BULLETIN ON COURSES OF STUDY

2023-2024

M. TECH AND PHD PROGRAMMES

Department of Civil Engineering

IIT Bombay

BULLETIN ON COURSES OF STUDY

2023-2024

CONTENTS

CIVIL ENGINEERING DEPARTMENT AT IIT BOMBAY

The Department of Civil Engineering has been a part of IIT Bombay since its inception in 1958. Over the years, the department has grown tremendously, and is now recognized as one of the best and major engineering departments in the country and ranked highly in the World for Civil Engineering. With its multifaceted faculty, it provides high quality teaching and instruction at both UG and PG as well as Ph. D levels. The department has strong focus in the broad research areas of seven specializations, namely, Transportation Systems Engineering (CE-1), Geotechnical Engineering (CE-2), Water Resources Engineering (CE-3), Structural Engineering (CE-4), Ocean Engineering (CE-5), Remote Sensing (CE-6), and Construction Technology and Management (CE-7). Besides, the department is actively involved in basic and applied research and consultancy and provides high quality technical advisory support through various R & D projects and consultancy to various organizations. Civil Engineering Department continues to maintain and cultivate its strong links with the public sector companies, planning agencies, public service providers, consultation firms, construction industry, academic and research institutions both within and outside the country.

The department has attracted significant amount of sponsored research funding from government and private agencies and is delivering excellent output in terms of implementable solutions and large number of research publications in high quality peer reviewed journals having high impact factor. The department disseminates the knowledge gained from its high-quality research through training programs and interacts with world renowned personalities through workshops and conferences. The students and faculty members have won prestigious national and international awards/fellowships/recognitions and continuing to bring laurels to the Institute and nation. As per Quacquarelli Symonds (QS) World University Rankings of 2022, the department is ranked 1st in India and ranked in range of 51-100 in the world ranking for the domain / area of Civil and Structural Engineering.

Contact Address: The Head, Department of Civil Engineering,
Indian Institute of Technology Bombay,
Powai, Mumbai - 400076, India.
Phone: +91-22-2576 7301
E-Mail: hod[at]civil.iitb.ac.in
Website: www.civil.iitb.ac.in

POST GRADUATE (PG) PROGRAMS AT CIVIL ENGINEERING DEPARTMENT

The Department of Civil Engineering offers post-graduate programmes in the following seven areas of specialization.

1. Transportation Systems Engineering
2. Geotechnical Engineering
3. Water Resources Engineering
4. Structural Engineering
5. Ocean Engineering
6. Remote Sensing
7. Construction Technology and Management

The department admits total about 93 M.Tech. students every year into the above specializations. Each specialization has well-equipped laboratories with excellent advanced instrumentation and equipment for research and teaching. State-of-art computational facilities are available in the departmental computational laboratory which is equipped with new servers, workstations and personal computers. All the computers in the department are networked with the institute Local Area Network and are connected to internet through IIT Bombay's proxy servers.

The students of the department use the Central Library that has more than 440,000 books and volumes, and subscribes more than 1800 current journals in Science, Engineering, Humanities and Social Sciences. Library cataloguing is fully computerized. The Department also has a library where all B. Tech., M. Tech. and Ph.D. Theses completed at the Department are available for reference. The department has about 51 faculty members, about 19 postdoctoral fellows and about 30 other technical and non-technical staff.

The department disseminates knowledge to working professionals regularly by organizing national and international conferences and workshops. Continuing Education Programme courses are also conducted by the Department on a regular basis. The faculty publishes extensively from the research and consultancy work carried out in the Department. More than 275 research journal papers are published every year by the faculty members and students in all areas of Civil Engineering in the national and international journals. Additionally, faculty and students are involved in publishing papers in various prestigious conference proceedings, book chapters, patents etc.

The M.Tech. Programme spans for a period of two academic years. The rules and regulations pertaining to M.Tech Programme at IIT Bombay can be found at:

https://www.iitb.ac.in/newacadhome/MTechRules.pdf

COURSES FOR PHD STUDENTS

The courses offered to M.Tech. students under various specializations are also open to the PhD students where the courses are relevant to their research area, subject to the rules as prescribed by IIT Bombay. The rules pertaining to PhD programme at IIT Bombay can be found at: https://www.iitb.ac.in/newacadhome/phdRules.pdf

COURSE WORK REQUIREMENTS IN CIVIL ENGINEERING

The minimum course requirement for a PhD student with an M.Tech. Degree is 3 - M.Tech. level courses, one seminar and communication skills. Thus, the minimum credit requirement in general would be 22. However, the same number may be reduced to 16 credits if the candidate has undergone relevant courses of IIT, subjected to approval of the competent authority. Every PhD student must maintain a minimum grade requirement from the courses with minimum CPI of 7.0 out of 10 scale at the end of the course work to continue in the PhD program. In addition to the course work requirement, the students need to take a two-stage qualifier examination. Successful completion of the course work and qualifier will lead to confirmation of the student's PhD registration.

QUALIFIER REQUIREMENTS IN CIVIL ENGINEERING

For the confirmation of a candidate's PhD registration, a two-stage qualifier examination in held.

Stage-1: The "credit seminar" will form Stage-1. This should be completed before the end of the first semester of joining. The credit seminar should be oriented towards formulation of the research proposal. It should include identification of the research topic and its importance, literature review and appraisal of current state-of-the-art, gaps in the area and motivation of the proposed work.

Stage 2: A "PhD Qualifier Examination" will form the Stage-2 of the qualifier. This should be conducted before the end of the second semester of joining. This PhD Qualifier Examination will be an oral examination conducted for evaluation of candidate's aptitude towards carrying out the proposed research work. The knowledge of the candidate in the basic subject areas of the proposed research will be tested by the examiners in the PhD Qualifier Examination.

QUALIFIER REQUIREMENT FOR STUDENTS CONVERTING FROM M.TECH. PROGRAM TO PHD

M.Tech students with minimum level of grades in the coursers with minimum CPI 8.0 out of 10 scale can convert to M.Tech. + PhD dual degree program. In such cases, the students have to only clear the stage-2 of the qualifier examination for the confirmation of their registration. The student has to appear for PhD qualifier examination within six months of the date of conversion from M.Tech. to PhD and should complete it within a maximum period of nine months from the date of conversion. https://www.iitb.ac.in/newacadhome/DDMPhDd.pdf

M.TECH IN TRANSPORTATION SYSTEMS ENGINEERING

Course Structure

Semester	I	II	III	IV	Total Credits
Core Courses	20	4	-	-	24
Elective Courses	12	24	-	-	36
Institute Electives	-	6	-	-	6
Laboratories	-	-	-	-	-
Seminar	-	4	-	-	4
R&D Project	-	-	-	-	0
Communication skills	-	6*	-	-	6
Course Total	32	38+6*	0	0	**70+6***
Project			48	42	90
Total Credits	32	38+6*	48	42	**160+6***

* **Pass or fail course (PP/NP)**

Sem.	*Course Name*	*L T P*	*Credits*	*Core/ Elective*
I	CE-751 Urban Transportation Systems Planning	3-0-0	6	C
	CE-740 Traffic Engineering	3-0-0	6	C
	CE 742 Pavement Systems Engineering	3-0-0	6	C
	CE 681 Advance Pavement Engineering Lab	0-0-2	2	C
	Elective I	3-0-0	6	E
	Elective II	3-0-0	6	E
	Semester total credits		**32**	
II	CE-694 Seminar		4	C
	CE 699 Transportation Systems Studio	0-0-4	4	C
	CE-899 Communication skills*	1-2-0	6*	C
	Institute elective	3-0-0	6	E
	Elective III	3-0-0	6	E
	Elective IV	3-0-0	6	E
	Elective V	3-0-0	6	E
	Elective VI	3-0-0	6	E
	Semester total		**38+6***	
III	CE-797 Dissertation I Stage		48	C
IV	CE-798 Dissertation II Stage		42	C
	Program total credits		**160+6***	

* **Pass or fail course (PP/NP)**

List of M. Tech (Transportation Systems Engineering) Electives

1. CE-605 Applied Statistics
2. CE-630 GIS in Civil Engineering
3. CE-744 Analysis of Transportation Systems
4. CE-780 Behavioral travel modeling
5. CE-771 Optimization in Civil Engineering
6. CE-772 Pavement materials
7. CE-773 Geometric Design and Analysis of High-Speed Roadways
8. CE-774 Traffic Management and Design
9. CE-776 Transportation project evaluation and decision making
10. CE-775 Airport planning and design
11. CE 749 Freight Transportation Planning and Logistics

M.TECH IN GEOTECHNICAL ENGINEERING

Course Structure

Semester	I	II	III	IV	Total Credits
Core Courses	12	-	-	-	12
Elective Courses	18	24	-	-	42
Institute Electives	-	6	-	-	6
Laboratories	4	-	-	-	4
Seminar	-	4	-	-	4
R&D Project	-	-	-	-	0
Communication skills	6*	-	-	-	6*
Course Total	34+6*	34	0	0	68+6*
Project	-	-	48	42	90
Total Credits	34+6*	34	48	42	158+6*

* **Pass or fail course (PP/NP)**

Sem.	*Course Name*	*L T P*	*Credits*	*Core/ Elective*
I	CE-782 Advanced Soil Mechanics	3-0-0	6	C
	CE-781 Advanced Foundation Engineering	3-0-0	6	C
	CE-643 Experimental Geotechnics	0-0-4	4	C
	CE-899 Communication skills*	1-2-0	6*	C
	Elective I	3-0-0	6	D
	Elective II	3-0-0	6	D
	Elective III	3-0-0	6	D
	Semester total credits		**34+6***	
II	CE-694 Seminar*		4	C
	Elective IV	3-0-0	6	D
	Elective V	3-0-0	6	D
	Elective VI	3-0-0	6	D
	Elective VII	3-0-0	6	D
	Institute elective	3-0-0	6	I
	Semester total		**34**	
III	CE-797 Dissertation I Stage		**48**	C
IV	CE-798 Dissertation II Stage		**42**	C
	Program total credits		**158+6***	

* **Pass or fail course (PP/NP)**

List of M. Tech (Geotechnical Engineering) Electives

1. CE-632 Ground Improvement
2. CE-633 Soil Structure Interaction
3. CE-637 Rock Mechanics
4. CE-641 Environmental Geomechanics
5. CE-645 Geotechnical Centrifuge Modelling
6. CE-647 Soil Dynamics and Machine Foundations
7. CE-648 Finite Element Methods in Geotechnical Engineering
8. CE-652 Foundations of Offshore Structures
9. CE-656 Plasticity and Application in Geomechanics
10. CE-677 Design and Testing of Pile Foundations
11. CE-683 Marine Geotechnical Engineering
12. CE-684 Advanced Geotechnical Earthquake Engineering
13. CE-688 Risk Assessment & Management in Geotechnical Engineering
14. CE-702 Geotechnical Constitutive Models
15. CE-746 Reinforced Earth and Geotextiles

M.TECH IN WATER RESOURCES ENGINEERING

Course Structure

Semester	I	II	III	IV	Total Credits
Core Courses	12	12	-	-	24
Elective Courses	18	12		-	30
Institute Electives	-	6	-	-	6
Laboratories	4	-	-	-	4
Seminar	-	4	-	-	4
R&D Project	-	-	-	-	0
Communication skills	6*	-	-	-	6*
Course Total	34+6*	34	-	-	68+6*
Project	-	-	48	42	90
Total Credits	34+6*	34	54	42	158+6*

* **Pass or fail course (PP/NP)**

Sem.	Course Name	L T P	Credits	Core/ Elective
I	CE-731 Mechanics of Fluid Flow	3-0-0	6	C
	CE-626 Groundwater Systems Planning and Management	3-0-0	6	C
	Elective I	3-0-0	6	E
	Elective II	3-0-0	6	E
	Elective III		6	E
	CE-675 Advanced Experimental Fluid Mechanics	0-0-4	4	C
	CE-899 Communication skills*	1-2-0	6*	C
	Semester total credits		**34+6***	
II	CE-654 Advanced Hydrological Analysis and Design	3-0-0	6	C
	CE-676 Water Resources System	3-0-0	6	C
	Elective IV		6	E
	Elective V		6	E
	Institute elective		6	E
	CE-694 Credit Seminar		4	C
	Semester total		**34**	
III	CE-797 Dissertation I Stage		48	C
	Semester Total		**48**	
IV	CE-798 Dissertation II Stage		42	C
	Program total credits		**158+6***	

* **Pass or fail course (PP/NP)**

List of M. Tech (Water Resources Engineering) Electives

1. CE-605 Applied Statistics
2. CE-607 Numerical Techniques in Hydraulic Engineering
3. CE-608 Eco-hydro climatology
4. CE 658 Hydrogeomorphology
5. CE-667 Hydraulic Structures
6. CE-672 River Mechanics and Control Structures
7. CE-682 Finite Element Application To Flow Problems
8. CE-686 Probabilistic Methods in Hydrology
9. CE-736 Environmental Impact Analysis of Water Resources Systems
10. CE-738 Irrigation and Conveyance Network
11. CE-764 Hydro informatics
12. CE-765 Environmental Fluid Mechanics
13. CE-766 Watershed Management
14. CE-767 Hydrological Hazard Mitigation Management
15. CE-768 Urban Water and Environmental Management

**List of other possible departmental electives for M.Tech. (Water Resources Engineering)

16. CE-603 Numerical Methods
17. CE-630 GIS in Civil Engineering
18. CE-680 Mechanics of Water Waves
19. CE-701 Remote Sensing Technology
20. CE-710 Remote Sensing and GIS for Water Resources Management
21. CE-712 Digital Image Processing of Remotely Sensed Data
22. CE-769 Coastal and Ocean Environment

**Note: Students may choose any of these electives in consultation with the faculty advisor

M.TECH IN STRUCTURAL ENGINEERING

Course Structure

Semester	I	II	III	IV	Total Credits
Core Courses	12	6	-	-	18
Elective Courses	12	18	6	-	36
Institute Electives	-	6**	-	-	6
Laboratories	4	-	-	-	4
Seminar	-	4	-	-	4
R&D Project	-	-	-	-	0
Communication skills	-	6*	-	-	6
Course Total	28	34+6*	6	0	68+6*
Project	-	-	48	42	90
Total Credits	28	34+6*	54	42	158+6*

*** Pass or fail course (PP/NP)**

**** Institute elective may be taken in fourth semester instead of second semester**

Maximum of 2 Undergraduate-Level Electives can be taken by M.Tech. students

Sem.	Course Name	L T P	Credits	Core/Elec.
I	CE-616 Structural Dynamics	3-0-0	6	C
	CE-623 Advanced Solid Mechanics	3-0-0	6	C
	Elective I		6	E
	Elective II		6	E
	CE-627 Structural Design Lab	0-0-4	4	C
	Semester total credits		**28**	
II	CE-794 Credit Seminar		4	C
	CE-620 Finite-Element-Methods	3-0-0	6	C
	Elective III		6	E
	Elective IV		6	E
	Elective V		6	E
	Institute elective**		6	E
	CE-899 Communication skills*	1-2-0	6*	C
	Semester total		**34+6***	
III	Elective VI		6	E
	CE-797 Dissertation I Stage		48	C
	Semester Total credits		**54**	
IV	CE-798 Dissertation II Stage		**42**	C
	Program total credits		**158+6***	

*** Pass or fail course (PP/NP), **Institute elective may be taken in fourth semester instead of second semester**

List of M. Tech (Structural Engineering) Electives

1. CE 324 Engineering Law
2. CE 403 Design of Structures III
3. CE 448 Prestressed-Concrete
4. CE 482 Construction Management
5. CE 602 Design of Offshore Structures
6. CE 603 Numerical Methods
7. CE 605 Applied-Statistics
8. CE 610 Introduction-to-Earthquake-Engg.
9. CE 611 Advanced Structural Mechanics
10. CE 615 Structural-Optimisation
11. CE 617 Plates-and-Shells
12. CE 619 Structural-Stability
13. CE 621 Plastic-Analysis
14. CE 622 Reliability-Based-Civil-Engg.-Design
15. CE 624 Nonlinear-Analysis
16. CE 625 Analysis-of-Offshore-Structures
17. CE 629 Elastic Waves in Solids
18. CE 633 Soil Structure Interaction
19. CE 639 Green-Building-Design
20. CE 647 Soil Dynamics and Machine Foundations
21. CE 651 Bridge Engineering
22. CE 653 Structural Reliability and Risk Analysis
23. CE 679 Advanced Mechanics of Reinforced Concrete
24. CE 684 Advanced Geotechnical Earthquake Engineering
25. CE 713 Advanced Concrete Technology
26. CE 720 Non-destructive-Testing-of-Materials
27. CE 727 Construction Materials
28. CE 743 Condition Assessment and Rehabilitation of Structures
29. CE 771 Optimization in Civil Engineering
30. CE 781 Advanced Foundation Engineering

M.TECH IN OCEAN ENGINEERING

Course Structure

Semester	I	II	III	IV	Total Credits
Core Courses	12	12	-	-	24
Elective Courses	18	12	-	-	30
Institute Electives	-	6	-	-	6
Laboratories	4	-	-	-	4
Seminar	-	4	-	-	4
R&D Project	-	-	-	-	0
Communication skills	6*	-	-	-	6
Course Total	34+6*	34	0	0	68+6*
Project	-	-	48	42	90
Total Credits	34	34+6*	48	42	158+6*

* **Pass or fail course (PP/NP)**

Sem.	Course Name	L T P	Credits	Core/ Elective
I	CE-680 Mechanics of Water Waves	3-0-0	6	C
	CE-769 Coastal and Ocean Environment	3-0-0	6	C
	Elective I		6	E
	Elective II		6	E
	Elective III		6	E
	CE-706 Ocean Engineering Lab	0-0-4	4	C
	CE-899 Communication skills*	1-2-0	6*	C
	Semester total credits		**34+6***	
II	CE-708 Offshore Engineering	3-0-0	6	C
	CE-707 Coastal, Port and Harbour Engineering	3-0-0	6	C
	Elective IV		6	E
	Elective V		6	E
	Institute elective		6	E
	CE-694 Credit Seminar		4	C
	Semester total		**34**	
III	CE-797 Dissertation I Stage		48	C
IV	CE-798 Dissertation II Stage		42	C
	Program total credits		**158+6**	

* **Pass or fail course (PP/NP)**

List of M. Tech (Ocean Engineering) Electives

1. CE-602 Design of Offshore Structures
2. CE-603 Numerical Methods
3. CE-605 Applied Statistics
4. CE-607 Numerical Techniques in Hydraulic Engineering
5. CE-613 Concrete Technology
6. CE-616 Structural Dynamics
7. CE-620 Finite Element Methods
8. CE-622 Reliability based Civil Engineering
9. CE-625 Analysis of Offshore Structures
10. CE-633 Soil Structure Interaction
11. CE-667 Hydraulic Structures
12. CE-687 Offshore Construction
13. CE-701 Remote Sensing Technology
14. CE-712 Digital Image Processing of Remotely Sensed Data
15. CE-731 Mechanics of Fluid Flow
16. CE-764 Hydro-informatics
17. CE-765 Environmental Fluid Mechanics
18. CE-767 Hazard Mitigation Management
19. CE-770 Ocean Renewable Energy
20. CE-781 Advanced Foundation Engineering

M.TECH IN REMOTE SENSING

Course Structure

Semester	I	II	III	IV	Total Credits
Core Courses	12	-	-	-	12
Elective Courses	18	24	-	-	42
Institute Electives	-	6	-	-	6
Laboratories	4	-	-	-	4
Seminar	-	4	-	-	4
R&D Project	-	-	-	-	0
Communication skills	6*	-	-	-	6
Course Total	34+6*	34	0	0	68+6*
Project	-	-	48	42	90
Total Credits	34+6*	34	48	42	158+6*

* **Pass or fail course (PP/NP)**

Sem.	Course Name	L T P	Credits	Core/ Elective
I	CE-630 GIS in Civil Engineering	2-0-2	6	C
	CE-701 Remote Sensing Technology	3-0-0	6	C
	CE-703 Remote Sensing Lab	0-0-4	4	C
	Elective – I		6	E
	Elective – II		6	E
	Elective – III/R&D Project		6	E
	CE-899 Communication skills*	1-2-0	6*	C
	Semester total credits		**34+6***	
II	Elective IV		6	E
	Elective V		6	E
	Elective VI		6	E
	Elective VII		6	E
	Institute elective		6	E
	CE-694 Seminar		4	C
	Semester total		**34**	
III	CE-797 Dissertation I Stage		48	C
IV	CE-798 Dissertation II Stage		42	C
	Program total credits		**158+6**	

* **Pass or fail course (PP/NP)**

List of M. Tech (Remote Sensing) Electives

1. CE 605 Applied Statistics
2. CE 608 Eco-Hydro Climatology
3. CE 659 Advanced Surveying
4. CE 705 Photogrammetric Engineering
5. CE 710 Remote sensing and GIS for Water Resources Management
6. CE 712 Digital Image Processing of Remotely Sensed Data
7. CE 757 Remote Sensing of Thermal Radiation
8. CE 764 Hydroinformatics
9. CE 771 Optimization in Civil Engineering
10. CE 778 Microwave Remote Sensing: Principles and Applications in Civil Engineering
11. US 601 Urban Geomatics and Analytics
12. GNR 618 Remote Sensing and GIS Applications to Cryosphere
13. GNR 629 Advances in Geospatial Standards, Interoperability and Knowledge Discovery
14. GNR 636 Remote Sensing of Vegetation
15. GNR 640 Geospatial Statistics
16. GNR 644 Remote Sensing of Water Resources
17. GNR 647 Microwave Remote Sensing
18. GNR 652 Machine Learning for Remote Sensing-I

M.TECH IN CONSTRUCTION TECHNOLOGY AND MANAGEMENT

Course Structure

Semester	I	II	III	IV	Total Credits
Core Courses	14	6	-	-	20
Elective Courses	12	18	-	-	30
Institute Electives	-	6	-	-	6
Laboratories	4	4	-	-	8
Seminar	-	4	-	-	4
R&D Project	-	-	-	-	0
Communication skills	6*	-	-	-	6*
Course Total	30+6*	38	0	0	68+6*
Project	-	-	48	42	90
Total Credits	30+6*	38	48	42	158+6*

