastic Solids, J.D. Achenbach (1973)
Ultrasonic Guided Waves in Solid Media, J.L. Rose, Cambridge University Press, 2014
Ultrasonic Nondestructive Evaluation, Tribikram Kundu, CRC Press, 2004
Wave Propagation in Structures, James F. Doyle, Second Edition, Springer, 1997

Electives in Structural Engineering

CE 228N (AUG) 3:0
Introduction to the Theory of Plasticity

The uniaxial tensile test & Bauschinger effect; Dislocations and the physical basis of plasticity; slip; dislocation mechanics, stress field and energy of a Volterra dislocation; 1D network models of plasticity and overstress viscoplasticity; structure of phenomenological plasticity theories; internal variables; yield criteria (Tresca, von Mises, Mohr-Coulomb, Drucker-Prager); geometry of yield surfaces; Levy Mises equations; flow rules; plastic/ viscoplastic potentials; consistency condition; elastoplastic tangent modulus; isotropic and kinematic hardening; back-stress tensor; Drucker's postulate; Principle of maximum plastic dissipation; associativity; POMPD as a nonlinear optimization problem; convexity; normality; uniqueness; selected elastic-plastic boundary value problems (tension and torsion of tubes and rods, pressurized thin and thick spherical shells); collapse; unloading and residual stresses; advanced hardening models; introduction to computational plasticity; integration of plasticity models; return mapping; principle of virtual work; overview of finite elements for plasticity; overview of topics in advanced plasticity.

Narayan K Sundaram

Theory of Plasticity, J. Chakrabarty, 2006 (3rd ed.), Butterworth-Heinemann
Plasticity Theory, J. Lubliner, 2008 ed., Dover
Computational Inelasticity, J.C. Simo, T.J.R. Hughes, 2000, Springer; Corr. edition

Prerequisites:
None, but a background grad-level solid mechanics course (CE 204 or ME 242) is strongly recommended.

CE 229 (JAN) 3:0
Non-Destructive Evaluation Methods for Concrete Structures

Planning and interpretation of in-situ testing of concrete structures; Surface hardness methods; Fundamental bases and methodologies of non-destructive evaluation (NDE) techniques related to concrete structures; NDE methods for concrete testing based on sounding: Acoustic emission (AE) testing of concrete structures; NDE methods for concrete testing based on sounding: Ultrasonic pulse velocity (UPV) methods; Partially destructive strength tests related to concrete; cores; Examples of UPV corrections for reinforcement; examples of evaluation of core results

R Vidya Sagar

J. H. Bungey and S. G. Millard (1996) Testing of concrete in structures. Blackie Academic & Professional, 1996, chapman & Hall publishers.
V. M. Malhotra and N. J. Carino (2005) Handbook on Nondestructive Testing of Concrete Ed. by V.M. Malhotra and N.J. Carino., CRC publishers.
C. V. Subramanian (2016) Practical Ultrasonics., Narosa publishers
C. U. Gross and M. Ohtsu (2008) Acoustic Emission Testing., Springer-Verlag Berlin Heidelberg
JSNDI (2016) Practical Acoustic Emission testing. Springer Japan 2016.

CE 235 (JAN) 3:0
Optimization Methods

Basic concepts, Kuhn-Tucker conditions, linear and nonlinear programming, treatment of discrete variables, stochastic programming, Genetic algorithm, simulated annealing, Ant Colony and Particle Swarm Optimization, Evolutionary algorithms, Applications to various engineering problems.

Ananth Ramaswamy

Arora, J.S. Introduction to Optimization, McGraw-Hill (Int. edition)1989.
Rao, S.S., Optimization: Theory and Applications. Wiley Eastern, 1992
Current Literature.

CE 236 (AUG) 3:0
Fracture Mechanics

Introduction; Linear Elastic Fracture Mechanics; Design based on LEFM; Elasto-Plastic Fracture Mechanics; Mixed Mode Crack Propagation; Fatigue Crack Propagation; Finite Elements in Fracture Mechanics.