* **Pass or fail course (PP/NP)**

Sem.	Course Name	L T P	Credits	Core/ Elective
I	CE-713 Advanced Concrete Technology	3-0-0	6	C
	CE-717 Construction Planning and Control	3-0-2	8	C
	Elective I	3-0-0	6	E
	Elective II	3-0-0	6	E
	CE-718 Construction Materials Laboratory	0-0-4	4	C
	CE-899 Communication skills*	1-2-0	6*	C
	Semester total credits		**30+6***	
II	CE 719 Construction Contracts	3-0-0	6	C
	Elective III	3-0-0	6	E
	Elective IV	3-0-0	6	E
	Elective V	3-0-0	6	E
	Institute elective	3-0-0	6	E
	CE-722 Construction Management Studio	0-0-4	4	C
	CE-694 Seminar		4	C
	Semester total		**38**	
III	CE-797 Dissertation I Stage		48	C
IV	CE-798 Dissertation II Stage		42	C
	Program total credits		**158+6***	

* **Pass or fail course (PP/NP)**

List of M. Tech (CTaM) Electives

1. CE-603 Numerical Methods
2. CE-605 Applied statistics
3. CE-639 Green building design
4. CE-687 Offshore Construction
5. CE-707 Coastal, Port and Harbour Engineering
6. CE-720 Non Destructive Testing of Materials
7. CE-723 Construction equipments and personnel management
8. CE-725 Construction economics and finance
9. CE-727 Construction materials
10. CE-729 Quality and safety in construction
11. CE-741 Formwork for concrete structures
12. CE-743 Condition Assessment and rehabilitation of structures
13. CE-771 Optimization in civil engineering
14. CE-776 Transportation Project Evaluation and Decision Making
15. US-602 Fundamentals of urban science and engineering
16. US-603 Research methods for urban science
17. US-604 Management techniques for urban systems

DETAILS OF COURSES OFFERED BY TRANSPORTATION SYSTEMS ENGINEERING GROUP

CE 681 ADVANCE PAVEMENT ENGINEERING LAB

The advance pavement engineering lab will cover various experiment on different types of pavement materials and field related exercise. The students will get exposure of advance instruments such as dynamic shear rheometer (DSR) for characterization of asphalt binder, brookfield viscometer for measuring viscosity of binders at high temperature, dynamic cone penetrometer (DCP) for in-situ characterization of subgrade, light weight deflectometer (LWD) for evaluating in field strength of subgrade, aggregate image measurement system (AIMS) a digital method to capture shape characteristics of aggregates, MERLIN for field roughness measurement, Indirect tensile strength (ITS) on bituminous mixes, field demonstration of falling weight deflectometer

References

1. ASTM D7175: Standard Test Method for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer
2. ASTM D2170: Standard Test Method for Kinematic Viscosity of Asphalts
3. ASTM D6951 Standard Test Method for Use of the Dynamic Cone Penetrometer in Shallow Pavement Applications
4. ASTM E2583 -Standard Test Method for Measuring Deflections with a Light Weight Deflectometer (LWD)
5. ASTM D6931-Standard Test Method for Indirect Tensile (IDT) Strength of Asphalt Mixtures
6. ASTM D4694 -Standard Test Method for Deflections with a Falling-Weight-Type Impulse Load Device
7. AASHTO TP 81-12: Standard method of test for determining aggregate shape properties by means of digital image analysis. Washington, DC

CE 699 TRANSPORTATIONS SYSTEMS STUDIO

Creation of zonal and network layer with attribute data using open source GIS resource, Processing of transportation planning data of a metropolitan area (study area) and produce P-A matrices, O-D matrices, zonal planning data and other relevant summary information using latest computing tools. Calibration and validation of four step travel demand models for the study area using transportation planning software. Generation of appropriate land use and transport scenarios and forecasting of travel demand for these scenarios. Evaluation of alternatives based on sustainability indicators.

Traffic Data Collection and Analysis: Study of Driver Testing Unit, Spot Speed Study, Travel time and Delay Studies, Moving Observer Method, O-D Survey, Parking Usage Survey, Traffic Volume Study, Saturation Flow Measurement, Intersection Delay Measurement, Gap Acceptance Study at Uncontrolled Intersection.

References

1. Ortuzar, J.D. and Willumsen, L.G., Modelling Transport, John Wiley & Sons, Ltd., 2011.
2. User manuals of transportation planning software like CUBE/TransCAD/Emme.
3. Murthy, A. S. N and Mohle, H. R., Transportation Engineering Basics, American Society of Civil Engineers, New York, NY.

CE-740 TRAFFIC ENGINEERING

Traffic stream characteristics: Road user and vehicle characteristics, Fundamental parameters and relations, Traffic Stream Models, Modeling vehicle arrivals: Continuous distributions to model Headways and speed, Modeling vehicle arrivals: Discrete distributions to model flow and evaluation of distributions. Traffic measurement procedures: Measurement at a Point (Volume data collection and analysis, PCU, PHF etc), Measurement over a Short Section (Speed data collection and analysis), Measurement along a Length of Road (Density and travel time measurement and analysis), Moving Observer Method, Traffic forecasting and growth studies.

Microscopic traffic flow modeling: Car Following Models: Linear models, Car Following Models: Non-linear models, Lane Changing Models, Microscopic Traffic Simulation (Vehicle generation, model frame work, calibration and validations, statistical error analysis, applications). Macroscopic and mesocopic models: Traffic Flow Modeling Analogies: First order models, analysis of shock waves, Traffic Flow Modeling Analogies: Numerical implementation and higher order models, Cell transmission models, Cellular automata models: Discrete Simulation, Traffic Progression and Platoon dispersion.

Traffic Analysis and Management: Capacity and Level of Service concepts, Queuing models and applications, Basics of traffic management. Traffic intersection control: Principles of Traffic Control and Traffic Signs, Road Markings and Channelization, Uncontrolled Intersection: Gap acceptance and capacity concepts, Uncontrolled Intersection: Capacity and LOS analysis, Traffic Rotaries and Grade Separated Intersection. Traffic signal design: Design Principles of Traffic Signal, Evaluation of a Traffic Signal: Delay Models, Capacity and LOS Analysis of a Signalized I/S, Coordinated Traffic Signal, Vehicle Actuated Signals and Area Traffic Control

References:

1. **Adolf D. May**. Fundamentals of Traffic Flow. Prentice - Hall, Inc. Englewood Cliff New Jersey 07632, second edition, 1990.
2. **William R McShane, Roger P Roesss, and Elena S Prassas**. Traffic Engineering. Prentice-Hall, Inc, 2010.
3. **C. S. Papacostas and P. D. Prevedouros**. Fundamentals of Transportation Engineering. Prentice-Hall, New Delhi, 2009.
4. **C. Jotin Khisty, B. Kent Lall**, Transportation Engineering: An Introduction, Prentice Hall, 2003.
5. **Nicholas J. Garber, Lester A.** Hoel, Traffic and Highway Engineering, Cengage Learning, 2008.
6. **L. R Kadiyali.** Traffic Engineering and Transportation Planning. Khanna Publishers, New Delhi, 2008.

7. **D R Drew**. Traffic flow theory and control. McGraw-Hill Book Company, New York, 1968.
8. Highway Capacity Manual. Transportation Research Board. National Research Council, Washington, D.C., 2010.
9. **Fred L. Mannering, Scott S. Washburn and Walter P. Kilareski,** Principles of Highway Engineering and Traffic Analysis, Wiley India, 2011.
10. **A. S. Narasimha Murthy and Henry R. Mohle**. Transportation Engineering Basics, ASCE Press, USA. 2001.
11. **Thomas R. Currin,** Introductions to Traffic Engineering: A Manual for Data Collection and Analysis, Brooks/Cole Thomason Learning, Canada, 2001.

CE-742 Pavement Systems Engineering

Historical development of pavements. Introduction to different types of flexible pavements and design factors, Stress and strain analysis of flexible pavements. Introduction to multi-layers elastic theory. Analysis of pavements using software such as IITPAVE and KENPAVE, Stress and strain (deflection) analysis of rigid pavements. Analysis of pavements using software such as IITRIGID and KENLAYER, and others. Introduction to traffic loading, Understanding the concept of equivalent standard axle load (ESAL), Design of flexible pavements as per IRC 37, AASHTO, and AI methods for stabilized and un-stabilized base and subgrade layers. Design of rigid pavements as per IRC 58, AASHTO, and PCA methods for stabilized and un-stabilized base and subgrade layers. Introduction to different types of overlays on flexible and rigid pavements (PCC over HMA, HMA over PCC, HMA over HMA, PCC over PCC) and their design philosophy. Introduction to Benkelman Beam method and design of HMA overlay as per IRC 81. Introduction to white-topping (conventional, thin, ultra-thin) and their design as per IRC:SP-76-2008. Introduction to drainage requirement for pavements. Pavement performance evaluation and distresses. Data requirement and database development. Different types of rehabilitation and maintenance strategies. Construction practices for building flexible and rigid pavements

References:

1. **Y.H. Huang** "Pavement Analysis and Design," 2nd Edition, 2004, Pearson Prentice Hall, USA
2. **N. Delatte** "Concrete Pavement Design, Construction, and Performance" Taylor and Francis
3. **MORT&H**- Specifications for Roads and Bridges, 5th Revision, 2013.
4. **IRC: 37-2012**. "Tentative Guidelines for the Design of Flexible Pavements," Indian Road Congress, Delhi.
5. **IRC: 58-2011**. "Tentative Guidelines for the Design of Rigid Pavements," Indian Road Congress, Delhi.
6. **IRC: 81-2012**. "Guidelines for Strengthening of Flexible Road Pavements Using Benkelman Beam Deflection Technique," Indian Road Congress, Delhi
7. **IRC: SP: 76-2008**. "Tentative Guidelines for Conventional, Thin and Ultra-Thin White-topping," Indian Road Congress, Delhi.

CE-744 Analysis of Transportation Systems

Introduction: transportation systems, transportation innovations, social and economic impacts of transportation, Decision makers and their options, demand modelling and predictions, Modelling transportation systems. Analysis of network flows: Shortest-Path Problems, Maximum-flow Problems, Minimum-cost network flow problems, Minimum Spanning tree problem, The network simplex method

Static Traffic Assignment: All-or-nothing (AON) assignment, Link cost function, Equilibrium principles: User Equilibrium (UE) and System Optimal (SO), Formulations of SO and UE, Uniqueness of UE and SO formulations, multi-mode traffic assignment, Variable Demand assignment, Stochastic Traffic Assignment, Solution of traffic assignment problems.

Dynamic Traffic Assignment (DTA): Introduction, Point queue model, Cell Transmission Model, Whole link model, Dynamic user equilibrium (DUE), Analytical Models of DUE, Solution of DUE formulations, Simulation based DUE. Public Transportation Systems: Transit Assignment, Transit route network planning, performance monitoring, vehicle and crew scheduling. Decision Making in Transportation Networks: Congestion pricing, network design problems, prioritizing investment

Optional Topics: Integrated land-use and transport modelling, Activity based travel demand modelling, Entropy in the analysis of utility maximizing systems, Entropy maximization and gravity models

References:

1. **Cascetta, E.** Transportation Systems Analysis: Models and Application, Springer, 2009
2. **Sheffi, Y.**, Urban Transportation Networks: Equilibrium Analysis with Mathematical Programming Method. Prentice-Hall, Englewood Cliffs, 1985
3. **Ran, B., and Boyce, D. E.,** Modeling Dynamic Transportation Network - An Intelligent Transportation System Oriented Approach, Springer-Verlag, Heidelberg, 1996.
4. **de Neufville, R.** Applied Systems Analysis: Engineering Planning and Technology Management, McGraw Hill, 1990,
5. **Ortuzar J. Luis G. Willumsen**, L. G. Modelling Transport, Willey, 2011
6. **Manheim**, Analysis of Transportation Systems, MIT, USA, 1980.
7. **R.G. Weilson**, Entropy in Urban and Regional Transportation, McGraw-Hill, 1980.

CE 749 Freight Transportation Planning and Logistics

Introduction to freight models; interregional freight demand models: Gravity model, Input output (IO) model, Spatial general equilibrium model (SGEM); Freight generation and freight trip generation models; Introduction to network flow: Network flow representation, Shortest path algorithm, Assignment Problem, Transportation Problem, Minimum spanning tree, Minimum cost network flow problem, Network simplex method; Distribution structure: Micro-level distribution structure, Logistics costs, Drivers of distribution structure, Micro-level normative models, Warehouse location; Inventory theory and freight transport modeling: the economic order quantity (EQQ) model, Optimal shipment size; Urban freight models: Push models, Pull models; Vehicle routing problem; Fleet size optimization; Urban logistics: parcel delivery, e-commerce, food delivery; Freight consolidation centers; Humanitarian logistics during disasters

Reference Books:

1. L. Tavasszy and G. De Jong, Modeling freight tranport, Elsevier, 2014
2. M. Browne, S. Behrends, Woxenius, G. Giuiano, and J, Holguin-Veras, Urban Logistics, Kogan Page, 2019
3. E. Taniguchi and R. G. Thompson, City Logistics, Emerald Group Publishing, Limited, 2001

CE-751 URBAN TRANSPORTATION SYSTEMS PLANNING

Introduction and scope; Definition and basic principles; Transportation problems; Types of models; Planning methodologies; Conventional transportation planning process; Sustainable urban transportation planning process; Study area delineation and data collection, Travel demand modelling and forecasting; Trip generation - regression, category analysis; Trip distribution - growth factor, Fratar and Furness methods, Gravity model, intervening opportunities model, competing opportunities model; Modal split models - aggregate and disaggregate models; Traffic Assignment – network representation, graph theory applications in transport network analysis, highway assignment, transit assignment; Land use - transport interaction.

References:

1. Ortuzar, J.D. and and Willumsen, L.G., Modelling Transport, John Wiley & Sons, Ltd., 2011.
2. Meyer, M.D. and Miller, E.J., Urban Transportation Planning: A Decision-oriented Approach, Mc Graw Hill, New York, 2001.
3. Hutchinson, B.G., Principles of Urban Transport Systems Planning, McGraw Hill, New York, 1974.
4. Thomas, R., Traffic Assignment Techniques, Avebury Technical, Aldershot, 1991.
5. Yosef Sheffi, Urban transportation networks, Prentice-Hall, Englewood Cliffs, N.J., 1985.
6. Patriksson, M., The traffic assignment problem: models and methods, Dover Publications, New York, 2015.
7. Dickey, J.W., Metropolitan Transportation Planning, Taylor & Francis, 1983.

CE-771 Optimization in Civil Engineering

Linear Programming: Formulating linear programs, Graphical solution of linear programs, Special cases of linear program, The Simplex Method: Converting a problem to standard form, The theory of the simplex method, The simplex algorithm, Special situations in the simplex algorithm, Obtaining initial feasible solution, Duality and sensitivity analysis: Sensitivity analysis, Shadow prices, Dual of a normal linear program, Duality theorems, Dual simplex method

Integer Programming: Formulating integer programming problems, The branch-and-bound algorithm for pure integer programs, The branch-and-bound algorithm for mixed integer programs,

Non-linear Programming: Introduction to non-linear programming (NLP), Convex and concave functions, NLP with one variable, Line search algorithms, Multivariable unconstrained problems, constrained problems, Lagrange Multiplier, The Karush-Kuhn-Tucker (KKT) conditions, The method of steepest ascent, Convex combination method, penalty function methods, Quadratic programming, Dynamic programming, Evolutionary algorithms such Genetic Algorithm, concepts of multi-objective optimization, Markov Process, Queuing Models.

References:

1. **S. S. Rao**, Engineering Optimization: Theory and Practice, Wiley & Sons, New Jersey, 2009.
2. **F. H. Hillier and G. J. Liberman**, Introduction to Operations Research, Tata McGraw-Hill, 2010.
3. **W. L. Winston**, Operations Research: Applications and Algorithm, 4th Edition, Cengage Learning, 1994.
4. **A. Ravindran, D. T. Phillips, and J. J. Solberg**, Operations Research: Principles and Practice, John Wiley and Sons, 1987.
5. **K. Deb**, Optimization for Engineering Design, Prentice Hall, 2013.
6. **M. C. Joshi and K. M. Moudgalay**, Optimization: Theory and Practice, Narosa, 2004.
7. **K. Deb**, Multi-objective Optimization using evolutionary algorithms, John Wiley and Sons, 2009

CE-772 Pavement Materials

Introduction materials used for construction of subgrade, aggregate base course, bituminous base and surface courses of pavements. Understanding different tests: CBR, Durability, Freeze-Thaw, Resilient Modulus, soil-suction, relationship between DCP and CBR, CBR and Mr, and other parameters.

Characterization of aggregates for application in the pavements. Different types of rocks and aggregate production. Introduction to bitumen production and process, penetration and viscosity grading system for bitumen. Modification of bitumen using polymer and crumb rubber. Visco-elastic modeling (creep, mechanical models).

Introduction to Superpave grading system. Understanding mixing and compaction temperature of bitumen. Introduction to different types of mixes: Hot mix asphalt, cold mix asphalt. Understanding volumetric calculation. Marshall and Superpave mix designs of different types of mixes. Performance tests: fatigue and rutting tests, moisture induced damage and tests, resilient modulus, dynamic modulus/flow number/flow time. recycling, foam mix asphalt, recycle technologies, and warm mix asphalt, construction of perpetual pavements. Cement concrete mix design for pavements. Application of waste and locally materials for construction of pavements, quality control and assurance practices.

References:

1. **F.L. Roberts, P.S. Kandhal, E.R. Brown, D.Y. Lee, and T.W. Kennedy** "Hot Mix Asphalt Materials, Mixture Design and Construction," National Asphalt Pavement Association Research and Education Foundation, Second Edition, 1996, USA.
2. **Y.H. Huang** "Pavement Analysis and Design," 2nd Edition, 2004, Pearson Prentice Hall, USA
3. **Asphalt Institute**, SP-1: Performance Grading of Asphalt Binder – Specifications and Testing.
4. **MORT&H**- Specifications for Roads and Bridges, 5th Revision, 2013.

CE-773 Geometric Design and Analysis of High-Speed Roadways

Introduction to highway geometric design: Introduction to design guidelines and principals, Definition and scope of geometric design, Primary and dependent design controls.

Human and Vehicle Factors: Concepts and application of human factors in design and typical vehicle factors used in geometric design, Considerations of high speed highway facilities.

Sight distance: Overview of different types of sight distances, Vehicle acceleration/deceleration profile, friction coefficient, Sight distance index, Sight distance profile.

Horizontal and Vertical Profile: Factors influencing profile selection, Geometric design consistency, Designing horizontal curve for speed harmony, Curves for special situations, General principles of horizontal and vertical profile coordination and technique. Elements of highway cross sections.

Intersection and interchange design: Driver expectancy, Intersection and interchange configurations, Managing conflicts and operations, Acceleration/deceleration lane, Unconventional intersection and interchange design.

Introduction to highway design software: Designing highway geometric features using MxRoad or AutoCAD Civil 3D.

References:

1. A policy on geometric design of highways and streets, American Association of State Highway Officials, 2011.
2. Geometric design standards for urban roads in plains (IRC: 86-1983), The Indian Roads Congress, 1983.
3. Geometric design standards for rural (non-urban) highways (IRC: 73-1980), The Indian Roads Congress, 1980.
4. Guidelines for expressways – Part I, Ministry of Road Transport & Highways, 2010.
5. Roadside design guide, American Association of State Highway Officials, 2002.
6. Manual of geometric design standards for Canadian roads, Transportation Associations of Canada, 1986.
7. **Pline, J.L**., Traffic Engineering Handbook, Institute of Transportation Engineers, 2009.
8. Manual on Uniform Traffic Control Devices, Federal Highway Administration, 2009.
9. **S.K. Khanna and C.E.G. Justo**, Highway Engineering, Khanna Publishers, Roorkee, 2001

CE-774 Traffic Management and Design

Traffic Impact: Transportation noise: standards, measurements and mitigation strategies. Parking Studies: Statistics and analysis. Fuel Consumption and vehicle operating cost. Vehicular emission and Air quality modelling. Environmental impact assessment. Traffic safety: Accident studies, Accident data analysis, Statistical methods for data analysis, Road safety principles and practice, Identification of hazardous locations. Capacity and LOS analysis: Two Lane Highways, Urban Streets, Multilane Highways, Transit systems, Pedestrians and bicycles. Design of Traffic Facilities: Transit route selection and design, Pedestrians and bicycles facilities, Intersection, roundabout configuration and design, Interchange design, Freeway Operations and design. Traffic Management: Traffic Management Strategies, Traffic Management Techniques, Work zone traffic management, Traffic calming, Congestion studies and Road pricing. Automated Data Collection Systems: Intrusive systems such as loop detectors, pneumatic, etc., Non-Intrusive systems such as video, infra-red, In-vehicle systems: GPS, Mobiles, Tracking; Positioning systems for location services, Geographical information systems. Intelligent Transportation System: ITS: User services and architecture, ITS: Standards and evaluation, Public transport and bus priority, Travel time estimation methods, Artificial intelligence in advanced traffic and ITS.

References:

1. **C. S. Papacostas and P. D. Prevedouros**. Fundamentals of Transportation Engineering. Prentice-Hall, New Delhi, 2009.
2. **C. Jotin Khisty, B. Kent Lall**, Transportation Engineering: An Introduction, Prentice Hall.
3. **N. J. Garber, L. A. Hoel**, Traffic and Highway Engineering, Cengage Learning, 2008.
4. **L. R Kadiyali**. Traffic Engineering and Transportation Planning. Khanna Publishers, New Delhi, 2008.
5. Highway Capacity Manual. Transportation Research Board, Washington, D.C., 2010.
6. **F. L. Mannering, S. S. Washburn and W. P. Kilareski**, Principles of Highway Engineering and Traffic Analysis, Wiley India, 2011.
7. **T. R. Currin**, Introductions to Traffic Engineering: A Manual for Data Collection and Analysis. Brooks/Cole Thomason Learning, Canada, 2001.
8. **Hensher, D.A. and K.J. Button** (eds) (2003) Handbook of Transport and the Environment, Handbooks in Transport #4, Amsterdam: Elsevier.
9. **M A Chowdhary and A Sadek**. Fundamentals of Intelligent Transportation systems planning. Artech House Inc., US, 2003.
10. **Sussman, J.** Perspectives on Intelligent Transportation Systems (ITS). New York, NY: Springer, 2005.

CE-775 Airport Planning and Design

History and organisation of air transport, Aircraft characteristics related to airport design, Airport configuration, Airport planning and air travel demand forecasting, Geometric design of the airside, Structural design of airfield pavements, airport drainage, Airport airside capacity and delay, Planning and design of the terminal area, Airport access, airport lighting and marking, Financial strategies for implementation, Environmental impacts of airports.

References:

1. **R. Horonjeff and F. X. Mckelvey**, Planning & Design of Airports, 5th Edition, Mc Graw Hill, New York, 2010.
2. **N. Ashford, S. Mumayiz and P. H. Wright**, Airport Engineering, 4th Edition, John Wiley, New York, 2011.
3. International Civil Aviation Organization (ICAO) Design Manuals
4. Federal Aviation Administration (FAA) Advisory Circulars

CE-776 Transportation Project Evaluation and Decision Making

Introductory Concepts in Transportation Decision Making: Overall transportation project development, budgeting, financial planning, the process of transportation project development, models associated with transportation impact evaluation, procedural framework for transportation systems evaluation. Estimating Transportation Demand and Supply: Demand-supply equilibration, dynamics of transportation demand and supply, elasticity of travel demand and supply, classification of elasticity, consumer surplus and latent demand. Transportation Costs: Classification of transportation costs, transportation agency costs, transportation user costs, general structure and behavior of cost functions and road pricing. Vehicle Operating Costs: Road user cost study in India, components of VOC, factors affecting VOC, fuel consumption relationships, procedural framework for assessing VOC impacts. Value of Travel Time Savings: Categorizations of travel time, framework for assessing travel time impacts, economic concept of evaluation of travel time savings, issues relating to travel time value estimation, methodology for monetary evaluation of passengers travel time, review of work in India on passengers' travel time. Accidents Costs: Relevance of accident costing for a developing country, procedural framework for safety impact evaluation, review of alternative methodologies for accident costing, certain issues connected with accident costing, methods for estimating crash reduction factors, before and after case studies. Economic Evaluation of Transportation Projects: Economic significance of transport, performance measures in transportation evaluation, costs and benefits of transport projects, basic principles of economic evaluation, elements of engineering economics, methods of economic evaluation, benefit-cost ratio method, first year rate of return, net present value method, internal rate of return method, comparison of the various methods of economic evaluation, life cycle cost analysis, case studies, software packages for economic efficiency analysis.(HDM-4). Evaluation of Transportation Projects and Programs using Multiple Criteria: Basic concepts, Single vs. multiple criteria, Evaluation, decision-making, and optimization, Steps in multi-criteria decision-making, Case study: evaluation of metro rail projects using multi-criteria. Financial Analysis of Transportation Projects: Financial analysis of highway project case study, PPP based transport project case study.

References:

1. McCarthy, P. Transportation Economics, Blackwell, 2001
2. Meyer John Robert Meyer, Jos303251 A. G303263mez-Ib303241303261ez, William B. Tye, Clifford Winston, Essays in Transportation Economics and Policy, Brookings Institution Press, 1999.
3. Kenneth Duncan Boyer, Principles of transportation economics, Addison-Wesley, 1998
4. Kumares C. Sinha, Samuel Labi, Transportation Decision Making: Principles of Project Evaluation and Programming, Wiley,2007

5. C. Jotin Khisty, B. Kent Lall, Transportation Engineering: An Introduction, Prentice Hall, 2003.
6. L. R Kadiyali. Traffic Engineering and Transportation Planning. Khanna Publishers, New Delhi, 2008.
7. Indian Roads Congress, (1992) 302223Manual for Road Investment Decision Model302224, Special Publication 38, New Delhi.
8. Indian Roads Congress, (2007) 302223Manual on Economic Analysis of Highway Projects302224, Special Publication 30, New Delhi.
9. Stuart Cole, Applied Transport Economics: Policy, Management & Decision Making, Kogan Page Publishers, 2005
10. John Hibbs, Transport Economics & Policy: A Practical Analysis of Performance, Efficiency and Marketing Objectives, Kogan, 2003.
11. Herbert Mohring, Transportation economics, Ballinger, 1976.

CE-780 Behavioural Travel Modelling

Survey design and analysis: travel surveys and their role in transport planning, survey methods, precision and accuracy in travel surveys, sample design, sampling procedures, survey format, pilot surveys, survey administration, collection of stated and revealed preference data, survey data processing. Individual choice theory: binary choice models, multinomial and multi-dimensional choice models, issues in model specification, methods and statistics of model estimation with emphasis on maximum-likelihood estimation, aggregation and forecasting with discrete choice models, validation and transferability aspects, ordered multinomial models, nested logit models, introduction to advanced concepts such as accommodating unobserved population heterogeneity in choice behavior, mixed logit models, joint stated preference and revealed preference modeling, and longitudinal choice analysis; discrete choice models for integrated land use and transport modelling, review of state-of-the-art and future directions.

References:

1. **Ben-Akiva, M. and Lerman, S**, Discrete Choice Analysis: Theory and Application to Travel Demand, MIT Press, 1985.
2. **Oppenheim, N.,** Urban Travel Demand Modeling: From Individual Choices to General Equilibrium, John Wiley, 1995.
3. **Borsch Supan Axel** , Econometric analysis of discrete choice, Springer-Verlag, Berlin, 1987.
4. **Richardson, Ampt, and Meyburg**, Survey Methods for Transport Planning, Eucalyptus Press, 1995.
5. **Domencich, T.A. and McFadden, D**., Urban Travel Demand: A Behavioral Analysis, North-Holland, 1975.
6. Selected papers from journals such as Transportation Research, Transportation Science, and Transportation Research Record.

DETAILS OF COURSES OFFERED BY GEOTECHNICAL ENGINEERING GROUP

CE-632 GROUND IMPROVEMENT

Problematic soils; Need for ground improvement; Various ground improvement techniques; Embankment construction on soft soils; Preloading with and without vertical drains; Admixture method; stabilisation and grouting methods; Deep mixing methods; Surface densification; Stone columns and their design;

References:

1. **Bowles, J.E. (1996).** Foundation Analysis and Design, 5th Edition, McGraw-Hill International Editions, publishers, New York.
2. **Hausmann, M.R. (1990).** Engineering Principles of Ground modification. McGraw-Hill Inc.,USA
3. **Mooseley, M.P. and Kirsch, K. (2004).** Ground Improvement. 2nd Edition, Spon Press, Taylor and Francis Group, London, United Kingdom.
4. **Xanthakos, P.P., Abramson, L.W., and Bruce, D.A. (1994).** Ground control and Improvement. Wiley Interscience Edition, John-Wiley & Sons, Inc, Newyork, USA.

CE-633 Soil Structure Interaction

Critical study of conventional methods of foundation design; Nature and complexities of soil structure interaction; Application of advanced techniques of analysis such as the finite element method, finite differences, relaxation and interaction for the evaluation of soil-structure interaction for different types of structures under various conditions of loading and subsoil characteristics; Preparation of comprehensive design oriented computer programmes for specific problems. Interaction problems based on the theory of sub-grade reaction such as beams, footings, rafts, bulkheads etc. Analysis of different types of frame structures founded on stratified natural deposits with linear and nonlinear stress-strain characteristics. Determination of pile capacities, negative skin friction and group action of piles considering stress-strain characteristics of real soils; Anchor piles and determination of pull out resistance; Well foundations.

References:

1. **J.E., Bowles**, Analytical and Computer Methods in Foundation Engineering, McGraw-Hill Book Co., New York, 1974.
2. **C.S. Desai and J.T. Christian** (Eds.), Numerical Methods in Geotechnical Engineering, McGraw-Hill Book Co., Yew York.
3. Elastic Analysis of Soil-foundation Interaction, Developments in Geotechnical Engineering, Vol.17, Elsevier Scientific Publishing Co.

CE-637 Rock Mechanics

Engineering properties of rock masses, subsurface investigations in rock deposits, field and laboratory testing of rocks, stress-deformation characteristics of rock masses under heavy loads, flow of water through rock masses, failure theories, shear strength of rock under high pressure, friction in rocks, time dependent properties of rock masses, stability of rock slopes, idealised rock system, anisotropic rock system, deep cuts, deep bore-holes, stability of bounder fills and embankment, lateral pressure on retaining structures for high hill slopes, bearing capacity of rock masses, opening in rocks, lines and unlined tunnels, pressure tunnels and tunnels for other purposes.

References:

1. **J.C. Jaeger** and **N.G.W. Cook**, Fundamentals of Rock Mechanics, Methuen and Co., London, 1971.
2. **Obert, Leonard** and **W.I. Duvall**, Rock Mechanics and Design Structures of Rock, 1967.
3. **J.A. Hudson et al.** (Ed.), Comprehensive Rock Mechanics, in 5 volumes, Pergamon Press, 1993.

CE-641 Environmental Geomechanics

General Principles: Introduction, Nature of soil and environment, Soil technology, Soil-water-air interaction, Shrinkage, Swelling, and Cracking characteristics of soil, Hydraulic conductivity and mass transport phenomena, Thermal and electrical properties of soils, Radiation effects on soil. Environmental geotechnical applications.

References*:*

1. **Dixon, J.B. and Weed, S.B.**, Minerals in Soil Environments, SSSA, 1989.
2. **Rees, J.F**., Contaminated Land Treatment Technologies, SCI, Elsevier Applied Science, London, 1992.
3. **Acar, Y.B. and Daniel, D.E.**, Geoenvironmental 2000: Characterisation, Containment, Remediation & Performance in Environmental Geotechnics, ASCE, New York, 2000.
4. Methods of Soil Analysis, SSSA, 2nd Edition, Physical and Chemical Processes of Water and Solute Transport/Retention in Soils, SSSA.
5. Singh, D.N., Asadi, Afshin, Goli, V.S.N.S, Environmental Geotechnology: Meeting Challenges Through Needs-based Instrumentation, https://doi.org/10.1142/9072. World Scientific.
6. NPTEL Lectures by Prof. D N Singh.

CE-643 Experimental Geotechnics

Processing of the soil, determination of hygroscopic moisture content, sieve analysis, hydrometer test, specific gravity test, liquid, plastic, and shrinkage limit tests, standard proctor compaction test, field density measurement tests (Sand replacement and core cutter), permeability test, oedometer test, direct shear test, consolidated undrained triaxial test, vane shear test, determination of free swell index for fine grained soils, evaluation of swelling pressure of soils, soil suction measurement, block vibration test, cyclic plate load test.

References*:*

1. **Head, K.H.** (2006). Manual of soil laboratory testing, Volume I – Soil Classification and Compaction Tests, 3rd Edition, Whittles Publishing, Scotland, UK.
2. **Head, K.H.** and **Epps, R. J.** (2011). Manual of soil laboratory testing, Permeability, shear strength and compressibility tests, Volume II, 3rd Edition, Whittles Publishing, Scotland, UK.
3. **Head, K.H.** and **Epps, R. J.** (2014). Manual of soil laboratory testing, Vol.III – Effective stress tests, Whittles Publishing, Whittles Publishing, Scotland, UK.
4. **Das, B.M.** (2009). Soil Mechanics Laboratory Manual, 7th Edition, Oxford University Press, New York.
5. Relevant Indian and ASTM standards.

CE-645 Geotechnical Centrifuge Modelling

Modelling and simulation - Dimensional analysis; Physical modelling using Centrifuge, historical perspectives, developments in hardware; Equipment - type of centrifuges; Principles of centrifuge modelling: scaling laws for static, dynamic loading and scaling laws for diffusion phenomena, Scale effects: Dependency of soil behaviour on stress level and stress history; Rotational acceleration and stress field, Modelling of models, Coriolis effect in Centrifuge, Grain size effects; Instrumentation in centrifuge modelling; Data acquisition systems; Applications of centrifuge modelling -Embankments and Dams, Shallow foundations, Deep foundations, Retaining structures, Anchorages, Ground improvement, Environmental geotechnics, Earthquake effects.

References*:*

1. **Craig, W.H.**, The application of centrifuges modelling to Geotechncial Design, Proceedings of a Symposium, Manchester, Balkema, April, 1984,
2. Proceedings of the International Conferences- Centrifuge `88, Centrifuge `91, Centrifuge `94, Centrifuge `98, Centrifuge 2002, Balkema.
3. **Taylor, R.N.,** (ed.), Geotechnical Centrifuge Technology, Blackie Academic & Professional, 1995.

CE-746 Reinforced Earth and Geotextiles

Basic introduction to the elements of Ground Engineering characteristics of reinforcing materials, definition of reinforced and advantage of RE, soil reinforcement interaction, behaviour of Reinforced earth walls, basis of wall design, the Coulomb force method, the Rankine force methods, internal and external stability condition, field application of RE, randomly reinforced earth and analysis of reinforced soils, testing of soil reinforcements. Definitions, functions, properties, and application of Geotextiles, design of Geotextile applications, definitions, functions, properties and applications of geo-membranes, design of geo-membranes applications, Geotextiles associated with geo-membranes, testing on geotextiles, environmental efforts, ageing and weathering.

References*:*

1. International Conference on Soil Reinforcement, RE and other techniques, Paris, March, 1979.
2. Second International Conference on Geotextiles, Las Vegas, August, 1982.
3. International Conferences in-situ soil and rock reinforcement, Paris, October, 1984.

CE-647 Soil Dynamics and Machine Foundations

Vibration of elementary systems, degrees of freedom, analysis of systems with several degrees of freedom, natural frequencies of continuous systems, elastic constants of soil and their experimental determination, damping of soil, effect of vibration on residual soil settlements, effect on porosity and hydraulic methods to reduce residual dynamic settlement of foundations, stress distribution in soil under dynamic loading. Influence on shearing strength, vibro-viscous soil resistance, liquefaction, bearing capacity of dynamically loaded foundations, such as those of water towers, chimneys and high-rise buildings, response of pile foundations, wave propagation in elastic half space, waves in layered systems and in saturated media, vibration isolation methods.

References*:*

1. **D.D. Barkan**, Dynamics of Bases and Foundations, McGraw-Hill, New York, 1962.
2. **E.E. Rihcart et al.**, Vibrations of Soils and Foundations, Prentice Hall Inc., 1970.
3. **S.P. Timoshenko, D.H. Young and William Weaver, Jr.**, Vibration Problems in Engineering, John Wiley and Sons, 1974.
4. **Braja M. Das and G. V. Ramana**, Principles of Soil Dynamics, 2nd Edition, Cengage Learning, 2010.
5. **Shamsher Prakash,** Soil Dynamics, 3rd Edition, John Wiley, 2000.
6. **R. Katzenbach, S. Leppla and D. Choudhury**; Foundation Systems for High-Rise Structures, CRC Press, Taylor & Francis Group, UK, ISBN: 978-1-4987-4477-5, pp. 1-298, 2016.
7. **D. Choudhury,** Soil Dynamics, NPTEL Video course, 2012. http://nptel.ac.in/courses/105101005/

CE-648 Finite Element Methods in Geotechnical Engineering

Theory: energy concepts and variational principles, discretization of continuous media, two and three dimensional analysis, stiffness of simple elements, Isoparametric elements and interface elements, assembly and solution techniques, computerisation, introduction to nonlinear problems, plasticity problems and no tension analysis, applications to problems such as stress distribution and deformations in isotropic and anisotripic soil and rock media, stress and deformations around excavations and built-up embankments, seepage through porous media, one dimensional consolidation, stress distribution around openings in intact and fisssured rock.

References*:*

1. **Robert D. Cook**, Concepts and Applications of Finite Element Analysis, Third Edition, John Wiley and Sons.
2. **C.S. Desai, J.F. Abel**, Introduction to the Finite Element Method, A numerical Method for Engineering Analysis, East-West Edition, 1972.
3. **O.C. Zienkiewicz and R.L. Taylor**, Finite Element Method, McGraw-Hill, 1991.

CE-652 Foundations of Offshore Structures

Nature and magnitude of loads on foundations of offshore structures, criteria of foundation design in offshore environment, features of foundations of gravity structures, bearing capacity and settlement under dynamic loads, immediate and long term behaviour, liquefaction under cyclic loads, problems relating to jack-up platforms, dynamic stress in pile driving, pile behaviour under cyclic lateral loads, axial and lateral capacities of piles, development of p-y curves, analysis of single piles and pile groups, finite element and other numerical methods of interactive analysis using linear and nonlinear foundation response, geotechnical aspects of anchors and submarine pipelines.

References*:*

1. **M. Randolph and S. Gourvenec**. Offshore Geotechnical Engineering, CRC Press, 2011.
2. Proceedings of the International Symposium on Frontiers in Offshore Geotechnics, Perth, Oslo, Texas, 2005, 2010, 2015, 2020.
3. Proceedings of Offshore Technology Conference, Houston, Texas.

CE-656 Plasticity Theory and Applications in Geomechanics

This course aims to provide fundamental understanding of several conceptual building blocks that form the foundation for plasticity theory and its implication on material constitutive behavior. Course content includes discussions on Cartesian tensors and indicial notation; tensor calculus; tensorial treatment of stresses and strains; rate-independent plasticity; flow rule and work-hardening; yield criteria; hardening rules; contained plastic deformation (e.g. cavity expansion problem); plastic flow and collapse; slip line theory; plastic dissipation; Drucker's postulate; limit analysis; lower bound and upper bound theorems and other methods to solve collapse problems.

References*:*

1. **Davis, O.** and **Salvadurai, A. P. S.** Plasticity and Geomechanics. Cam. Univ. Press, 2002
2. **Lubliner, J.** Plasticity Theory. Macmillan Publishing Company, 1990.
3. **Malvern, L.E.** Introduction to the Mechanics of a Continuous Medium. Prentice-Hall, NJ, 1969.
4. **Y. C. Fung.** A First Course in Continuum Mechanics, Prentice-Hall Inc., 1992
5. **Yu, H.S.** Plasticity and Geotechnics, Springer, 2006

CE-677 DESIGN AND TESTING OF PILE FOUNDATIONS

Types of piles and choice of pile type: Classification piles, large-displacement piles, small-displacement piles, replacement piles, special pile types; Design of piles: Building loads, Pile design in relation to geology, design philosophies, allowable stress design, Ultimate and serviceability limit state design, LRFD design concepts, axially loaded piles in soil, rock socketed piles, uplift capacity of piles, lateral load capacity of piles, negative skin friction, Settlement analysis; Pile group effects: ultimate capacity of pile groups, settlement of pile groups, negative skin friction of pile groups, piled raft foundations; Pile installation and construction control: equipment, liners, hammers and vibratory drivers, selection of method of pile installation, potential problems prior to and during pile installation, impact of installation techniques, damaging effects and mitigating measures; Design of basement walls and excavations: Walls types, design issues, design criteria, analysis and design methods, control measures; Integrity tests of piles: Role of integrity tests, types of non-destructive integrity tests, practical considerations in the use of integrity tests; Pile load tests: static and dynamic loading tests, vertical and lateral load testing, load tests using Osterberg cell, timing of load tests, design and construction of ground anchors, construction of test pile, equipment, reaction arrangement, instrumentation, test procedures, interpretation of test results; Hands-on experience to the students in pile testing and interpretation: Static pile load testing at large-scale pile testing setup at IIT Bombay, working with hydraulic jack and load cell, load maintenance, interpretation of ultimate capacity of pile and design capacity; Case studies and forensic aspects of pile foundations.

References*:*

1. M.J.Tomlinson and J Woodward, Pile Design and Construction Practice, 6th Edition, CRC Press, Taylor and Francis Group, 2014.
2. H.G.Poulos, Tall building Foundation Design, 1st Edition, CRC Press, Taylor and Francis Group, 2017.
3. K. Fleming, A. Weltman, M. Randolph, K.Elson, Piling Engineering, CRC Press, 2008.
4. M.Randolph and S.Gourvenec, Offshore Geotechnical Engineering, 1st Edition, Spon Press, Taylor and Francis Group, 2011.
5. J.E. Bowles, Foundation Analysis and Design, McGraw-Hill International Edition, Fifth Edition, 2001.
6. GEO Publication No. 1/2006: Foundation Design and Construction, Geotechnical Engineering Office, Hong Kong.

7. V.N.S. Murthy, Advanced Foundation Engineering, Geotechnical Engineering Series, CBS Publishers, 2010.

8. Design of Pile Foundations, US Army Corp of Engineers, University Press of the Pacific, 2005.

9. R. Katzenbach, S. Leppla and D. Choudhury; Foundation Systems for High-Rise Structures, CRC Press, Taylor & Francis Group, UK, ISBN: 978-1-4987-4477-5, pp. 1-298, 2016.

CE-683 Marine Geotechnical Engineering

Origin and formation of submarine deposits, characteristics of continental shielding various parts of the world and around Indian coast, methods of exploration of submarine deposits, obtaining undistributed samples and determination of in-situ strength, evaluation of physical and chemical properties of submarine soils, consolidation, settlement characteristics and shear strength characteristics under static and wave loading, pore pressure and liquefaction under dynamic and earthquake stresses, bearing capacity of large bases and tips, development of design parameters for use in pile soil and gravity platform soil, analysis both under static and dynamic conditions.

References*:*

1. Proceedings of the Conferences on Behaviour of Offshore Structures.
2. Proceedings of Offshore Technology Conferences.
3. Proceedings of Annual Offshore Technology Conferences, Houston, Texas, 1969-1979.
4. Proceedings of First International Conference on Behaviour of Offshore Structures, Oslo, Published by the Institute of Technology, Norway, 1976.
5. Proceedings of Second International Conference on Behaviour of Offshore Structures, London, Published by BHRA Fluid Engineering, 1979.