R Vidya Sagar

T. L. Anderson, Fracture Mechanics, CRC press, Fourth Edition, 2017, Boca Raton, Florida
David Broek, Elementary Fracture Mechanics, Sijthoff and Noordhoff, The Netherlands.
Prashanth Kumar, Elements of Fracture Mechanics, Wheeler Publishing, New Delhi.
J. F. Knott, Fundamentals of Fracture Mechanics, Butterworths, London.

CE 243 (AUG) 3:0
Bridge Engineering

Bridge types, aesthetics, general design considerations and preliminary design, IRC / AASHTO design loads, concrete bridge design - reinforced and prestressed girder bridges, steel bridge design Composite bridges, design of bridge bearings, Pier, Abutment and foundation; seismic and wind load analysis, analysis of cable supported bridge systems, bridge inspection and maintenance.

Ananth Ramaswamy

Barker and Puckett Design of Highway Bridges, John Wiley and Sons 2007

CE 250 (Jan) 3:0
Stability and Design of Steel Structures

Concepts and principles of stability of beam-columns- Differential equations for beam-columns, effects of concentrated lateral loads, effects of different end conditions such as built-in or elastic supports; continuous beams and columns with axial loads, torsion in Thin walled sections, Lateral buckling of beams, elastic buckling of rigid frames, arches; influence of material inelasticity and imperfections in the structural stability of member ; application of energy and numerical methods in critical buckling load assessments; design of structural steel thin walled members and built up sections.

Ananth Ramaswamy

Timoshenko, S. and Gere, J., "Theory of Elastic Stability" McGraw Hill.
Wai-Fa Chen and Lui, E.M., "Structural Stability: Theory and Implementation" Elsevier.
Bazant , Z.P.,and Cedolin, Luigi "Stability of Structures:. Elastic, Inelastic, Fracture and Damage Theories", Dover Publications.

CE 274 (Aug) 3:0 Earthquake Resistant design

J M Chandra Kishen

CE 297 (**AUG**) **3:0**
Problems in the Mathematical Theory of Elasticity

Introduction: Review of linear elasticity, equilibrium, compatibility, statements of 2D (plane strain / plane stress) and 3D elastic BVPs, Review of Airy stress functions. Functions of a complex variable: Introduction to holomorphic and sectionally holomorphic functions. Laurent series, contour integrals, generalized Cauchy integral formulae. Bi-harmonic equation in the complex plane. Kolosov-Muskhelishvili formulation for planar elasticity. Conformal mapping. The Riemann-Hilbert problem. Analysis of selected problems using complex variable methods: Plate with an elliptic hole. The slit infinite plane. Singular and distributed solutions for halfplanes, disks, and plates with holes. Contact of a rigid punch and halfplane. Multivalued displacements and disloca-tions. Planar inclusions. Other topics as time permits (e.g. anisotropic elasticity)

Prerequisites : Graduate-level solid mechanics (CE-204 / ME-242 or equivalent) with a grade of B or higher, or instructor consent.

Narayan K Sundaram

Current and historic literature

CE 210A (AUG) 3:0
Thermodynamic Modelling of Cementitious Systems

A brief recap of cement chemistry, cement hydration and concrete technology (influence of binder chemistry on reaction products, concrete microstructure, mineral and chemical admixtures, microstructure and pore structure; concrete mechanics and durability); A brief recap of thermodynamics (zeroth law, first law, second law, activity); Law of mass action; Mass Balance calculations; Determination of Reactivity; Fundamentals of thermodynamic modelling; Predicting reaction products; Predicting pore solution compositions; Predicting pore volumes; Kinetic modelling; Structure-property relations in concrete.

Prerequisites: The participants are expected to have basic knowledge of cement hydration and concrete durability. Undergraduate level courses on Concrete Technology and Civil Engineering Materials are recommended. Registration will only be permitted after an initial discussion with the instructor.

Keshav Bharadwaj

References and Textbooks:

1. “Concrete: Microstructure, Properties, and Materials” by P.K. Mehta and Paulo J. M.

Monteiro, 4th Edition (2014), McGraw Hill Education (India), New Delhi, India.