CE-684 ADVANCED GEOTECHNICAL EARTHQUAKE ENGINEERING

Introduction to Geotechnical Earthquake Engineering, Seismology and Earthquakes, Strong Ground Motion, Earthquake Hazards Related to Geotechnical Engineering, Wave Propagation, Liquefaction, Liquefaction computation from laboratory and field tests, Seismic Slope Stability, Behaviour of reinforced slope under seismic condition, Seismic Design of Retaining Walls, Force based Pseudo-Static Pseudo-Dynamic Analysis, bearing capacity and settlement, Seismic Design of Pile Foundations, Seismic Uplift Capacity of Anchors, Soil Improvement for Remediation of Seismic Hazards, Recommendations of Seismic Design Codes related to Geotechnical Earthquake Engineering.

References*:*

1. **Steven L. Kramer** (2003). Geotechnical Earthquake Engineering, Prentice Hall International Series, Pearson Education, New Delhi.
2. **Ikuo Towhata** (2010). Geotechnical Earthquake Engineering, Springer, ISBN-10: 3642071457, pp. 1-684.
3. **R. W. Day** (2002). Geotechnical Earthquake Engineering Handbook, McGraw Hill, New York.
4. **IS 1893** (2016). Indian Standard Criteria for Earthquake Resistant Design of Structures, New Delhi.
5. **B.M. Das** (2011). Principles of Foundation Engineering, 7th Ed. SI Units, Cengage Learning, USA.
6. **R. Katzenbach, S. Leppla and D. Choudhury** (2016). Foundation Systems for High-Rise Structures, CRC Press, Taylor & Francis Group, UK, ISBN: 978-1-4987-4477-5, pp. 1-298.
7. **D. Choudhury, K. M. El-Zahaby and I. M. Idriss** (2018). Dynamic Soil-Structure Interaction for Sustainable Infrastructures. Springer, Switzerland, Online ISBN: 978-3-030-01920-4; Print ISBN: 978-3-030-01919-8, pp. 1-230.
8. **D. Choudhury** (2013). Geotechnical Earthquake Engineering, NPTEL Video course. http://nptel.ac.in/courses/105101134/

CE-688 Risk Assessment & Management in Geotechnical Engineering

Working stress and limit state design approaches, Ultimate and Service limit states, Basics of probability and statistics, Sources of uncertainty in Geotechnical design parameters, In-situ soil characterization, Sensitivity analysis, Modelling of uncertainty, Fragility curves, Probability of failure, FORM, Monte Carlo Simulation Techniques, Response Surface Method, Parallel and series systems, Explicit and implicit functions, Target reliability index, LRFD approach, Code calibration, Applications to shallow and deep foundations, landslides and embankments, liquefaction behaviour of soils.

References*:*

1. **Ang, A.H-S. And Tang, W.H.** (2006). Probability Concepts in Engineering: Emphasis on Applications to Civil and Environmental Engineering, John Wiley & Sons.
2. **Baecher, G. and Christian, J.** (2005). Reliability and Statistics in Geotechnical Engineering, Wiley Publications, 618 p.
3. **Haldar, A. and Mahadevan, S.** (2000): Probability, Reliability and Statistical Methods in Engineering Design, John Wiley & Sons Inc., 304 p
4. **Nowak, A.S. And Collins, D. R.** (2000). Reliability of Structures, McGraw-Hill International Editions, Civil Engineering Series, Singapore, 338 p.
5. **Ranganathan, R.** (1990). Reliability Analysis and Design of Structures, Tata McGraw Hill, New Delhi.
6. **Fenton, G.A.** (1997). Probabilistic Methods in Geotechnical Engineering, ASCE Geotechnical Safety and Reliability Committee, 95 p.

CE-702 Geotechnical Constitutive Models

Introduction to shear strength of soils, Critical state line, Taylor's stress-dilatancy equation, Generalised Hooke's Law, isotropy and anisotropy, elastic and plastic deformation, ingredients of a plastic soil model, normality assumption and associated flow rule, compression behaviour and plasticity, behaviour of Cam Clay under drained and undrained loading, relationship between undrained shear strength, effective stress and over-consolidation ratio, generalised equations of state boundary surface.

References*:*

1. **A.N. Schofield,** Disturbed soil properties and geotechnical design, Thomas Telford, 2006.
2. **A.M. Britto and M.J. Gunn,** Critical State Soil Mechanics via Finite Elements, Ellis Horwood, Chichester, 1987.
3. **D.M. Wood,** Soil Behaviour and Critical State Soil Mechanics, Cambridge University Press, New York, 1990.
4. **M.D. Bolton,** A Guide to Soil Mechanics, McMillan, London, 1984.
5. **P.K. Banerjee and R. Butterfield,** Advanced geotechnical analyses, Elsevier Science Publishers, Cambridge University Press, 1991.

CE-781 ADVANCED FOUNDATION ENGINEERING

Subsoil exploration for foundation engineering, In situ tests and interpretation of their results, Types and selection of foundation elements, Foundation design framework, Tolerable foundation movement, Bearing capacity and settlement analysis of shallow foundations, Design of isolated and combined footings, Raft foundation, Analysis and design of axially-loaded piles, Laterally loaded piles, Piles in group, Pile driving analysis, Design of earth retaining structures, Special foundations, Foundation on problematic soils, Modeling soil-structure interaction for foundations

References:

1. **Salgado, R.** The Engineering of Foundations, Mc Graw Hill, 2006, ISBN: 9780072500585
2. **Coduto**, **D. P., Kitch**, **W. A.** and **Yeung, M. R.** Foundation Design: Principles and Practices. Pearson Education Inc. 2016, ISBN 0133411893
3. **Poulos, H. G.** and **Davis, E. H.** Pile Foundation Analysis and Design. John Wiley and Sons Inc., 1980.
4. **Das, B. M**. Principles of Foundation Engineering, 7th edition, Cengage Learning, Inc., 2010, ISBN: 0495668109
5. **Bowles, J. E**. Foundations Analysis and Design, 5th Ed., McGraw-Hill, New York, 1997.
6. **Peck, R.B.**, **Hanson, W.E.** and **Thornburn, T.H.** Foundation Engineering, 2nd Edition, John Wiley and Sons, New Jersey, 1974.
7. **R. Katzenbach, S. Leppla and D. Choudhury**; Foundation Systems for High-Rise Structures, CRC Press, Taylor & Francis Group, UK, ISBN: 978-1-4987-4477-5, pp. 1-298, 2016.

CE-782 ADVANCED SOIL MECHANICS

Introduction to natural soils and ground water; Flow through soils - Bernoulli's Equation; Darcy's Law, hydraulic conductivity of soil, seepage analysis; Consolidation - consolidation theory, settlement and time rate of consolidation; stress analysis – background and applications, Mohr circle of stress and pole method; Shear strength of soils and concept of critical state - factors affecting shear strength, Mohr-Coulomb failure criterion, frequently used laboratory tests, concept of critical state, drained and undrained shear strength of sand and clays, stress paths, modelling of soil mechanical behaviour; Lateral earth pressure - plastic equilibrium in soil, Rankine's earth pressure theory, Coulomb's earth pressure theory, graphical method of calculation of earth pressure; Stability analysis of ground slopes - slope stability assessment for infinite slopes, stability assessment for finite slopes, total stress analysis – Taylor's slope stability charts, effective stress analysis – method of slices.

References:

1. Bolton, M. D. "A Guide to Soil Mechanics", Universities Press, 2003
2. Budhu, M. "Soil Mechanics and Foundations", John Wiley & Sons, 2011
3. Craig, R. F. "Craig's Soil Mechanics", 7th Ed., Spon Press, 2004
4. Das, B.M. "Advanced Soil Mechanics", 4th Ed, CRC Press, 2014
5. Holtz, R.D. and Kovacs, W.D., "An Introduction to Geotechnical Engineering", Prentice Hall, 1981
6. Lambe, T.W. and Whitman, R.V., "Soil Mechanics", John Wiley & Sons, 1979
7. Mitchell, J.K. and Soga, K., "Fundamentals of Soil Behaviour", John Wiley & Sons, 2005
8. Ranjan, Gopal and Rao, A.S.R., "Basic and Applied Soil Mechanics", New Age Int. Pvt. Ltd., 2004
9. Salgado, R. The Engineering of Foundations, McGraw-Hill, 2008.

DETAILS OF COURSES OFFERED BY WATER RESOURCES ENGINEERING GROUP

CE 605 - APPLIED STATISTICS

Introduction to Probability and Random Variables: Probability Space; Axioms of Probability; Joint Probability; Conditional probability; Independence; Baye's Rule; Sequential Continuity; Union of Events; Numerical examples; Random Variable (RV): Definition, Notation and Inverse Image; Discrete and Continuous Random variables. Probability Distribution: Cumulative Distribution Function; Distribution Function of Indicator RV; Probability Density Function; Probability Mass Function; Examples of Probability Mass Function: Bernoulli Trials, Binomial Distribution, Hypergeometric Distribution, Negative Binomial Distribution, Poisson's Distribution, Geometric Distribution; Examples of Probability Density Function: Uniform Distribution, Gamma Distribution, Erlang Distribution, Exponential Distribution, Rayleigh Distribution, Laplace Distribution, Gaussian Distribution, Lognormal Distribution and Extreme Value Distribution; Generation of RV, Probability Plotting, Fitting a Distribution, Nonparametric pdf. Conditional and Joint Distribution Function: Conditional CDF, Joint Distribution Function, Marginal Distribution Function; Conditional Distribution and Independence; Gaussian Random vector. Function of RV: Function of a RV; Monotonically Increasing and Decreasing Functions; Function of Jointly Distributed RVs; Function of iid RVs.

Moments: Moments of a RV; Joint Central Moments; Covariance Matrix; Correlation Co-efficient; Ecological Correlation; Moment Generating Function; Probability Generating Function; Characteristic Function; Moment Inequalities, Central Limit Theorem.

Linear Regression: Linear Regression, Hypothesis Testing, Multiple Regression Analysis, Dummy Variable Regression Analysis, Assumptions of Regression: Multicollinearity, Heteroscedasity, Autocorrelation among Residuals; Introduction to SPSSMultivariate Statistics, Principal Component Analysis, Introduction to Clustering.

Introduction to Stochastic Process.

References:

1. **Gujarati**, Basic Econometrics, Mc Grawhill.
2. **Hoel, Port** and **Stone**, Introduction to Probability Theory, Universal Book Stall.
3. **Papoulis, A.** and **Pillai, S. U**., Probability, Random Variables and Stochastic Processes, Tata Mc-Grawhill.
4. **Wilks, D S.**, Statistical Methods in Atmospheric Sciences, Academic Press 2011.

CE 607 - NUMERICAL TECHNIQUES IN HYDRAULIC ENGINEERING

• Mathematical Modeling: Mathematical tools and techniques, Advanced modeling applications to water resources and environmental engineering problems.

• System of Equations & Solutions– Linear equations; Iterative methods, direct methods, conjugate gradient method; Newton Raphson method; sparse matrices and compact storage schemes; Inversion of matrices; Non-linear equations and solutions; Gauss Jordan method; Gauss Siedel method; Eigen Values and Vectors & applications;

Numerical Solution of Ordinary Differential Equations: Single step method, multi-step method; Runge-Kutta methods; Numerical differentiation and integration; boundary value and initial boundary value problems – Applications in water resources/ ocean/ environmental engineering.

• Partial differential equations & Solutions: different types and solution approaches.

• Finite Difference Method: Various Finite difference schemes, implicit and explicit methods, ADI method; Method of Characteristics - Applications in water resources/ ocean/ environmental engineering.

• Approximate Methods – Method of weighted residuals (Sub-domain, Collocation, Least squares, Galerkin, Raleigh-Ritz methods), Applications to solve linear and nonlinear differential equations.

• Finite Element Method: Discretization of domain – Grid generation, Interpolating polynomials, Integration of shape functions over the domain; Formulation of element matrices and its global assembly - Applications in water resources/ ocean/ environmental engineering.

• Introduction to boundary element method and Meshfree methods - Applications in water resources/ ocean/ environmental engineering.

• Applications of various computer software based on finite difference method & finite element method – Applications in groundwater flow, Fluid dynamics, Pollutant transport in surface and subsurface water

References

1. K. A. Hoffmann and S. T. Chiange, Computational Fluid Dynamics for Engineers, Vol. I, Engineering Education System, Wichita, Kanasas, 1993.
2. S. C. Chapra and R. P. Canale, Numerical Methods for Engineers, McGraw-Hill, New York, 1990.
3. M.K. Jain, S.R.K. Iyengar & R.K Jain, Numerical Methods for Scientific & Engineering Computation, Wiley Easter Ltd., New Delhi, 1995.

4. O.C. Zienkiewics, Finite Element Method, McGraw Hill Book Co., New York, 1991.
5. T.R. Chandrupatla, Introduction to Finite Elements in Engineering, Prentice Hall, Englewood Cliffs, New Jersey, 1991.
6. K.J. Bathe, Finite Element Procedure in Engineering Analysis, Prentice Hall of India, New Delhi, 1990.
7. C.A. Brebbia, J.C.F. Telles, L.C. Wrobel, Boundary Element Techniques- Theory and Applications in Engineering, Springer-Verlag, Berlin , 1984.
8. J.N. Reddy, Finite Element Method, McGraw-Hill Inc, New York, 1993.
9. Wang, H., and Anderson, M. P. (1982). Introduction to Groundwater Modeling Finite Difference and Finite Element Methods, W. H. Freeman and Company, New York.
10. Pinder, G. F., and Gray, W. G. (1977). Finite Element Simulation in Surface and Subsurface Hydrology, Academic press, New York.
11. Desai, Y.M., Eldho T.I., Shah A.H. (2011). Finite Element Method with Applications in Engineering, Pearson Education, New Delhi.

CE 608 - ECO-HYDRO-CLIMATOLOGY

Introduction to Eco-hydro-climatology: an interdisciplinary framework; Climate System; Climate, weather and Climate Change; Overview of Earth's Atmosphere; Vertical Structure of Atmosphere; Radiation and Temperature; Laws of Radiation; Heat-Balance of Earth-Atmosphere System; Random Temperature Variation; Modeling Vertical Variation in Air Temperature; Temporal Variation of Air temperature; Temperature Change in Soil; Thermal Time and Temperature Extremes.

Hydrologic Cycle: Introduction; Global water balance; Cycling of water on land, a simple water balance model; Climate Variables affecting Precipitation, Precipitation and Weather, Humidity, Vapor Pressure, Forms of Precipitation, Types of Precipitation; Cloud; Atmospheric Stability; Monsoon; Wind Pattern in India; Global Wind Circulation; Indian Summer Monsoon Rainfall.

Thermodynamics and Cloud Micro-physics: 1st and 2nd law of thermodynamics with application to meteorology. C-C theory, Cloud Microphysics (Introduction)Climate Variability: Floods, Droughts, Drought Indicators, Heat waves, Climate Extremes.

Climate Change: Introduction; Causes of Climate Change; Modeling of Climate Change, Global Climate Models, General Circulation Models, Downscaling; IPCC Scenarios;

Commonly used Statistical Methods in Hydro-climatology: Trend Analysis; Empirical Orthogonal Functions, Principal Component Analysis; Canonical Correlation; Statistical Downscaling with Regression

Ecological Climatology: Leaf energy fluxes and leaf photosynthesis; Plant canopies, ecosystem and vegetation dynamics; Coupled climate vegetation dynamics, Carbon cycle climate feedbacks, Introduction to Precipitation Recycling

References:

1. **Bonan G. B.** ,Ecological Climatology, Cambridge University Press, 2002
2. **Campbell, G. G.** and **Norman J. M**., An Introduction to Environmental Biophysics, Springer, 1998
3. IPCC Assessment Report 4
4. Recent articles in journals, specifically, Water Resources Research, Journal of Geophysical Research, Journal of Climate, Climatic Change, Nature Geoscience, Nature Climate Change etc.

CE 626 – GROUNDWATER SYSTEMS PLANNING AND MANAGEMENT

Concept of Groundwater System, Definition of input and output to the system and system's parameters, Generalized governing equations for groundwater flow in confined, phreatic and sloping base aquifers involving heterogeneous anisotropic flow domains,

Steady state and time variant problems in groundwater flow, Applicable boundary conditions to the flow regions and derivation of free surface boundary conditions. Importance of numerical modeling, Finite difference and finite element modeling of regional aquifers

Application of simulation optimisation models, Optimisation of collective well drawdown in heterogeneous anisotropic systems. Optimisation of groundwater fed irrigation regions,

Concept of Inverse modeling and its application to aquifer systems incorporating auto calibration, sea water intrusion in coastal aquifers, Introduction to the emerging techniques of genetic algorithm, simulated annealing, ant colony, differential evolution and particle swarm with reference to groundwater system optimisation.

Aquifer remediation, bioremediation, pump and treat.

Reference:

1. Bjerg P L et al. (Eds), Groundwater 2000, A A Balkema, Rotterdam, 2000.
2. Freeze R. & Cherry J. Groundwater, 1979, Englewood Cliffs, New York
3. Karamouz M et al. Groundwater Hydrology, Engineering, Planning and Management,
4. CRC Press, Taylor and Francis, 2011.

Rastogi A K., Numerical Groundwater Hydrology, Penram International Publication, 2012 (Reprint)

CE 654 - Advanced Hydrological Analysis and Design

Review of Various Processes in the Hydrological Cycle: Precipitation, Abstracts, Evaporation, Infiltration, Evapotranspiration, Runoff, Streamflow and its measurements, floods, flood routing.

Problems and Models in Hydrology: Systems Approach, Parameter Estimation methods, Watershed Runoff Modeling, Response Time Characteristics, Linear Models: Rational Method, Time Area Methods, Unit Hydrograph Method, Derivation of UH and IUH, Clark Model, Nash Model, Time-Variant Linear Reservoir, Time-Area Method.

Hydrologic Time Series Models: Time series introduction, Introduction to stochastic models like AR, ARMA and ARIMA. Rainfall-runoff models-case studies, case studies of other hydrological time series models.

Hydrologic and Hydraulic Design: Design of Water Supply, Sewerage and Storm Water Networks: standards and case studies, finding the capacity of reservoir, rain water harvesting systems, case studies on conventional water storage structures.

Soft Computing and Recent Techniques in Hydrologic Models: Introduction and applications of soft computing techniques like, Artificial neural networks, Genetic programming, Model tree, chaos theory, singular spectrum analysis.

References:

1. Mc.Cuen, R.H., (1989) Hydrologic Analysis and Design, Prentice Hall, New Jersey, 1989.
2. Chow, V.T., (1964) Handbook of Applied Hydrology, McGraw - Hill, 1964.
3. Vijay, P. Singh (1989) Hydrologic systems, Vol. I & II, Prentice Hall, New Jersey, 1989.
4. Kottegoda, N. T., (1980) *Stochastic Water Resources Technology,* The Macmillan Press Ltd. London
5. Salas, J.D., J.W. Delleur., V. Yevjevich and W.L. Lane, (1980) *Applied Modelling of Hydrologic Time Series*, Water Resources Publications, Colorado.
6. Yevjevich, (1972) *Stochastic Process in Hydrology,* Water Res. Publ., Colorado.
7. Subramanya K, (2008) *Engineering Hydrology (3rd Edition),* Tata McGraw Hill Publishing Company, New Delhi, 2008.

CE 658 – HYDROGEOMORPHOLOGY

A quantitative glance at river basins

Hillslopes and channels. The problem of defining channel heads. Drainage density and the hillslope scale. Horton-Strahler stream ordering scheme. Horton's law. Hack's law. Discharge-area relationships. Magnitude-area relationship. Slope-area relationship. The width function. The source function.

Fractal characteristics of river basins

The box counting dimension. The cluster dimension. The correlation dimension. Self-similarity and power Laws. Self-similarity in river basins. Horton's laws and the fractal structure of drainage networks. Power-law scaling in river basins. Hack's law and self-affinity. Generalized scaling laws for river networks.

Multi-fractal characteristics of river basins

Peanos basin and the binomial multiplicative process. Multifractal spectra. multifractal spectra of width functions. Multiscaling and multifractality. Multifractal topographies. Random cascades.

Landscape evolution modelling

Experimental fluvial-geomorphology. Statistical models of drainage network evolution. Deterministic models for drainage network evolution. The principles of minimum energy expenditure in river networks. Optimal channel networks. Thermodynamics of optimal channel networks.

Geomorphological origin of hydrologic response

Travel time distributions in channel links. The geomorphological unit hydrograph. The width-function unit hydrograph. Can one gauge the shape of a basin? Tothian flow system vs. Dupuit-Boussinesq flow system. Geomorphological recession flow model. Storage-discharge non-linearity. The general geomorphological recession flow model. Geomorphological origins of storage-discharge relationships. Estimation of drainable storage – a geomorphological approach. Channel networks in hydrological response modelling.

Self organization in hydrological systems

The concept of self organized criticality. Bak's sandpile model. Fractals and self-organized criticality. Self-organization of river networks. Geomorphic signatures of climate. Chaos vs. self-organization. The concept of dominant processes. The Budyko framework and the concept of catchment co-evolution. Self-organization in water-controlled ecosystems. The dynamic Budyko model

References:

1) Rodriguez-Iturbe, I., & Rinaldo, A. (2001). Fractal river basins: chance and self-organization. Cambridge University Press (ISBN: 9780521004053).
2) Mandelbrot, B. B. (1983). The fractal geometry of nature. New York: WH freeman (ISBN: 9781441918970).
3) Bak, P. (2013). How nature works: the science of self-organized criticality. Springer Science & Business Media (ISBN: 9781475754261).
4) Rodríguez-Iturbe, I., & Porporato, A. (2007). Ecohydrology of water-controlled ecosystems: soil moisture and plant dynamics. Cambridge University Press (ISBN: 9780511535727).
5) Sivakumar, B. (2016). Chaos in hydrology: bridging determinism and stochasticity. Springer (ISBN: 9789048125517).
6) Recently published relevant research papers

CE 667 - HYDRAULIC STRUCTURES

Hydraulic and structural design of storage reservoirs,

Dams, spillways, outlet works, river training and regulations, conduit systems, transition structures, fluid elasticity,

Irrigation structures and designs

Design, Fundamental and engineering aspects of fluid structure iteration, static and dynamic response of elastic structures.

References:

1. **Bourgin**, Design of Dams and Sons, Ltd., 1953,
2. **Sir Issac Pitman. S. Leliavsky**, Irrigation and Hydraulic Design, Vols.I, II, and III, Chapman and Hall, Ltd., London, 1957.
3. **M.M. Grishin** (Ed.), Hydraulic Structures, Vol.II, Mir Publishers, Moscow, 1982.
4. F. M. Henderson, Open Channel Flow, MacMillan, New York, 1996.
5. H. H. Chang, Fluvial Processes in River Engineering, John Wiley, 1988.

CE 672 - River Mechanics & Control Structures

Open channel control structures; Varied flow profiles; River morphology, Sediment properties, hydrodynamics of fluid particle systems, setting velocity of particles, sediment transport in open channels;

Bed-load, Duboys, Einstein, Kalinske, Bagnold transport formulae, suspended load and the total load, design of stable channels-regime concept, bed forms, ripples, dunes and antiduness,

Principles of dimensional considerations, river models, sedimentation in reservoirs, coastal sediment problems.

References:

1. **C. T. Yang**, Sediment Transport-Theory and Practice, The McGraw Hill Companies, Inc. New Delhi, 1996.
2. **F. M. Henderson**, Open Channel Flow, MacMillan, New York, 1996.
3. **H. H. Chang**, Fluvial Processes in River Engineering, John Wiley, 1988.
4. **D. B. Simons** and **F. Senturk**, Sediment Transport Technology, Water Resources Publications, Fort Collins, Colorado, 1977.

CE 675 - Advanced Experimental Fluid Mechanics

Open channel control structures; Varied flow profiles; River morphology, Sediment properties,

Experiments in open channel hydraulics – Flow measurements in channels; Hydraulic jump; surges and waves in channels; weirs and spillways; sedimentation and scouring.

Experiments in Fluid Mechanics: Basic fluid mechanics experiments; Drag and lift experiments; experiments in wind tunnel; pipe network experiments; water hammer experiments; potential flow experiments; vortex flows.

Hydraulic machinery experiments: Experiments on turbines (Francis, Pelton, Kaplan); centrifugal pump.

Hydrologic experiments: Rainfall intensity measurements; hydrology bench and watershed based experiments.

Errors in Experimentation, Uncertainty in experiments, law of propagation of errors, instruments for measurements of Stage, discharge and velocity, current meters, data reduction and report preparation.

Reference:

1. **A.T. Troskolansky**, Hydrometry-Theory and Practice of Hydraulic Measurements, Pergamon Press, New York, 1970.P.R.
2. **Bevington**, Data Reduction and Error Analysis for Physical Sciences, McGraw Hill Book Co., New York, 1970.
3. **E.O. Doebelin**, Measurement Systems-Application and Design, McGraw-Hill Book Co., New York, 1980.
4. **Lab Manual on Fluid Mechanics, Department of Civil Engineering, IIT Bombay (unpublished)**

CE 676 - WATER RESOURCES SYSTEMS

Importance of Systems Approach in Water Resources; Introduction to system concepts, mathematical modeling, Simulation, Optimization, Unconstrained and Constrained Optimization.

Classical Optimization methods: Calculus based methods; Single and multiple variable optimization; Lagrange Multipliers; Kuhn Tucker conditions; applications in water resources.

Linear Programming: Definitions; Graphical solutions; Simplex method; Big-M Method; Duality theory; Sensitivity Analysis in LP; Numerical examples; applications in water resources.

Dynamic Programming: Definitions; recursive equations; numerical examples; applications in water resources: water allocation, capacity expansion, reservoir operation.

Reservoir Systems: Reservoir sizing, modeling of reservoir systems for flood control, hydropower, irrigation, water quality control; optimal operation for single and multireservoir systems; simulation models for hydropower systems and examples;

Performance evaluation of water resources projects- reliability, resiliency, vulnerability, sustainability measures.

Stochastic Optimization: Chance constrained optimization; stochastic dynamic programming; Applications in water resources & reservoir operation.

Evolutionary algorithms for optimization - Genetic algorithms (GA)and other EAs, applications in water resources.

Decision making with multiple objectives: conventional and non-conventional approaches; multi-objective GAs; applications in water resources.

References:

1. Vedula, S. and PP MujumdarWater Resources Systems, Tata McGraw-Hill, New Delhi, 2005.
2. Simonovic, S.P. Managing water resources: Methods and tools for a systems approach, UNESCO publishing, France, 2009.
3. Karamouz, M., Szidarovszky, F., Zahraie, B.Water resources systemsanalysis, CRC Press, Boca Raton, 2003.
4. Loucks, D.P. and Eelco van Beek. Water resources systems planning and management: An introduction to methods, models and applications., UNESCO Publ., 2005.
5. Mays, L.W., Y.K. Tung.Hydrosytems engineering and management, McGraw-Hill, New York, 1992.

6. Loucks, D. P., Stedinger, J. R., and Haith, D. A., Water Resources Systems Planning and Analysis, Prentice-Hall, Englewood Cliffs, NJ, 1981.

7. ReVelle, C. and McGarity, A. E., Design and Operation of Civil and Environmental Engineering Systems, John Wiley & Sons, New York, 1997.

CE 682 - FINITE ELEMENT APPLICATIONS TO FLOW PROBLEMS

Approximate methods: Method of weighted residuals (Sub-domain, Collocation, Least squares, Galerkin, Raleigh-Ritz methods), Applications to solve linear and nonlinear differential equations,

Discretization of domain: Grid generation, Interpolating polynomials, Integration of shape functions over the domain.

Formulation of element matrices and its global assembly for Laplace, Poisson, Diffusion, Advection-diffusion and Navier Stokes equations.

Solution of system of equations: Linear and nonlinear equations, Solution procedure with compact storage schemes for sparse matrices.

Boundary element method: Basic theory, Integral equations, Fundamental solutions, Applications in potential problems.

Applications of finite element method and boundary element method: Applications in groundwater flow, Fluid dynamics, Pollutant transport in surface water and ground water, Computer packages.

References:

1. K. A. Hoffmann and S. T. Chiange, Computational Fluid Dynamics for Engineers, Vol. I, Engineering Education System, Wichita, Kanasas, 1993.
2. O.C. Zienkiewics, Finite Element Method, McGraw Hill Book Co., New York, 1991.
3. T.R. Chandrupatla, Introduction to Finite Elements in Engineering, Prentice Hall, Englewood Cliffs, New Jersey, 1991.
4. K.J. Bathe, Finite Element Procedure in Engineering Analysis, Prentice Hall of India, New Delhi, 1990.
5. C.A. Brebbia, J.C.F. Telles, L.C. Wrobel, Boundary Element Techniques- Theory and Applications in Engineering, Springer-Verlag, Berlin, 1984.
6. J.N. Reddy, Finite Element Method, McGraw-Hill Inc, New York, 1993.
7. Wang, H., and Anderson, M. P. (1982). Introduction to Groundwater Modeling Finite Difference and Finite Element Methods, W. H. Freeman and Company, New York.
8. Pinder, G. F., and Gray, W. G. (1977). Finite Element Simulation in Surface and Subsurface Hydrology, Academic press,New York.
9. Desai, Y.M., Eldho T.I., Shah A.H.. (2011). Finite Element Method with Applications in Engineering, Pearson Education, New Delhi.
10. Liu G R and Gu Y T 2005 An introduction to meshfree methods and their programming Springer New York.

CE 731 - Mechanics of Fluid Flow

Fluid flow theories – an Introduction

Equation of motion, continuity and energy in differential forms, integral equations of momentum and energy and control volume approach

Navier Stokes Equations – Solution and Applications

Laminar flow in pipes and channels

Turbulent flow in pipes and channels

Elements of boundary layer concepts, boundary shear stress-skin-friction drag

Environmental fluid mechanics – diffusion, dispersion in open channels, transport mechanism & solutions

Unsteady flow in open channels, surges in channels

Transients in closed conduits, water hammer analysis

References:

1. R.A. Granger, "Fluid Mechanics", Dover Publications, 1995.
2. Daily and Harleman, “Fluid Dynamics”, Addition Wesley, New York, 1973.
3. James A. Fay, “Introduction to Fluid Mechanics”, Prentice Hall, New Delhi, 1996.
4. Wylie & Streeter, “Fluid Mechanics”, Mc Graw Hill, New York, 1998
5. R.H. French, “Open Channel Hydraulics”, Mc Graw Hill, New York, 1986.
6. Bruce R. Munson, D.F. Young, T.H. Okiishi, Fundamentals of Fluid Mecahnics, John Wiley, New York, 2002.
7. Daugherthy, R.L., Franzini, J.B., Finnemore, E.J. Fluid Mechanics with Engineering Applications, McGraw Hill, New York, 1985.
8. Douglas, J.F. ,Gasiorek, J.M. ,Swaffield, J.A., Fluid Mechanics, Addison-Wesley, Harlow 1999.
9. Shames, I.H., Mecahnics of Fluids, McGraw Hill, New York, 1992.
10. Video Course on Fluid Mechanics: Prof. T.I. Eldho, Dept. Civil Engg., IIT Bombay

    (http://www.youtube.com/course?list=PL3F50D04B70A5B935&category=University/Engineering) (http://nptel.iitm.ac.in/video.php?subjectId=105101082)

CE 736 - Environment Impact Analysis of Water Resources Systems

Water resources projects that needs EIA, Sequence of studies in Environmental Impact assessment of water resources projects, Matrix, Checklists, Network, Overlays and other techniques of environmental impact assessment.

Oxygen sag models, Empirical and self-information models, Planning and management of impact studies, Prediction and assessment of impact on surface water environments,

Prediction and assessment of impact on groundwater environments, Sources of Contamination of groundwater environment, Development of solute transport equations for surface and sub-surface flows,

Finite differences and finite element models, Numerical dispersion, Solutions by particle tacking methods, Modified method of characteristics, Random walk transport models.

References:

1. **Canter L.W**., Environmental Impact Assessment, McGraw-Hill, New York, 1977.
2. **M. G. Stewart** (Ed.), Integrated Risk Assessment, Applications and Regulations, Balkema Publications, Rotterdam, 1998.
3. **R. S. Jose** and **C. A. Brebbia** (Ed.), Measurements and Modelling in Environmental Pollution, Comp. Mech. Publ., Barcelona, 1997.
4. **V. Novotny**, Water Quality: Prevention, Identification and Management of Diffuse Pollution, Van Nostrand Reinhold, New York, 1994.

CE 738 - IRRIGATION AND CONVEYANCE NETWORK

Irrigation fundamentals, types of irrigation, tank irrigation, lift irrigation, Principles of soil physics & soil chemistry

Soil-plant-water relationships: Water relation of soils, soil moisture and plant growth, water requirement and yield response; Crop water requirements estimation; irrigation scheduling; irrigation efficiencies.

Irrigation economics: Economic analysis of on-farm irrigation; financial analysis – Central and State financing – Economic instruments- water charges, cess, taxes, subsidies and compensation- Irrigation water pricing – Cost Benefit analysis of irrigation projects; Irrigation project planning and management.

Water conveyance and control, Canal and pipe network planning - principles of branching network systems for flexibility, alignment of network components, determination of the network flows and demands

Analysis and design of different surface irrigation methods -furrow system, level basin, graded border and other types with examples; Computer models for surface irrigation design;

Planning and design of sprinkler irrigation systems- types of sprinklers, Pipeline hydraulics and economics, lateral design and main delivery system design, Pump and power unit selection, design of different types of sprinklers with examples;

Micro-irrigation system- types and components, Drip irrigation planning factors, Emitter selection and design criteria, Drip lateral and manifold design, Drip system design synthesis; examples

Computer models for micro irrigation design, and Case study applications.

References:

1. Michael, A.M. (2008). Irrigation: Theory and Practice, 2nd edition, Vikas Publishing House, 772p.
2. Ali, M. H. (2010). Fundamentals of Irrigation and On-farm Water Management: Volume 1. 1st Edition., 2010, 556 p.
3. Keller, J. and Bliesner, R.D. (2001). Sprinkle and trickle irrigation. Published by The Blackburn press, Springer-Verlag, 2001, 652p..
4. Cuenca, R.H. (1989). Irrigation System Design. Prentice Hall, Englewood Cliffs, NJ., 1989, 552p.
5. Walker, W.R. and Skogerboe, G.V. (1987). Surface Irrigation - Theory and Practice. Prentice Hall, Inc. Englewood Cliffs, Newjersy.
6. Jensen, P.A. and Barnes, J.W.(1980). Network Flow Programming, John Wiley and Sons, New York.

CE 764 – HYDROINFORMATICS

Module 1: Introduction: Introduction to data-driven modeling for water systems; Model classification; Introduction to Matlab and R Programming.

Module 2: Supervised Learning for classification/regression: Linear Models and Generalized Linear Models (GLM) including Logistic and Poisson Regression; k-Nearest Neighbor (k-NN) method; Polynomial Regression and Generalized Additive Models; Kernel-based Methods; Decision trees – Classification and Regression Trees (CART) – Bagging, Boosting and Random Forests; Support Vector Machines (SVM); Artificial Neural Networks (ANN); Resampling Methods - Bootstrap; Regularization and Machine Learning System Design.

Module 3: Unsupervised Learning: Clustering: i) hard (k-means) clustering and ii) fuzzy clustering (fuzzy c-means) with introduction to fuzzy logic; Multivariate analysis – dimension reduction, Singular Value Decomposition (SVD), Principal Component Analysis (PCA), Canonical Correlation Analysis (CCA).

Module 4: Applications: Hydroinformatics for Climate Change Impact Assessment and Regional Flood Frequency Analysis; Example of a Hydrologic Information System..

References:

1. James, G., Witten, D., Hastie, T., & Tibshirani, R. (2013). An introduction to statistical learning (Vol. 112). New York: Springer. (Or Hastie et al. for advanced)
2. von Storch and Zwiers, 1999, Statistical Analysis in Climate Research, Cambridge Univ. Press, U.K.
3. Myers, R. H., Montgomery, D. C., Vining, G. G., & Robinson, T. J. (2012). Generalized linear models: with applications in engineering and the sciences (Vol. 791). John Wiley & Sons.
4. Abbott, 1991, Hydroinformatics- Information Technology and the Aquatic Environment, Avebury Technical, Aldershot, U.K.
5. Nielsen, 2016, Neural Networks and Deep Learning, Web-book. http://neuralnetworksanddeeplearning.com/index.html
6. Other relevant research articles.

CE 765 - Environmental Fluid Mechanics

Introduction: The role of fluid mechanics in environmental planning, Transport of substances in the hydrologic cycle, Protection of water quality

Basic Relationships: Conservation of mass, energy and momentum, Law of fluid motion - Navier-Stokes equations -Turbulent flow, Diffusion process

Heat and Mass Transfer: Diffusive transport of substances (molecular diffusion), Heat transfer equations,

Relationships Turbulence: Properties of turbulent flow, Basic equations of turbulent momentum transport, Turbulent hypothesis, Dispersion Stratification and Density Driven Flow: Density variations in fluids, Stability and stratification (hydrostatics, hydrodynamics), Stratified flow examples

Jets and Plumes: similarity theory, entrainment hypothesis, applications for different environmental conditions and source configurations

Emission Standards for Sewage and Heat Discharges; Flow, transport and mixing Process in lakes, Reservoirs and rivers

Water Quality Standards: River and estuarine water quality models (model formulation, dimensionality, applications), Integrated Water Quality management

References:

1. **Liggett, J.A.,** Fluid Mechanics, McGraw Hill International, Singapore, 1994.
2. **Wilkes, J.O**., Fluid Mechanics for Chemical Engineers, Prentice Hall, Englewood Cliffs, 1999.
3. **Douglas, J.F., Gasiorek, J.M.** and **Swaffield, J.A.,** Fluid Mechanics, Addison Wesley, Reading, 1999.
4. **Streeter, V.L., Wylie, E.B.** and **Bedford, K.W.,** Fluid Mechanics, WCB/McGraw-Hill, 1998.
5. **Papanastasiou, T.C.,** Applied Fluid Mechanics, Prentice-Hall, 1994.
6. **Gerhart, P.M., Gross, R.J.** and **Hochstein, J.I.,** Fundamentals of Fluid Mechanics, Addison Wesley, Reading, 1992.
7. **Brown, R.A**., Fluid Mechanics of the Atmosphere, Academic Press, 1991.
8. **Denn, M.M.,** Process Fluid Mechanics, Prentice Hall, Englewood Cliffs, 1980.

CE 766 - WATERSHED MANAGEMENT

Principles of Watershed Management: Basics concepts, Hydrology and water availability, Surface water, Groundwater, Conjunctive use, Human influences in the water resources system, Water demand, Integrated water resources system - River basins Watershed Management Practices in Arid and Semi-arid Regions, Watershed management through wells, Management of water supply - Case studies, short term and long term strategic planning Conservation of Water: Perspective on recycle and reuse, Waste water reclamation Social Aspects of Watershed Management: Community participation, Private sector participation, Institutional issues, Socio-economy, Integrated development, Water legislation and implementations, Case studies Sustainable Watershed Approach: Sustainable integrated watershed management, natural resources management, agricultural practices, integrated farming, Soil erosion and conservation Water Harvesting: Rainwater management - conservation, storage and effective utilisation of rainwater, Structures for rainwater harvesting, roof catchment system, check dams, aquifer storage Applications of Geographical Information System and Remote Sensing in Watershed Management, Role of Decision Support System in Watershed Management

References:

1. **Murty, J.V.S**., Watershed Management, New Age Intl., New Delhi 1998.
2. **Allam, G.I.Y**., Decision Support System for Integrated Watershed Management, Colorado State University, 1994.
3. **Vir Singh, R.,** Watershed Planning and Management, Yash Publishing House, Bikaner, 2000.
4. **Murthy, J.V.S.,** Watershed Management in India, Wiley Eastern, New Delhi, 1994.
5. **American Society of Civil Engineers**, Watershed Management, American Soc. of Civil Engineers, New York, 1975.

CE 767 - HYDROLOGICAL HAZARD MITIGATION AND MANAGEMENT

Flood Hazard Mitigation: Basics of floods, Natural and man-made floods, Flood control structures, Flood management,

Applications of geographical information systems and remote sensing in flood management, Case studies Drought Hazard Mitigation: Basics of droughts, Natural and man-made droughts, Watershed management, Drought management, Applications of geographical information systems and remote sensing in drought management, Drought problems in arid and semi-arid regions, Case studies

Crisis and Emergency Management: Nature of extreme events, Cyclone and related flooding, Global problems of catastrophe solution and emergency situations, Mobilisation of communities, Community involvement, Case studies Risk Management: Risk assessment, Risk reduction and management, Role of insurance companies Advanced Warning Systems: Global positioning systems, Applications of remote sensing and GIS, Role of Information Technology in natural hazard mitigation management

References:

1. Centre for Science & Environment, Wrath of Nature: Impact of Environmental Destruction on Floods and Droughts, Centre for Science & Environment, New Delhi.
2. **Beven, K.** and **Carling, P.,** (eds.), Floods: Hydrological, Sedimentological and Geomorphological Implications, British Geomorphological Research Group Symposia Series, Wiley, Chichester, 1989.
3. **B.H.R.A.,** Hydraulic Aspects of Floods & Flood Control, B.H.R.A., England, 1983.
4. **Brown, J.P.,** Economic Effects of Floods, Springer-Verlag, Berlin, 1972.
5. **Prasad, P.,** Famines and Droughts: Survival Strategies, Rawat, Jaipur, 1998.
6. **A.K. Schwab, K. Eschelbach, David J. Brower,** Hazard Mitigation and Preparedness, John Wiley, 2007.

CE 768 - URBAN WATER AND ENVIRONMENTAL MANAGEMENT

Urban Water Demand- Basic requirements for water supply, drainage and sanitation; Present and future demand for Indian cities, Estimation and fulfillment-Feasibility and Case studies

Administrative and Legal Aspects and Financing: International, national and municipal legal aspects, Administrative structure for drainage planning, Financing for drainage projects, Preparation of ToR, Case studies

Introduction to Drainage Problems in Different Climates: Urbanisation - Its effects and consequences for drainage, Interaction between urban and peri-urban areas.

Planning concepts and System Planning, Drainage Master Plan: Objectives of urban drainage and planning criteria, Drainage options and system layout, Planning tools and data requirement, Drainage structures, Case studies

Urban Hydrologic and Hydraulic Procedures: Urban hydrologic cycle, Rainfall analysis, Design storm, Determination of peak flow rates, Hydraulic and hydrodynamic principles, Calculation methods and mathematical tools: Modeling formulas, Hydrologic models, Hydrodynamic models, Regression analysis, Urban runoff and water quality models, Case Studies

Best Management Practices - Source control techniques: Infiltration basins, Porous pavements, Rooftop rainwater harvesting, Detention basins/ ponds, Case studies

Design of Drainage System Elements: Hydraulic fundamentals, Design guidelines and considerations; Design of sewerage and drainage channels, Case studies

Detention and Retention Facilities: Design objectives and considerations, Storage facility types, On-site and off-site detention, Preliminary design computations, Orifices, Weirs, Discharge pipes, Emergency spillway, Routing procedures, Water budget, Land-locked retention, Case Studies

Pavement Drainage: Hydroplaning, Design frequency and spread, Surface drainage, Flow in gutters, Drainage inlet design,

Inlet types- selection considerations

Roadside Drains: Design parameters, Stable channel design, Design procedure for roadside and median channels, Case studies

Airport Drainage: Special considerations for airport drainage, Design example, Case studies

Culvert Design: Culvert Hydraulics, Objectives, Types of flow, Inlet control, Outlet control, Entrance efficiency, Design investigation, Design of new culvert, Culvert replacement, Case studies

Pumping Stations: Design considerations, Design criteria, Pump station storage requirements, Case studies

Control of Stormwater Pollution in Urban Areas: Pollution build-up and washoff processes with reference to urban drainage systems and eutrophication of urban lakes, Case studies

Operation and Maintenance of Urban Drainage Systems: Maintenance requirements and planning, Cleansing of sewers and drains, repair options, Case studies

Removal of Solid waste and silt from urban stormwater channels and drains, Case studies

Flood and Cyclone Early warning systems

References:

1. Gribbin,J.E., 2014, Introduction to Hydraulics and Hydrology with Applications for Stormwater Management, Cengage
2. Mays, L.W., 2001, Stormwater Collection Systems Design Handbook, McGraw Hill
3. Butler and Davis, Urban Drainage, 3rd edition, 2010
4. Haestad Publishers, 2003, Stormwater Conveyance Modeling and Design, 1/E
5. Haestad Publishers, 2002, Computer Applications in Hydraulic Engineering, 5/E.