2. “Introduction to the Thermodynamics of Materials” by David R. Gaskell and David E. Laughlin, 6th Edition (2018), CRC Press, Boca Raton, FL, USA

3. Online tutorials

4. Recent literature

CE 211A (JAN) 3:0
Concrete Durability and Repair

Introduction to concrete; Concrete constituents and manufacture; Introduction to cement and concrete microstructure; Transport through concrete - physics and measurement; Dimensional Changes in Concrete - shrinkage and creep; Corrosion of steel and repair, role of chlorides; Carbonation; Aggregates and durability of concrete; Freeze-thaw and salt-scaling; Sulphate attack and delayed ettringite formation, physical salt attack; Effect of fire, acid attack, abrasion and cavitation; Concrete quality control, workmanship and choice of materials; Biological processes and mic; Non-destructive and laboratory test-methods; Inspection, repair and protection of structures; Durability based design of structures.

Keshav Bharadwaj

Mehta P.K. and Monteiro P.J.M., Concrete Microstructure Properties and Materials, Fourth Edition, Tata McGraw Hill, 2014
Newman J. and Choo B.S., Advanced Concrete Technology - Testing and Quality, Elsevier, 2003
Neville A.M., Properties of Concrete, Fourth Edition, Pearson, 2006
Wilson M., Paul D. Tennis, Design and Control of Concrete Mixtures, Seventeenth Edition, Portland Cement Association, 2021

CE 240 (JAN) 3:0
Uncertainty Modeling and Analysis

Deterministic vs nondeterministic perspectives. Sources of uncertainty. Epistemic vs. aleatoric uncertainty. Data driven vs. physics driven uncertainty modelling. Introductory probability and statistics, point estimation, hypothesis testing, time series. Modelling: connecting data to the probabilistic models. Discretization of random fields. Tools for uncertainty propagation. Computational aspects of uncertainty propagation.

Debraj Ghosh

Prerequisite: Familiarity with Probability and Statistics, Computer programming

References: Will be given during the course

Electives in Water Resources Engineering

CE 213 (JAN) 3:0
Systems Techniques in Water Resources Engineering

Optimization Techniques - constrained and unconstrained optimization, Kuhn-Tucker conditions, Linear Programming (LP), Dynamic Programming (DP), Multi-objective optimization, applications in water resources, water allocation, reservoir sizing, multipurpose reservoir operation for hydropower, flood control and irrigation. Review of probability theory, stochastic optimization. Chance constrained LP, stochastic DP. Surface water quality control. Simulation - reliability, resiliency and vulnerability of water resources systems.

D Nagesh Kumar

Loucks, D.P., Stedinger, J.R. and Haith, D.A., Water Resources Systems Planning and Analysis, Prentice Hall, Englewood Cliffs, N.J, 1981.
Vedula, S. and Mujumdar, P. P., Water Resources Systems: Modelling Techniques Tata-McGraw Hill, 2005.
Srinivasa Raju, K and Nagesh Kumar, D., Multicriterion Analysis in Engineering and Management, PHI Ltd., New Delhi, 2010.

CE 247 (AUG) 3:0
Remote Sensing and GIS for Water Resources Engineering

Basic concepts of remote sensing. Airborne and space borne sensors. Digital image processing. Geographic Information System. Applications to rainfall - runoff modeling. Watershed management. Irrigation management. Vegetation monitoring. Drought and flood monitoring. Environment and ecology. Introduction to digital elevation modeling and Global Positioning System (GPS). Use of relevant software for remote sensing and GIS applications.

D Nagesh Kumar

Lillesand T.M. and Kiefer R.W. Remote Sensing and Image Interpretation, John Wiley & Sons, 2000.

Sabins, F.F. Remote Sensing - Principles and Interpretation, Freeman & Co., New York, 1986.
Heywood, I., Cornelius, S., and Carver, S. An Introduction to Geographical Information Systems, Pearson Education, 1998.

CE 249 (AUG) 3:0
Water Quality Modeling

Basic characteristics of water quality, stoichiometry and reaction kinetics. Mathematical models of physical systems, completely and incompletely mixed systems. Movement of contaminants in the environment. Water quality modeling in rivers and estuaries - dissolved oxygen and pathogens. Water quality modeling in lakes and ground water systems.

M Sekhar

Chapra, S.C., Surface Water Quality Modeling, McGraw Hill, 1997.
Tchobanoglous, G., and Schroeder, E.D., Water Quality, Addison Wesley, 1987.