DETIALS OF COURSES OFFERED BY STRUCTURAL ENGINEERING GROUP

CE 324 ENGINEERING LAW

The Indian legal system from an engineer's perspective. Socratic-method analysis of statutory and case law. Contract, patent, corporation, antitrust, property, and environmental laws. Development of law, courts, and ethics; law on contracts, agency, sales, property, and patterns; specifications; preparation of contract documents. Coverage of following topics: 1. Overview of Indian legal system, 2. Contracts: Definitions and essentials, 3. Conditions: 3rd parties and law, 4. Construction: Performance/Breach/Damages and Contracts, 5. General Conditions: Proposals, advertisements and applications, 6. Financial Considerations: Loans and leans, 7. Specifications: Workmanship, material, drawings, 8. Agencies: Partnerships and corporations, 9. Torts: Limited coverage, 10. Professional liability: Insurance, bonds, property, 11. Litigation: Evidence, expert witness, mediation, ethics.

References:

1. Judgements and case studies.

CE 403 Design of Structures III

Design of RCC watertanks, silos, bunkers and simple bridges - Design of steel roof trusses, steel frames - Design of industrial buildings - Design of residential buildings - Design of arches and shells.

References:

1. J. Krishna and O.P. Jain, Plain and Reinforced Concrete, Vol. I and II Nemchand Bros. Roorkee, 1968.
2. IS 456, 1978. Code of Practice for Plain and Reinforced concrete.
3. Design Aids for R.C. to IS 456-1978, ISI-SP-16-sand-T, 1980.
4. A.S. Arya and J.L. Ajmani : Design of Steel Structures, Nemchand Bros. Roorkee, 1990.
5. A.S. Arya and J.L. Ajmani : Design of Steel Structures, Nemchand Bros. Roorkee, 1990.
6. S.M.A. Kazimi and R.S. Jindal - `Design of Steel Structures, Prentice Hall (India), New Delhi, 1981.
7. S.K. Duggal - `Design of Steel Structures, Tata McGraw Hill, New Delhi, 1993.
8. P. Dayaratnam - `Design of Reinforced Concrete Structures, Third Edition, Oxford - IBM Publishing Co., New Delhi, 1989.
9. S.N. Sinha - `Reinforced Concrete Design, Tata McGraw Hill, New Delhi, 1990.

CE 448 - Prestressed Concrete Design

Prestressing concepts, materials, systems of prestressing and losses. Introduction to working stress method, limit state analysis and design of members for bending. Shear torsion and axial forces. End block design. Deflections, use of relevant codes of practice.

References:

1. **T.Y. Lin** and **N.H.** Burns, Design of Prestressed Concrete Structures, 3rd Ed., Wiley, New York, 1981.
2. **A.E. Naaman**, Prestressed Concrete Analysis and Design: Fundamentals, 2nd Ed., Technopress, New York, 2004.
3. **N. Krishnaraju**, Prestressed Concrete, Tata McGraw Hill, New Delhi, 1981.
4. **Y. Guyan**, Limit State Design of Prestressed Concrete, Applied Science Publishers, 1972.

CE 482 – Construction Management

Project Initiation and Planning, Time Value of Money, Investment Analysis, Cost-Benefit Analysis, Work Breakdown Structures, Development of project activity networks, Precedence Diagram Method, Critical Path Method (CPM), Program Evaluation and Review Technique (PERT), Line Balance Methods in scheduling, Resources in construction, Resource levelling, crashing of project schedules, earned value analysis, Safety and occupational hazards in construction, Fundamentals of quality control in construction, Contracts in construction, fundamentals of delay analysis and claims, Introduction to Building Information Modelling (BIM), Lean construction, and Integrated Project Delivery in construction

References:

1. **Bennett, F. Lawrence**., The management of construction: a project life cycle approach. Routledge, 2003.
1. **Oberlender, Garold D**., Project management for engineering and construction. Vol. 2. New York: McGraw-Hill, 1993.
2. **Peurifoy, Robert Leroy, Cliff J. Schexnayder** and **Shapira A..** Construction planning, equipment, and methods. No. 696 pp. McGraw-Hill, 2010.
3. **Riggs, James L., David D. Bedworth**, and **Sabah U. Randhawa**., Engineering economics. 4th Ed., McGraw-Hill, 2004.
4. **Jha, Kumar Neeraj**. Construction project management: theory and practice. Pearson Education India, 2011.
5. **Chitkara, K. K**. Construction Project Management. Tata McGraw-Hill Education, 2014.

CE 603 Numerical Methods

Programming fundamentals; Fundamentals of numerical methods; Error analysis; Curve fitting; Interpolation and extrapolation; Differentiation and integration; Solution of nonlinear algebraic and transcendental equations; Elements of matrix algebra; Solution of systems of linear equations; Eigenvalue problems; Solution of differential equations. Computer oriented algorithms; Numerical solution of different problems.

References:

1. **J. H. Wilkinson**, The Algebraic Eigenvalue Problem, Oxford University Press, London, 1965.
2. **K.E. Atkinson**, An Introduction to Numerical Analysis, John Wiley and Sons, New York, 1989.
3. **G. E. Golub** and **C.F. Van Loan**, Matrix Computations, Johns Hopkins University Press, Baltimore, 1989.

CE 610 - Introduction to Earthquake Engineering

Characterisation of ground motion, Earthquake intensity and magnitude; Recording instruments and base line correction; Predominant period and amplification through soil; Earthquake spectra for elastic and inelastic systems; Idealisation of structural systems for low, medium and high rise buildings; Lateral force evaluation by mode superposition and direct integration; Reserve energy technique; Effect of foundation/soil on earthquake response; Analysis for torsion; Review of damages during past earthquakes and remedial measures; Reinforcement detailing for members and joints coupling; Codal provisions.

References:

1. **A. K. Chopra**, Dynamics of Structures: Applications to Earthquake Engineering, Prentice-Hall, New York, 1995.
2. **R.W. Clough** and **J. Penzien**, Dynamics of Structures, 2nd edition, McGraw-Hill, New York, 1992.
3. **N.M. Newmark** and **E. Rosenblueth**, Fundamentals of Earthquake Engineering, Prentice Hall, New York, 1971.
4. **D. Key**, Earthquake Design Practice for Building, Thomas Telford, London, 1988.
5. **R.L. Wiegel**, Earthquake Engineering, 2nd edition, Prentice Hall, London, 1989.
6. J**.A. Blume, N.M. Newmark,** and **L.H. Corning**, Design of Multi-storied Buildings for Earthquake Ground Motions, Portland Cement Association, Chicago, 1961.
7. Proceedings of World Conferences on Earthquake Engineering, 1956-2000.
8. I.S. Codes No.1893, 4326,13920.

CE 611 - Advanced Structural Mechanics

Review of Concepts: Basic concepts of structural analysis; Basis for principle of virtual work; Principle of virtual forces - standard and matrix formulation; Force method for analysing skeletal structure; Principles of virtual displacements - standard and matrix formulation; Displacement method for analysing skeletal structures; Extension of displacement method to the generalised stiffness method; Basic concepts associated with computer implementation of stiffness method. One dimensional beam element: Basis for cross-sectional level formulation of flexibility and stiffness; Gauss quadrature numerical integration scheme; Flexibility approach for determining element stiffness; Stiffness approach for determining element stiffness; Special consideration of shear effects in stiffness approach; Consideration of torsional effects for thin walled member - incl. torsion bending; special considerations for finite joints(both rigid and flexible); Consideration of local load(incl. temp.)effects; Formulation of geometric stiffness due to axial force; Linearised buckling analysis. Simplifications to reduce computational effort in analysis: Substructure analysis(static condensation); Symmetry consideration in structures.

References:

1. **M.B. Kanchi**, " Matrix Structural Analysis"
2. **Gere Weaver**, " Matrix Structural Analysis"
3. **Pandit Gupte**, S.A. by Matrix Approach, T.M., 1994.

CE 613 - Concrete Technology

Review of constituents of concrete and mix design and properties of concrete; High strength concrete; High density and lightweight concrete; Concreting under extreme weather conditions; Behaviour of concrete under aggressive environmental conditions including temperature; Admixtures; Polymers in concrete; Fibre reinforced concrete; Fracture mechanics of concrete; Repairs and rehabilitation of old concrete.

References:

1. **Lea, F.M.,**302240 Chemistry of cement and concrete 3rd ed, Edward Arnold, London, 1970
2. **De Larrard, F**, Concrete Mixture proportioning: A scientific Approach, E&FN Spon, London, 1999.
3. **Neville, A.M.,** 'Properties of concrete', 4th ed., Pearson Education Limited, London, 2000.
4. **P. Kumar Metha** and **P. J. M. Monterio**, Concrete- Microstructures, Properties and Materials, Indian Edition, Indian Concrete Institute, Chennai.
5. **Aitcin, P. C**., High Performance Concrete, E&FN Spon, London, 1998.
6. **Peter H. Emmons**., Concrete Repair and Maintenance Illustrated: Problem Analysis; Repair Strategy; Techniques, R S Means Company, Kingston, 1993.
7. ASCE Journal of Materials in Civil Engineering, Cement and Concrete Research Materials and Structures, ACI Materials Journal, Cement and Concrete Composites, Construction and Building Materials, Magazine of Concrete Research, KSCE Journal of Civil Engineering, The Indian Concrete Journal, Concrete International,
8. Advanced Cement Based Materials Standards
9. ASTM Standards, IS Standards, ACI Manual of Concrete Practice

CE 615 - STRUCTURAL OPTIMIZATION

Formulation of different types of structural optimisation problems; Optimality criteria based structural optimisation; Computational of derivatives of response quantities with respect to design variables; Classical optimisation; Lagrange multiplier technique and Kuhn-Tucker conditions; Solution of NLP by direct methods and by series of unconstrained optimisation problems and by series of linear programming problems.

References:

1. **S.S.Rao**, Optimisation, Theory and Applications, 2nd Edition, Wiley Eastern Ltd., New Delhi, 1991.
2. **J.S.Arora**, Introduction to Optimum Design, McGraw-Hill International Edition, New York, 1989.
3. **A.J.Morris** (Editor), Foundations of Structural Optimisation - A Unified Approach; John Wiley and Sons, Chichester, 1982.
4. **G.V.Reklaitis, A.Ravindran** and **K.M.Ragsdell**, Engineering Optimisation Methods and Applications, John Wiley, New York, 1983.

CE 616 - Structural Dynamics

SDOF System : Equation of motion; Free vibration; Harmonic load; Evaluation of damping,; Periodic load; General load (time domain, frequency domain); Response spectrum load. MDOF Systems : Structural matrices; Un-damped free vibration; Generation of damping matrix, Mode superposition analysis; Practical considerations. Continuous Systems : Equation of motion; Un-damped free vibration; Forced response. Random Vibrations : Random variables and random recesses; Models of random dynamic loads; Stochastic response of SDOF and MDOF systems.

References:

1. **A. K. Chopra**, Dynamics of Structures Applications to Earthquake Engineering, Prentice Hall, 1994.
2. **R. W. Clough** and **J. Penzien**, Dynamics of Structures, 2nd ed., McGraw-Hill, Singapore, 1993.
3. **L. Meirovitch**, Elements of Vibration Analysis, 2nd edition, McGraw-Hill, Singapore, 1986.

CE 617 - PLATES AND SHELLS

Plate equation and behaviour of thin plates in cartesian, polar and skew coordinates; Curvilinear coordinates and coordinate transformation; Isotropic and orthotropic plates, bending and twisting of plates; Navier?s solution and Energy method, rectangular, circular plates and plates with variable rigidity in cartesian and polar coodinates; Numerical solutions. Shell behaviour, shell surfaces and characteristics, classifications of shells, equilibrium equations in curvilinear coordinates, force displacement relations; Membrane analysis of shells of revolution and cylindrical shells under different loads, shallow shells, concept of pseudo-stresses, membrane solution of elliptic paraboloids and hyperboloids, solutions of typical problems.

References:

1. **S. P. Timoshenko** and **S. W. Krieger**, Theory of Plates and Shells, McGraw-Hill, 1959.
2. **R. Szilard**, Theory and Analysis of Plates: Classical and Numerical Methods, Prentice Hall, New York, 1974.
3. **N. K. Bairagi**, Shell Analysis, Khanna Publishers, New Delhi, 1990.
4. **V.V. Novozhilov**, Thin Shells, Groringen Publications, Netherlands, 1959.

CE 619 - Structural Stability

Concepts of stability, static, dynamic and energy criteria; Buckling Snap through and post-buckling; stability of columns and beams; Inelastic buckling; Beam-columns; stability of frames; Matrix stiffness and finite element methods applied to stability problems; introduction to stability of plates, shells and stiffened plates.

References:

1. **Don O. Brush** and **B.O.Almorth**, Buckling of Bare, Plates and Shells, McGraw-Hill, New York 1975.
2. **S.P.Timoshenko** and **J.M.Gere**, Theory of Elastic Stability, 2nd Edition, McGraw Hill New York, 1961.
3. **A.Chajes**, Principles of Structural Stability Theory, Prentice Hall, New York, 1974.
4. **N.G.R.Iyengar**, Structural Stability of Plates and Shells (Ellis Horwood Series in Civil Engineering), East-West Press, New Delhi.
5. **G.J.Simitses**, An Introduction to the Elastic Stability of Structures, Prentice Hall, New York, 1976.
6. **Z.P.Bazant** and **L.Cedolin**, Stability of Structures: Elastic, Inelastic, Fracture and Damage theories, Oxford University Press, New York, 1991.

CE 620 - Finite Element Methods

Principles of discretisation; Element stiffness mass formulation based on direct, variational and weighted residual techniques and displacements, hybrid stress and mixed approaches, shape functions and numerical integrations, convergence, Displacement formulations for rectangular, triangular and isoparametric elements for two dimensional and axisymmetric stress analysis; Thin and Thick plates and shells, Semi-analytical formulations; Three dimensional elements and degenerated forms; Stiffener elements and modifications such as use of different coordinate systems, use of nonconforming modes and penalty functions; Application to layered composite plate/shells, bridge, roof, nuclear and offshore structures; Hybrid stress and mixed formulations for plates.

References:

1. **O.C. Zienkiewicz**, The Finite Element Method, Tata McGraw-Hill, New Delhi, 1977.
2. **K. J. Bathe**, Finite Element Procedures, Prentice Hall, New York, 1995.
3. Finite Element Method with Applications in Engineering by, **Y. M. Desai, T.I. Eldho** and **A. H. Shah** Pearson, 2011

CE 621 - Plastic Analysis

Yield condition and concepts of simple plastic collapse, idealisational collapse criteria, virtual work in the elastic-plastic state; Theorems of plastic collapse; Methods of analysis and design, Applications to planar and simple space structures; Deflection at collapse; Minimum weight analysis; Variable repeated loads; Combined stress problems; Introduction to stability.

References:

1. **J.F. Baker, M.R. Home** and **J. Heyman**, Steel Skeleton, Vol.II, Cambridge Univ. Press, London, 1961.
2. **B.G. Neal**, The Plastic Methods of Structural Analysis, Champman and Hall.
3. **P.G. Hodge (Jr.)**, Plastic Analysis of Structures, McGraw-Hill, New York, 1959.
4. **J. Heyman**, Beams and Framed Structures, Pergamon Press, 1974.
5. SP: 6(6)-1972, Applications of Plastic Theory in Design of Steel Structures, Indian Standards Institution, New Delhi, 1972.
6. **A. Mrazik, M. Skaloud** and **M. Tochacek**, Plastic Design of Steel Structures, Ellis Horwood, Chichester, 1987.

CE 622 - Reliability Based Civil Engineering Design

Concepts of structural safety; Basic statics and probability; Resistance parameters and distributions; Probabilistic analysis of loads, live load and wind load; Basic structural reliability; Monte Carlo study of structural safety; Level 2 reliability methods; Reliability analysis of components; Reliability based design-determination of partial safety factors, code calibration; Reliability of structural systems; Fatigue reliability ? S-N curve approach; Applications to steel and concrete structures; Offshore structures etc.

References:

1. **R. Ranganatha**, Structural Reliability Analysis and Design, Jaico Publications, Mumbai, 1999.
2. **P. T. Christensen** and **M. J. Baker**, Structural Reliability Theory and its Application, Springer-Verlag, Berlin Haldelberg, New York, 1982.
3. **R. E. Melchers**, Structural Reliability Analysis and Prediction, Ellis Horwood, Chichester, 1987.
4. **A.H.S. Ang** and **W.H. Tang**, Probability concepts in Engineering Planning and Design, Vol.II, John Wiley, New York, 1984.
5. **P. T. Cristensen** and **Y. Murotsu**, Applications of Structural Systems Reliability Theory, Sopringer-Verlag, Berlin, 1986.

CE 623 - Advanced Solids Mechanics

Linear elasticity, Stress, strain, constitutive relations; Boundary conditions, Description of an Elasticity problem as a boundary value problem, Plane stress, strain, axi-symmetric problems, Large displacements and large strains; Cartesian, cylindrical and spherical coordinates; Introduction to curvilinear coordinates; Thermal strains. Introduction to plasticity; Yield condition; Ideal elasto-plastic material; complete formulation for an elasto-plastic problem.

References:

1. **N. Filonenko-Borodich**, Theory of Elasticity, Mir Publishers, Moscow, 1965.
2. **S.P. Timoshenko** and **J.N. Goodier**, Theory of Elasticity, 3rd edition, McGraw Hill, Singapore, 1970.
3. **C.R. Calladine**, Plasticity for Engineers, Ellis Herwood, Chichester, U.K., 1985.

CE 624 - NONLINEAR ANALYSIS

Geometrical and material non-linear problems; Basic equations for continuum; Beams, plates and shells, Analytical and discrete numerical solution techniques; Applications of finite element method.

References:

1. **K.Washizu**, Variational Methods in Elasticity and Plasticity, 3rd ed., Pergamon Press, Oxford, U.K., 1982
2. **D.R.J. Owen** and **E. Hinto**n, Finite Elements in Plasticity, Theory and Practice, Penridge Press, Swansea, U.K., 1980.
3. **M.A. Crisfield**, Nonlinear Finite Element Analysis of Solids and Structures, Vol.1, Essentials, Wiley, New York, 1991.
4. **K.J. Bathe**, Finite Element Procedures in Engg. Analysis, Prentice Hall, New Jersey, 1982.

CE 625 - Analysis of Offshore Structures

Loads and structural forms of different types of offshore structures; Elements of single d.o.f. system subjected to free and forced vibrations; Analysis for transient and steady state force; Equivalent damping for nonlinear systems; Dynamics of multi d.o.f. systems, Eigen values and vectors; Iterative and transformation methods; Mode superposition, Fourier series mand spectral method of response of single d.o.f. systems; Vibration of bars, beams and cones with reference to soil as half space; Behaviour of concrete gravity platform as a rigid body on soil as a continuum; Short and long term statistics of wind; static wind load; effect of size, shape and frequency; Aerodynamic admittance function and gust factor, spectral response due to wind for various types of structures; Wave loads by Morison"s equation; Static and dynamic analysis of fixed equation; Static and dynamic analysis of fixed structures; Use of approximate methods.

References:

1. **Brebbia C.A. and Walker**, "Dynamic Analysis of offshore structures", Newness butterworth, London, 1978.
2. **Sarpakaya T. and Isaacson M**., "Mechanics of Wave Forces on Offshore Structures", Van Nostrand Rainhold, NewYork, 1981.
3. **Hallam M.G., Heaf N.J. and Wootton, L.R.,** "Dynamics of Marine Structures", CIRIA Publicartions, Underwater Engg. Group, London, 1978.
4. **Graff W.J.,** "Introduction to Offshore Structures", Gulf Publishing Co., Houston, Texas, 1981.
5. **Clough R.W. and Penzien J.,** "Dynamics of Structures", IInd Edition, McGraw hill, 1992.
6. **Simiu E. and Scanlan R.H.,** "wind effects on Structures", Wiley,New York, 1978.
7. Codes of Practices (latest versions) such as API R-2A, bureau Veritas etc.

CE 627 - STRUCTURAL DESIGN

Complete design and structural detailing for standard structures like framed structures for residential, industrial, public utility and recreational purposes; Trusses, bridges, storage vessels, underground structures etc. in concrete, steel and other materials.

References:

1. **F. Mark**, Handbook of Concrete Engineering, V.N.R.Co., New York, 1974.
2. Handbook on Civil Engg. such as Merritt, Gaylord, Kemp etc.
3. Relevant I.S. Codes of practices, Bureau of Indian Standards, New Delhi.

CE 629 ELASTIC WAVES IN SOLIDS

Review of Solid Mechanics, strain and stress tensors, Cauchy's equation of motion, energy balance, boundary and initial conditions; Solution of one dimensional problems - waves in thin rods, spherical cavity subjected to dynamic pressure; Plane waves in unbounded media - longitudinal and shear waves, propagation in isotropic, anisotropic and dissipative media, dispersion and attenuation; Green's functions for unbounded solids; Half space problems – Rayleigh waves, interface waves; concentrated loads on half spaces; Waves in layered media - Rays and normal modes, guided waves in composite materials; Applications – wave motion from impact, blast and seismic events; nondestructive evaluation, acoustic emission, structural health monitoring, LS-DYNA simulations

References:

1. J. D. Achenbach, Wave Propagation in Solids, Noth Holland Pub, Amsterdem, 1973.
2. K. Graff, Wave Motion in Elastic Solids, Clarendon Press, Oxford, 1975.
3. M. Ewing, W. Jardetzky and F. Press, Elastic Waves in Layered Media, McGraw-Hill, New York, 1957.
4. J. L. Rose, Ultrasonic Waves in Solid Media, Cambridge University Press, Cambridge, 1999.
5. T. Kundu, Ultrasonic Nondestructive Evaluation: Engineering and Biological Material Characterization, CRC Press, Boca Raton, 2004

CE 639 - Green Building Design

Buildings are like living organisms that contribute to the life in the cities. A well-designed building that uses natural materials, passive heating and cooling systems can not only make the life of its inhabitants healthier, but also contribute to preserving the environment and natural resources. This course aims to teach the fundamentals of sustainable and energy efficient building design, by focusing on Building envelopes Building materials and properties Building systems and operations (HVAC, lighting, water supply, sewage, garbage disposal, recycling and composting) Clean & renewable energy in buildings Rainwater harvesting Water and energy conservation Energy modeling and performance evaluation of buildings Smart buildings (Sensing and control systems) Net Zero buildings, Passive house standards Building Rating systems (LEED, BREEAM, IGBC etc)

References:

4. **Hong, Wen** et. al., Building Energy Efficiency - Why Green Buildings Are Key to Asia`s Future. The Asia Business Council (2007)
5. **Yudelson**, **Jerry**, Green Building A to Z: Understanding the Language of Green Building. New Society Publishers (June 2007).
6. **Mendler, Sandra F., Odell, William, Lazarus, Mary Ann**, The HOK Guidebook to Sustainable Design Second Edition. Wiley (November 2005) ISBN 97804716961314.
7. **McDonough, William and Braungart, Michael**, Cradle to Cradle. Farrar, Straus & Giroux (April 2002) ISBN 9780865475878
8. **Snell, Clarke and Callahan, Tim**, Building Green: A Complete How-To Guide to Alternative Building Methods Earth Plaster, Straw Bale, Cordwood, Cob, Living Roofs. Lark Crafts(August 2009) ISBN 978-1600595349
9. **Keeler, Marian and Burke, Bill** - Fundamentals of Integrated Design for Sustainable Building. Wiley (May 2009) ISBN 9780472935
10. **Hindrichs, Dirk U.**, Plusminus 20/40 Latitude: Sustainable Building Design in Tropical and Subtropical Regions. Axel Menges (October 2007) ISBN 9783930698837
11. **Kibert, Charles J.**, Sustainable Construction: Green Building Design and Delivery, III edition. Wiley (October 30, 2) ISBN 9780470904459
12. **McHarg, Ian L.,** Design with Nature, I edition. Wiley (February 1995) ISBN 9780471114604
13. **Mazria, Edward,** The Passive Solar Energy Book. Rodale Press (1980) ASIN B000VNM20C
14. **Kwok, Alison and Grondzik, Walter**, The Green Studio Handbook: Environmental Strategies for Schematic Design, II edition. Architectural Press (April 2011) ISBN 9780080890524

15. **Shurcliff, William A.,** Thermal Shutters & Shades - Over 100 Schemes for Reducing Heat Loss through Windows, 1st edition. Brick House Publishing Co (April 1981) ISBN 9780931790140 \
16. Indian Green Building Council: www.igbc.inIGBC Green Homes Abridged Reference Guide
17. IGBC Green Factory Building Abridged Reference Guide
18. LEED India NC Reference Guide / LEED India CS Reference Guide
19. Background material of green building training programme conducted by IGBC
20. Green Rating for Integrated Habitat Assessment: http://grihaindia.org/
21. United States Green Building Council: http://www.usgbc.org/
22. The Whole Building Design Guide: http://www.wbdg.org/Technical Manual,
23. Australia home: http://www.yourhome.gov.au/technical/index.html
24. United States Department of Energy: http://energy.gov/

CE 651 – Bridge Engineering

Historical evolution of different bridge types: Stone masonry bridges, timber bridges, iron bridges, steel arch and truss bridges, reinforced concrete bridges, box girder bridges, prestressed concrete bridges, cable stayed bridges, suspension bridges; Bridge classification based on different criteria: function, material of construction, connections and inter-span relations; Superstructure design: standard specifications and loads, dead loads, standard live loads from IRC Bridge code, impact effects, temperature effects, shrinkage effects, deformation stresses; Superstructure design examples: reinforced concrete slab bridge design, steel girder bridge design, prestressed concrete box-girder bridge design; Superstructure design through software applications; Types of bridge superstructure elements: bearings and joints, piers, abutments, foundations; Substructure design: Standard specifications and loads, hydrologic forces, wind loads, seismic forces, barge/ship impact forces, earth pressure; Substructure design examples: pier design, abutment design.

References:

1. **D. Johnson Victor,** "Essentials of Bridge Engineering", Oxford & IBH Publishing Company Pvt. Ltd.
2. **Richard M. Barker & Jay A. Puckett**, "Design of Highway Bridges: An LRFD Approach", Wiley Publications
3. **M.G. Aswani, V. N. Vazirani, M.M. Ratwani**, "Design of Concrete Bridges", Khanna Publishers
4. **Raju N. Krishna**, "Prestressed Concrete Bridges", CBS Publishers
5. IRC:5-1998, Standard Specifications and code of practice for road bridges, Section I – General features of design, Indian Road Congress
6. IRC:6 –2000, Standard specifications and code of practice for road bridges, Section II – Loads and stresses, Indian Road Congress
7. IRC:21-2000 Standard specifications and code of practice of road bridges, Section III – Cement concrete (plain and reinforced), Indian Road Congress
8. IRC: 112-2011 Code of practice for concrete road bridges, Indian Road Congress

CE 653 - Structural Reliability and Risk Analysis

Review of Probability Basics: Introduction; Probability basics; Random variables; Probability distributions; Vectors; Correlation; Joint distributions

Structural Reliability Analysis 1: Basic concepts; Exact solution; MVFOSM; FOSM; FORM; Sensitivity

Probabilistic Simulations: Monte Carlo simulations; Stratified sampling; Importance sampling

Structural Reliability Analysis 2: System reliability; SORM; Time-varying reliability; Response surface

Reliability-Based Design Codes: Introduction; LRFD; Calibration of safety factors

Risk Assessment: Introduction; Logic trees; Applications in earthquake engineering; Bayesian decision making

References:

1. Nowak AS & Collins KR, Reliability of Structures, 2nd ed., CRC Press,
2. Melchers RE, Structural Reliability Analysis and Prediction, 2nd ed., Wiley, 1999.
3. Ang AH-S & Tang WH, Probability Concepts in Engineering Planning and Design: Decision, Risk, and Reliability (Volume II), 1st ed., Wiley, 1990.
4. Halder A & Mahadevan S, Probability, Reliability, and Statistical Methods in Engineering Design, 1st ed., Wiley, 2000.

CE 679 - ADVANCED MECHANICS OF REINFORCED CONCRETE

Bernoulli Compatibility Truss Model: Linear and Non-linear theories for Bending of Beams, Stress-Strain Curves for Unconfined and Confined Reinforced Concrete, Interaction of Bending and Axial Loads in Columns.

Plasticity Truss Model: Derivation of Ultimate Strengths under Flexural, Shear and Torisonal Loads and their Interactions.

Strut-and-Tie Model: Equilibrium Approach to Local Regions with Irregular Stress and Strain Distribution.

Mohr Compatibility Truss Model: Linear Theory of Shear and Torsion.

Softened Truss Model: Non-linear Theory of Shear and Torsion.

Softened Membrane Model: Poisson Effect in Cracked Reinforced Concrete; Uniaxial and Biaxial Strains in Reinforced Concrete Elements.

References:

1. T.T.C. Hsu and Y.L. Mo, Unified Theory of Concrete Structures, Wiley, 2010, USA.
2. K. Maekawa, H. Okamura and A. Pimanmas, Non-Linear Mechanics of Reinforced Concrete, CRC Press,2003, Japan.
3. T. Paulay and M.J.N. Priestley, Seismic Design Reinforced Concrete and Masonry Buildings, Wiley, 1992,USA.
4. ACI Committee 318, Building Code Requirements for Structural Steel (ACI 318-14), American ConcreteInstitute, 2014, USA.
5. Cement and Concrete Sectional Committee, CED 2, Plain and Reinforced Concrete
6. Code of Practice (IS456: 2000), Bureau of Indian Standards, 2000, India.

CE 720 - Non-Destructive Testing of Materials

Types of materials, tests and the variables involved, destructive and non-destructive testing correlation of properties obtained by NDT with the basic structure of matter and other properties; NDT of different materials by various techniques such as radiographic, sonic and ultrasonic, electrical and magnetic, soleoroscopic, microwave, eddy current penetrant, thermal optical, holographic etc., practical applications and advances in NDT.

References:

1. **J.F. Hinslay**, Non-Destructive Testing, MacDonald and Evants, 1959.
2. **H.B. Egerton**, Non-Destructive Testing, Oxford University Press, 1969.
3. **Krautkramer**: Ultrasonic Testing of Materials, Springer-Verlag, 1969.
4. **M.A. Novgoresky**, Testing of Building Materials and Structures, Mir Publishers, 1973.
5. American Society of Metals: Handbook, Vol II, Destructive Inspection and Quality Control, 1976.

DETAILS OF COURSES OFFERED BY OCEAN ENGINEERING GROUP

CE 602 - DESIGN OF OFFSHORE STRUCTURE

Materials and their behaviour under static and dynamic loads, allowable stresses, various design methods and codes, design consideration, design loads, design of decking of template type steel structures, design of supporting legs, design of braces. Corrosion and other allowances, consideration of stress concentration, design of concrete platforms, Ingredient materials and protective measure, design of raft foundation, design of slide walls, design of decking of composite structures.

References:

1. Rules for the design, construction and inspection of fixed offshore structures, 1977. **Defnorske Veritas**
2. **Energy Department**, U.K., Guidance of Design and Construction of Offshore Installation, 1974.
3. **American Petroleum Institute**, API RP-2A, Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms, 1974.
4. Offshore Technology Conference Volumes.
5. **O.C. Zienkiewicz, R., Wlewis and K.G. Stagg**, Numerical Methods in Offshore Engineering, Wiley Interscience Publication, 1978.

CE 625 - Analysis of Offshore Structures

Loads and structural forms of different types of offshore structures; Elements of single d.o.f. system subjected to free and forced vibrations; Analysis for transient and steady state force; Equivalent damping for nonlinear systems; Dynamics of multi d.o.f. systems, Eigen values and vectors; Iterative and transformation methods; Mode superposition, Fourier series mand spectral method of response of single d.o.f. systems; Vibration of bars, beams and cones with reference to soil as half space; Behaviour of concrete gravity platform as a rigid body on soil as a continuum; Short and long term statistics of wind; static wind load; effect of size, shape and frequency; Aerodynamic admittance function and gust factor, spectral response due to wind for various types of structures; Wave loads by Morison"s equation; Static and dynamic analysis of fixed equation; Static and dynamic analysis of fixed structures; Use of approximate methods.

References:

1. **Brebbia C.A. and Walker**, "Dynamic Analysis of offshore structures", Newness butterworth, London, 1978.
2. **Sarpakaya T. and Isaacson M**., "Mechanics of Wave Forces on Offshore Structures", Van Nostrand Rainhold, NewYork, 1981.
3. **Hallam M.G., Heaf N.J. and Wootton, L.R.,** "Dynamics of Marine Structures", CIRIA Publicartions, Underwater Engg. Group, London, 1978.
4. **Graff W.J.,** "Introduction to Offshore Structures", Gulf Publishing Co., Houston, Texas, 1981.
5. **Clough R.W. and Penzien J.,** "Dynamics of Structures", IInd Edition, McGraw hill, 1992.
6. **Simiu E. and Scanlan R.H.,** "wind effects on Structures", Wiley,New York, 1978.
7. Codes of Practices (latest versions) such as API R-2A, bureau Veritas etc.

CE 680 - MECHANICS OF WATER WAVES

Introduction to wave phenomena. Wave classification, measurement, generation, forecasting. Wave theories: linear, non-linear. Wave spectrum: basic concepts, analysis and derivation. Statistical analysis of waves: short and long term. Propagation in shallow water-refraction, diffraction, reflection, breaking, current effects. Wave effects like, run-up, overtopping and transmission. Littoral transport under wave action.

References:

1. **T. Sarpkaya and M. Issacsson**, Mechanics of Wave Induced Forces on Offshore Structures, Van Nostrand Reinhold, London, UK, 1981.
2. **Shore Protection Manual**, U S Army Corps of Engineers, CERC, Washington, D.C., USA, 1984.
3. **R. L. Wiegel**, Oceanographical Engineering, Prentice Hall, New Jersey.

CE 687 - Offshore Construction

Offshore environment: operational aspects of waves, currents, tides, wind. Structural material: types and properties of steel, concrete and synthetics. Construction equipments: specialized barges and OSVs. Common operations: surveying, diving, crew transfer, etc. Installation: Pile supported, gravity and complaint structures. Repair and maintenance: structures and pipelines. Rehabilitation: strengthening and salvage. Specialized constructions: OTEC, wave power devices, channel, etc.

References:

1. **B. C. Gerwick,** Construction of Offshore Structures, John Wiley and Sons, London, UK, 2000.
2. **J. B. Herbich**, Handbook of Coastal and Ocean Engineering, Gulf Pub., Houston, USA, 1990.
3. **B. McClleland and M. D. Reifel**, Planning and Design of Fixed Offshore Platforms, Van Nostrnad Reinhold, London, UK, 1986.

CE 706 - Ocean Engineering Laboratory

Wave flume experiments to study propagation, refraction, reflection, diffraction, wave forces. Hydraulic modeling for ports, harbours. Numerical modeling of waves, tides, currents, fluid-structure interaction.

References:

1. **Steven A. Hughes**. 1995. Physical models and laboratory techniques in coastal engineering, Advanced series on Ocean Engineering-Vol. 7,World Scientific, Singapore.
2. **Robert A. Darlymple**. 1985. Physical modelling incoastal engineering, A.A.Balkema, Rotterdam,Netherlands.
3. **Charles L. Mader**. 2004. Numerical modeling ofwater waves, CRC Press, Boca Raton, Florida.
4. **Subrata K. Chakrabarti**. 1994. Offshore StructureModeling, Advanced Series on Ocean Engineering-Vol. 9, World Scientific.

CE 707 - COASTAL, PORT AND HARBOR ENGINEERING

Coastal protection works, Port and harbors - planning, design and construction aspects; harbor layout, model studies: physical and numerical breakwaters, wharf, jetty, mooring and dolphins, dry docks, shipyards, dredging, CRZ and guidelines, navigation, shipping: ship stability (static and dynamic); submarine pipelines: forces, laying, stresses, buckling; equipment.

References:

1. **Coastal Engineering Manual** (CEM). 2011. US Army Coastal Engineering Research Centre,Vicksburg, USA.
2. **Robert M. Sorenen**. 2006. Basic coastal engineering, Springer, USA.
3. **John W. Gaythwaite**. 2004. Design of Marine Facilities for the Berthing, Mooring, and Repair of Vessels, Amer Society of Civil Engineers.
4. **John B. Herbich** and Charles L. Bretschneider.1992. Handbook of Coastal and Ocean Engineering, Gulf publishing Company.
5. **Per Brunn**. 1989. Port engineering, Vol. 1, 2 and 3, Gulf Publishing Company.

CE 708 - Offshore Engineering

Types of offshore structures, planning and design aspects, wave loads regular and random, loads due to wind, tides and currents. Operational environment, equipments, materials and corrosion, repairs and maintenance, installation, common operations.

References:

1. **Subrata K. Chakrabarti**. 2003. Hydrodynamics offshore structures, WIT press.
2. **Yashimi Goda**. 2010. Random seas and design of marine structures, World Scientific.
3. **Tugut S. Sarpkaya**. 2010. Wave Forces on Offshore Structures, Cambridge University Press.
4. **Ben C. Gerwick**. 2000. Construction of marine and offshore structures, CRC Press.
5. **Minoo H. Patel**. 1989. Dynamics of offshore structures, Buttersworth.

CE 769 - COASTAL AND OCEAN ENVIRONMENT

Sea bed morphology; Wave mechanics - generation, forecasting, wave theories, shoaling, refraction, diffraction, breaking; Tidal propagation in estuaries; Coastal currents; Littoral processes; Sediment transport; Shore protection measures; Planning and operation of harbor, coastal and offshore structures.

References:

1. **Gaythwaite, J.,** The Marine Environment and Structural Design, Van Nostrand Reinhold, New York, 1981.
2. **Herbich, J.B**., Handbook of Coastal and Ocean Engineering, Gulf publishing Co., 1990.
3. Shore Protection Manual, US Army Coastal Engineering Research Centre, Vicksberg, USA. 1984.
4. **Gerwick, B.C.,** Construction of Offshore Structures, Wiley, New York, 1986.

CE 770 - Ocean Renewable Energy

Introduction to Physical Oceanography, Ocean Processes: Waves, Tides, Currents. Need for Renewable Energy, Ocean Thermal Energy, Wave Energy, Tidal Energy, Tidal Stream Energy, Salinity Gradients, Ocean-Structure Interactions; Resource Assessment, Power Take-off, Wave Energy Devices, Tidal Energy Devices, Stream Energy Devices, Offshore Wind Energy and Devices, Environmental and Social Impacts.

References:

1. **G. Boyle**, Renewable Energy: Power for a Sustainable Future, Oxford University Press, 2012.
2. **J. Cruz**, Ocean Wave Energy: Current Status and Future Perspectives, Springer, 2008.
3. **J. Falnes**, Ocean Waves and Oscillating Systems, Cambridge University Press, 2004.
4. **R. Bhattacharyya** and M.E. McCormick, Wave Energy Conversion, Elsevier Ocean Engineering Book Series Volume 6, 2005.
5. **R.H. Charlier** and **C.W. Finkl**, Ocean Energy: Tide and Tidal Power, Springer Berlin Heidelberg, 2009.
6. **R.M. Sorensen**, Basic Coastal Engineering (3rd edition), Springer, 2006.

DETAILS OF COURSES OFFERED BY REMOTE SENSING GROUP

CE-630 GIS IN CIVIL ENGINEERING

Introduction to the concepts, principles, and theories behind Geographic Information Systems and Science (GIS), with emphasis on the nature of geographic information, data models and structures for storing geographic information, geographic data input, data manipulation, simple spatial analysis and modeling techniques and applications to various civil engineering projects. Recent trends in GIS applications.

References:

1. **Lo, C.P.** and **Yeung, Albert K.W**., Concepts and Techniques of Geographic Information Systems Prentice Hall, 2002.
2. **Ian Heywood Sarah, Cornelius and Steve Carver**, "An Introduction to Geographical Information Systems". 3rd Edition, Pearson Education. New Delhi, 2006.
3. **Burrough P.A.** and **McDonnell R.A**., "Principles of Geographical Information Systems", Oxford University Press, 2006.
4. **Michael Worboys** and **Matt Duckham**, GIS: A Computing Perspective -2nd edition, CRC Press, Boca Raton, 2004.
5. **Maling D.H.**, "Coordinate Systems and Map Projections", Pergamon; 1992, 2nd ed.
6. **DeMers, M. N.** 2000. Fundamentals of Geographic Information Systems, 2nd Edition, John Wiley & Sons, Inc., 498pp.

CE 659 – ADVANCED SURVEYING

Total Station- Basics, Different types of surveying methods; Different sources of errors, Least Square Error adjustments; GNSS- Basic concepts, Different types of GNSS errors, Different types of GNSS surveying techniques; Unmanned Aerial System (UAS) Photogrammetry & Remote Sensing overview; LiDAR concepts- Terrestrial LiDAR, Airborne LiDAR overview.

References:

1. **Satheesh Gopi, R. Sathikumar, and N. Madhu (2007)**. Advanced Surveying: Total Station, GIS and Remote Sensing 1st Edition, Pearson India.
2. **Charles D. Ghilani, Paul R. Wolf (2006)** Adjustment computations: spatial data analysis – 4th ed. John Wiley and Sons, USA.
3. **Jan Van Sickle (2001),** GPS for Land Surveyors, Third Edition, CRC Press.
4. **Pinliang Dong, Qi Chen**. LiDAR Remote Sensing and Applications, 1st Edition, CRC Press
5. **Hofmann-Wellenhof, Bernhard, Lichtenegger, Herbert, Wasle, Elmar (2008)**. GNSS – Global Navigation Satellite Systems. 1st Edition, Springer-Verlag Vienna
6. Journal articles as informed by the instructor.

CE 701 - REMOTE SENSING TECHNOLOGY

Electromagnetic radiation (EMR), concepts of radiometry, EMR interaction with atmosphere and terrain, remote sensing systems and platforms for remote sensing, remote sensing in the visible, near-infrared, thermal infrared and microwave portions of the EMR, digital classification of remote sensing data

References:

- Jensen, J. R. (2007), Remote sensing of the environment: An earth resource perspective, Second edition, Pearson
- Lillesand, T. M., Kiefer, R. W. and Chipman, J. W. (2008), Remote sensing and image interpretation, Sixth edition, Wiley
- Elachi, C. and Van Zyl, J., (2006), Introduction to the physics and techniques of remote sensing, Second edition, Wiley Interscience
- Rees, W.G. (2012), Physical principles of remote sensing, Third edition, Cambridge University Press.
- Schowengerdt. R. A. (2007), Remote sensing: Models and methods for image processing, Third edition, Elsevier
- Jensen, J.R. (2018), Introductory Digital Image Processing, a remote sensing perspective, Fourth Edition, Pearson
- Journal articles as informed by the Instructor

CE-703 Remote Sensing Laboratory

Remote sensing images, searching and downloading openly available satellite data, atmospheric correction of optical data, Spectral reflectance behavior analysis of various Earth features and vegetation indices, estimation of land surface temperature, processing of synthetic aperture radar data, land use/land cover classification.