Electives in Transportation Systems Engineering

CE 262 (JAN) 3:0
Public Transportation Systems Planning

Modes of public transportation and application of each to urban travel needs; comparison of transit modes and selection of technology for transit service; transit planning, estimating demand in transit planning studies, demand modeling, development of generalized cost, RP & SP data and analysis techniques; functional design and costing of transit routes, models for planning of transit routes, scheduling; management and operations of transit systems; integrated public transport planning; operational, institutional, and physical integration; models for integrated planning; case studies.

Ashish Verma

A. Verma and T. V. Ramanayya, Public Transport Planning and Management in Developing Countries, CRC Press, 2014
VuchicVukan R., Urban Transit: Operations, Planning and Economics, Prentice Hall, 2005.
Gray G. E., and Hoel L. A., Public Transportation, Prentice Hall, 1992.

CE 269 (AUG) 3:0
Traffic Engineering

Traffic flow elements and its characterization: vehicle characteristics, human factors, infrastructure elements, capacity and LoS concepts, Highway Capacity Manual (HCM) methods. Uninterrupted Traffic Flow: speed-flow-density relationships, multi-regime models, car-following, lane-changing, simulation framework. Interrupted Traffic Flow: signal design, shock-wave theory, gap-acceptance behavior, delay and queue analysis. Design of traffic facilities: expressways, signalized and un-signalized intersections, interchanges, parking, signs and markings.

Vijay Gopal Kovvali and Ashish Verma

Roess, R.P., Prassas E.S. & McShane, W.R. (2010), Traffic Engineering, Prentice Hall, USA.
May, A. D. (1990), Traffic Flow Fundamentals, Prentice Hall, USA.
Highway Capacity Manual (2010), Transportation Research Board, USA.
Kadiyali, L. R. (2000), Traffic Engineering and Transport Planning, Khanna Publishers, India.
Salter, R J. & Hounsell, N. B. (1996), Highway Traffic Analysis and Design, Macmillan Education, UK.

CE 207A (AUG) 3:0
Characterization of Bituminous Materials

Introduction and overview of mixture design; chemical, physical, and rheological properties of asphalt binder; behavior, testing, and selection of aggregates; design of asphalt mixtures, compaction and properties; common distresses and characterization of distresses; additives and surface properties; engineered materials, warm mixtures, RAP, and other special mixtures.

Satyavati Komaragiri

F.L. Roberts, P. S. Kandhal, E.R. Brown, D-Y. Lee and T. W. Kennedy, 2nd Edition, NAPA Research and Education Foundation, 1996.
Dallas N. Little, David H. Allen, and Amit Bhasin. Modeling and design of flexible pavements and materials, Springer, 2018.
C. E. G. Justo, S.K. Khanna, and A. Veeraragavan, Highway engineering, Nem Chand & Bros, 2017.

SL 222 (Aug) 3:1 Transportation Demand and Supply Modeling

Travel demand-supply interactions and equilibrium; Aggregate modeling methods for travel demand analysis (generation, spatial and temporal distribution, and modal split of travel); Statistical and econometric methods for transportation data analysis; Discrete choice models for travel behaviour analysis; Agent-based methods for travel demand analysis; Traffic assignment in transportation networks; Basics of Convex optimization; Shortest path algorithms; Wardrop user equilibrium; System optimum; Link-based algorithms and their implementation.

Abdul Pinjari and Tarun Rambha

- J. de D. Ortuzar and L.G. Willumsen, Modelling Transport (4th edition), John Wiley and Sons, 2011.
- F. Koppelman and C.R. Bhat. A Self-Instructing Course in Mode Choice Modeling: Multinomial and Nested Logit Models, 2006.
- Boyles, S. D., Lownes, N. E., & Unnikrishnan, A. (2020). Transportation network analysis. *Vol. I: Static and Dynamic Traffic Assignment*.
- *S*heffi, Y. (1985). Urban Transportation Networks. Prentice-Hall.

Brief description of lab component: The lab component will involve the implementation of travel demand and supply models and algorithms using R, Python, NetworkX, and QGIS-based software tools.