References:

1. Jensen, J. R. (2007), Remote sensing of the environment: An earth resource perspective, Second edition, Pearson
2. Lillesand, T. M., Kiefer, R. W. and Chipman, J. W. (2008), Remote sensing and image interpretation, Sixth edition, Wiley
3. Schowengerdt. R. A. (2007), Remote sensing: Models and methods for image processing, Third edition, Elsevier
4. Jensen, J.R. (2018), Introductory Digital Image Processing, a remote sensing perspective, Fourth Edition, Pearson
5. Journal articles as informed by the Instructor

CE-705 PHOTOGRAMMETRIC ENGINEERING

Geometry of aerial photographs; Stereoscopy; Relief displacement; Coordinates; Stereoscopic parallax measurement and formula; Radial triangulation; Theory of inner, relative and absolute orientation; Numerical orientation; Model deformation; Plotting Instruments; Aerial triangulation; Base map and thematic map compilation; Analytical photogrammetry; UAV Photogrammetry, Digital Terrain Modelling generation and its applications. Advanced topics in Terrain Data Collection.

References:

1. **Moffit, F.,** Photogrammetry (3rd Edn.), International Text Book Co. Scranton, 1967.
2. **Wolf, P.R**., Elements of Photogrammetry, McGraw Hill, New York, 1974.
3. **Colwel, R.N.,** (Ed.), Manual of Remote Sensing: Vol. I, II, American Society of Photogrammetry and Remote Sensing, Falls Church, VA, USA, 1983.
4. Journal articles shared by the instructor.

CE 710 Remote Sensing and Geographical Information Systems in Water Resources Management

Hydrologic cycle, relationship between water, energy and carbon cycles, Estimation of energy balance components, hydrologic modelling, remote sensing of rainfall, soil moisture estimation, evapotranspiration modelling, drought monitoring, Irrigation assessment, GIS based watershed modelling, Geospatial statistics, Remote sensing and GIS data sources for water resources, Case studies of remote sensing and GIS applications for various water resources projects.

Prerequisite: Knowledge in remote sensing and experience with different satellite

References:

1. **Chen, Y., Takara, K., Cluckie, I. and Smedt, F.H.** (Eds.), GIS and Remote sensing in Hydrology, Water resource and Environment, IAHS Publication 289, IAHS press. 2004.
2. **Burrough P.A. and McDonnell R.A.,** Principles of Geographical Information Systems, Oxford University Press, New York, 1998.
3. **David Maidment and Dean Djokic**, Hydrologic and Hydraulic Modelling Support with GIS, ESRI Press, 2000.
4. **Lillesand, T.M. and Kiefer, R.W.,** Remote Sensing and Image Interpretation, 6th Edition, John Wiley and Sons, New York. 2010.
5. Journal articles as given by instructor.

CE 712 Digital Image Processing of Remotely Sensed Data

Remotely Sensed Data: Satellite Systems & Acquisition, Data Storage, Concept of Resolution Digital Image: Fundamentals, Spatial Statistics (Univariate & Multivariate), Image Sampling and Quantization. Geometric Preprocessing: Image Registration, Sampling, Orthorectification, Image Mosaic Image Enhancement: Basics of Spatial Filtering, Edge Enhancement Image Transforms: Arithmetic Operations, PCA, Color Transforms Filtering Techniques: Low pass filters, High pass filters Image Classification for Land Use Mapping Geomorphology of Drainage basins: Digital Terrain Analysis and Watershed Analysis

References:

1. Lillesand T. M & Kiefer R. W., 2000. Remote Sensing and Image Interpretation, Wiley & Sons.
2. R. C. Gonzalez, R. E. Woods, 2008, Digital Image Processing, Prentice Hall.
3. R. C. Gonzalez, R. E. Woods, W. L. Eddins, 2009, Digital Image Processing using Matlab, Pearson.

CE 757 REMOTE SENSING OF THERMAL RADATION

Revision of basic radiometry definitions, thermal radiation laws, Earth's thermal radiation, atmospheric effects, concepts of emissivity and land surface temperature (LST), Emissivity and LST retrieval techniques for single and multi-channel thermal sensors, Sea Surface Temperature (SST), retrieval of LST from passive microwave radiometry, combining thermal infrared and passive microwave radiometry • Spatiotemporal resolution tradeoff, disaggregation and data fusion for improving the spatiotemporal resolutions of thermal sensors. • Surface energy balance equation and its relation to thermal remote sensing, applications of thermal remote sensing in hydrology, hydrometeorology, urban studies, vegetation monitoring and agriculture.

References:

H. Tang and Z.L. Li, Quantitative Remote Sensing in the Thermal Infrared: Theory and Applications, Springer, 2014302225

Glenn Hulley and Darren Ghent (Editors), Taking the temperature of the Earth – Steps towards Integrated Understanding of Variability and Change, Elsevier, 2019302225

Claudia Kuenzer and Stefan Dech (Editors), Thermal Infrared Remote Sensing: Sensors, Methods, Applications, Springer, 2013

CE 778 Microwave Remote Sensing: Principle and Applications IN Civil Engineering

Introduction to microwave remote sensing, Overview of non-imaging and imaging microwave sensors, Synthetic Aperture Radar (SAR), Basics of SAR Image processing using open source Programming Radar equation, Image defects - Geometric distortions, Introduction to Sentinel Application Platform (SNAP) Speckle, Doppler Shift in SAR Imagery, Multilooking, Spatial Convolution, Introduction to Texture, GLCM Image classification, Radar Interferometry, using phase as a relative distance measure, Digital Elevation Models, Applications of Microwave Remote sensing in various aspects of Civil Engineering related studies: Radar altimetry for rivers and lakes, algorithms for estimation of radar based precipitation and soil moisture for water resources and geotechnical engineering, handling of SAR images for detecting flood inundation extents and classifying vegetation, DEM analysis for water resources and transportation engineering, processing of doppler weather radar data for hydrology etc.

References:

1. Lillesand T. M & Kiefer R. W., 2000. Remote Sensing and Image Interpretation, Wiley & Sons.
2. Varotsos, C.A and Krapivin, V.F, (2020), Microwave Remote Sensing tools in Environmental Science, Springer International Publishing
3. Pampaloni and Paloscia. (2019), Microwave Radiometry and Remote Sensing of the Earth302222s surface and Atmosphere, CRC Press, Taylor & Francis Group
4. Wood house, I. H . (2017), Introduction to Microwave Remote Sensing, CRC Press, Taylor and Francis
5. GroupSharkov, E. A. (2004), Passive microwave remote sensing of the Earth, Springer Berlin Heidelberg
6. Jensen, J. R. (2000), Remote Sensing of the Environment An Earth Resource Perspective Prentice Hall. Upper Saddle River (NJ), USAHenderson, F. M. & Lewis, A. J. (ed.) (1998), Principles & Applications of Imaging RADAR. Manual of Remote Sensing. Third Edition, Volume 2. John Wiley & Sons, USA.
7. Ulaby, F.T, Moore, R. K, Fung, A. K. (1981), Microwave Remote Sensing: Active and Passive, Artech House Publishers

DETAILS OF COURSES OFFERED BY CONSTRUCTION TECHNOLOGY AND MANAGEMENT GROUP

CE 713 ADVANCED CONCRETE TECHNOLOGY

Cement – production - Composition & properties - Cement chemistry – Heat of hydration – Microstructure – Hydration products and pores; Aggregates – Geological classification - Physical classification – Characteristics and significance – Natural and Recycled aggregates; Mineral admixtures – Classification – Pozzolanic reaction – Natural and Industrial By-Products- effect on fresh and hardened concrete properties; Chemical admixtures – Classification - Water reducers, Set Controllers, Air entraining agents – Admixture chemistry – Mechanism of action - types - Optimisation – Compatibility issues - Speciality Admixtures

Advanced Mixture Design – Design Philosophy - Particle Packing & Rheology - Discrete and Continuous approach – Packing density of powders and aggregates - Experimental tests and Models – Ternary Packing Diagram – Mixture Design of Self - Compacting Concrete (SCC); Fresh Concrete Properties – Empirical test for SCC - Rheology – Basics – Parameters – Models – Rheometers – Rheology of Paste and concrete - Pumping – Setting – Curing – Plastic shrinkage – Strength Development – Maturity Method; Hardened Concrete Properties – Factors influencing strength – Interfacial Transition Zone – Stress strain relationship - Localisation – End effects – Loading Conditions; Dimensional Stability – Creep and Shrinkage

Durability – Permeability and Porosity – Chemical attack (Sulphate attack, Delayed Ettringite Formation, Chloride attack, Acid Attack, Sea Water attack, Carbonation, Freezing and Thawing, Alkali aggregate reaction, Alkali carbonate reaction Corrosion – Mode of action, failure – Tests – Protection methods.

References:

1. Neville, A.M., 'Properties of concrete', 4th ed., Pearson Education Limited, London, 2000.
2. P. Kumar Metha and P. J. M. Monterio, Concrete- Microstructures, Properties and Materials, Indian Edition, Indian Concrete Institute, Chennai, 1999.
3. Lea, F.M., Chemistry of cement and concrete, 3rd ed, Edward Arnold, London, 1970 .
4. De Larrard, F, Concrete Mixture proportioning – A scientific Approach, E&FN Spon, London, 1999.
5. Aitcin, P. C., High Performance Concrete, E&FN Spon, London, 1998.
6. Santhakumar, A. R., Concrete Technology, Oxford University Press, New Delhi, 2007.
7. Neville, A.M., and Brooks, J. J., Concrete Technology, Pearson Education Ltd., 2012.

CE 717 Construction Planning and Control

Planning for construction projects: Project conceptualization, project organization, Feasibility studies, Detail Project Reports, Planning for construction, Work method statements, and work breakdown structures.

Planning for time on projects: Project scheduling techniques, CPM and PERT, Limitations, Case studies, Constructability conditions during scheduling

Planning for resources and costs: Handling resources on projects, planning and levelling resources, Time-Cost trade-off on construction projects.

Project monitoring and control: Updating project schedules, Earned Value analysis, monitoring the progress, Daily progress reports, managing data on projects, course correction on projects.

References:

1. Bennet, F. Lawrence., The management of construction: a project life cycle approach, Routledge 2003
2. Oberlender, Garold D., Project Management for engineering and construction, Vol 2. New York: McGraw-Hill, 1993
3. Roger Miller and Donald Lessard, The strategic management of Large Engineering Projects: Shaping Institutions, Risks and Governance, The MIT Press, 2001
4. Peurifoy, Robert Leroy, Cliff J. Schexnayder and Shapira A., Construction Planning, equipment and methods, McGraw-Hill, 2010
5. Jha, Kumar Neeraj, Construction Project Management: Theory and Practice. Pearson India, 2011
6. Case studies on construction projects

CE 718 CONSTRUCTION MATERIALS LABORATORY

Exp No.	Name of the Experiment	Laboratory
1	Bricks/Blocks, Tiles - Strength and Water Absorption	SEMT Lab.
2	Mineral Admixtures – Particle size and Shape Analysis	CMMC Lab.
3	Chemical Admixture optimisation - Mini Slump and Marsh Cone	SEMT Lab.
4	Concrete - Slump, Slump retention, Setting Time	SEMT Lab.
5	Concrete - Strength (Normal Curing & Steam Curing)	SEMT Lab.
6	Concrete - Non Destructive Test (Rebound Hammer & UPV Test)	SEMT Lab.
7	Concrete - Carbonation Test, Water Permeability Test	SEMT Lab.
8	Concrete - Porosity (MIP)	SEMT Lab.
9	Concrete - Abrasion Resistance	SEMT Lab.
10	Steel (HYSD bars) - Tension Test	HS Lab.

References:

1. IS 3495 (1992) Methods of tests of burnt clay building bricks. Part 1 determination of compressive strength. Part 2 determination of water absorption, Bureau of Indian Standards, New Delhi.
2. IS 13630 (2006) Ceramic tiles – Methods of Test. Part 2 Determination of water absorption. Part 6 Determination of modulus of rupture, Bureau of Indian Standards, New Delhi.
3. IS 1786 (1990) Specification for high strength deformed steel bars and wires for concrete Reinforcement, Bureau of Indian Standards, New Delhi.
4. IS 9103 (2004) Concrete admixtures - Specification, Bureau of Indian Standards, New Delhi.
5. IS 10262 (2004) Recommended guidelines for concrete mix design, Bureau of Indian Standards, New Delhi.
6. IS 13311 (2004) Non-destructive testing of concrete - Methods of test. Part 1 ultrasonic pulse velocity. Part 2 rebound hammer, Bureau of Indian Standards, New Delhi.
7. IS 1199 (1999) Methods of sampling and analysis of concrete, Bureau of Indian Standards, New Delhi.
8. IS 8142 (2002) Method of test for determining setting time of concrete by penetration resistance, Bureau of Indian Standards, New Delhi.
9. IS 516 (1997) Method of test for strength of concrete, Bureau of Indian Standards, New Delhi.
10. IS 3085 (1997) Method of test for permeability of cement mortar and concrete, Bureau of Indian Standards, New Delhi.
11. Nanthagopalan, P and Santhanam, M (2008) A new approach to optimisation of paste composition in self-compacting concrete, The Indian Concrete Journal, vol. 82, 11 - 18.
12. de Larrard, F., F. Bosc, C. Catherine, and F. Deflorenne (1997) The AFREM method for the mix-design of high performance concrete. Materials and Structures, 30, 439 - 446.

CE 719 Construction Contracts

Comprehensive study of different types of contracts and their working. Important clauses in the contracts. Standard forms of con***tracts used in India and abroad;*** Owner- construction contractor prime contract, labor agreements; purchase order and subcontract agreements; insurance contracts; surety bonds; joint-venture agreements; bid and proposals; mistakes in bids; breach of contract; contract changes; differing site conditions; delays, suspensions, and terminations; liquidated damages, force majeure, and time extensions; allocating responsibility for delays; constructive acceleration; common rules of contract interpretation;

Problems in the operation of contracts, Enforcement of contracts, I***ncentive mechanism in contracts;*** Claims and disputes, Claim process, Dispute resolutions, Arbitrations settlements, Litigations on contracts, Case studies on arbitration and litigations in contracts.

Professional practice ethics, duties and responsibilities of project managers in con***struction projects;*** Construction specifications - standard specifications, development, interpretation***.***

References:

1. Bartholomew, Stuart H. Construction contracting: Business and legal principles. 2nd ed. Prentice Hall, 2001.
2. Hughes,W., Champion, R. and Murdoch, J., Construction Contracts – Law and Management. 5th ed. Routeledge, Taylor and Francis, 2015.
3. Hinze, J., Construction contracts. 3rd edition, McGraw-Hill Science Publishers, 2000.
4. Central Public Works Department, General Conditions of Contract and The Arbitration and Conciliation Act, 1996
5. Case studies on contracts

CE 722 CONSTRUCTION MANAGEMENT STUDIO

Software used in construction management. Introduction to MS Project. Exercises on MS Project

Simulation Software, Discrete Event Simulations in Construction, Monte-Carlo Simulations.

Introduction to Building Information Modelling, Exercises with Building Information Modelling Software: Autodesk Revit.

Exercises on visualization, MEP modelling, clash detection, 4D-BIM, 5D BIM**.**

References:

1. Krygiel, E. and Vandezande J., Mastering Autodesk Revit Architecture 2015, Sybex and Autodesk, Joh Wiley and Sons, 2014.
2. Chatfield and Johnson, T., Step by Step Microsoft Project 2013, Microsoft Press, 2013.

CE-723 Construction Equipments and Personnel Management

Construction Equipments

- Factors affecting selection of equipment and methods - Technical and Economic.
- Analysis of production outputs and costs, equipment power requirements
- Equipment used in earthwork construction, compaction and stabilization, earthmoving, material transport, drilling.
- Equipment used in aggregate production, concrete production, asphalt mix production and placement
- Lifting equipment, Piling equipment, Pumps and forming systems.
- Case studies on equipment usage in construction

Personnel in construction

- Managing labour on construction sites.
- Productivity in construction, Analysis of productivity, Productivity measurement, Work sampling methods, Foreman Delay Survey, Crew Balance Charts, Process Charts.
- Introduction to wastes in construction sites.

References:

1. Peurifoy, Robert Leroy, Cliff J. Schexnayder and Shapira A., Construction Planning, equipment and methods, McGraw-Hill, 2010
2. Sharma, S. C., Construction Equipment and Its Management, Khanna Publishers 2002.
3. Jha, Kumar Neeraj, Construction Project Management: Theory and Practice. Pearson India, 2011
4. Case studies in construction equipment usage.

CE-725 Construction Economics and Finance

Time value of money, Cash flows in construction projects. Evaluation of alternatives: Present Worth Comparisons, Rate of Return analysis, Incremental Rate of Return, Break –Even , Benefit-Cost Analysis, Replacement Analysis, Depreciation: Capital cost recovery, Accounting techniques, insurance costs

Taxes: Tax laws, Accounting treatment of taxes, Inflation: Nature of inflation, real interest rates, price indexes, taxes and inflation, Construction accounting, Sources of funding for finance, Infrastructure financing, Project finance techniques.

Life-cycle costing, Construction Cost Control, Personnel costs, Equipment costs, Job in directs and mark-up, Approximate estimates

References:

1. Collier C. A., and Ledbetter W. B., Engineering Cost Analysis, Harper and Row Publishers, 1982
2. Riggs, James L., David D. Bedworth, and Sabah U. Randhawa., Engineering economics. 4th Ed., McGraw-Hill, 2004.
3. Park, C. S., Fundamentals of Engineering Economics, Pearson Education Inc. 2004
4. Newnan, D. G., Ted G. E., Lavelle J. P., Engineering Economic Analysis, 9th edition, Oxford University Press, 2004.

CE-727 Construction Materials

Science, Engineering and Technology of Materials - Atomic Bonding-Structure of solids - Development of Microstructure - Surface Properties - Response to stress - Failure Theories - Fracture Mechanics - Thermal properties - Review of Construction Materials and criteria for selection - wood - Polymers - Fibre reinforced composites - Metals - Concrete - Glass - Bituminous materials - Water proofing Materials.

References:

1. Materials Science and Engineering: An introduction, W.D. Callister, John Wiley, 1994.
2. Properties of Engineering Materials, R.A. Higgins, Industrial Press, 1994.
3. Building Materials, P.C. Varghese, Prentice-Hall India, 2005.
4. Construction materials: Their nature and behaviour, Eds. J.M. Illston and P.L.J. Domone, 3rd ed., Spon Press, 2001.
5. The Science and Technology of Civil Engineering Materials, J.F. Young, S. Mindess, R.J. Gray & A. Bentur, Prentice Hall, 1998.
6. Engineering Materials 1: An introduction to their properties & applications, M.F. Ashby and D.R.H. Jones, Butterworth Heinemann, 2003.
7. The Science and Design of Engineering Materials, J.P. Schaffer, A. Saxena, S.D. Antolovich, T.H. Sanders and S.B. Warner, Irwin, 1995.
8. Concrete: Microstructure, properties and materials, P.K. Mehta and P.J.M. Monteiro, McGraw Hill, 2006.

CE 729 QUALITY AND SAFETY IN CONSTRUCTION

Quality in Construction

Need for quality in construction, Definition of Quality, Principles of Quality Assurance and Quality Control, Concepts of Total Quality Management, The Plan Do Check Act concept. Seven basic tools of quality – Cause and effect diagrams, Check Sheets, Control charts, Histograms, Pareto Charts, Scatter Diagrams, Run Charts. Sampling Techniques for quality, Standards on Quality – ISO 9001, Development of Quality Manuals in projects, Quality Audits. Quality procedures for various materials and procedures used in construction.

Safety in Construction

Construction safety management systems, Safety culture, Performance measurements of safety – lead indicators, lag indicators, Injuries in construction, Cause analysis, Human error reduction. Hazard Analysis and risk assessment, Development of Safety management plans, Personnel protective Equipment, Safety strategies for various construction processes. Health issues in construction. Incident investigations, Audit requirements

***References*:**

1. Paul Watson and Tim Howarth, Construction Quality Management, Spon Press, 2011
2. J. L. Ashford, The Management of Quality in Construction, Spons Architecture, 1989
3. James J. O'Brien, Construction Inspection Handbook, Total Quality Management, Springer Science, 1997
4. Steve Rowlinson, Construction Safety Management Systems, Taylor & Francis 2003
5. P S Gahlot and Deep Gehlot, Quality Management in Cement Concrete Construction, CBS Publishers, 2010
6. R. K. Mishra, Construction Safety, Atibs Publishers, 2011
7. Fred A. Manuele, Advanced Safety Management, Wiley Interscience, John Wiley and Sons, 2008
8. International standards on quality and safety in construction - ISO-9001 Quality Management, ISO-45001 – Occupational Health and Safety.
9. Case studies on construction projects

CE-741 FORMWORK FOR CONCRETE STRUCTURES

Introduction to formworks - Emphasis on formwork based design - Formwork management - Formwork materials - Pressure of concrete on formwork - Key aspects of formwork design - Failure of formworks (case studies) - Design of formworks for walls, slabs, columns - Design of back-propping - Modern formwork systems - Scope for research in the field of formworks.

References:

1. Peurifoy, R. L., and Oberlender, G. D., 2011, *Formwork for Concrete Structures*, 4th edition, McGraw-Hill.
2. Hurd, M. K. Formwork for Concrete. ACI 347, 6th edition, American Concrete Institute, Detroit, Michigan, 1995.
3. Ratay, Robert T. Handbook of Temporary Structures in Construction. 2nd edition, McGraw Hill, New York, 1996.
4. IS 14687 (2005) Falsework for concrete structures - Guidelines, Bureau of Indian Standards, New Delhi.
5. IS 883 (1994) Design of structural timber in building - Code of practice, Bureau of Indian Standards, New Delhi

CE-743 Condition Assessment and rehabilitation of constructed facilities

Performance of construction materials and components in services - Causes of deterioration - preventive measurements and maintenance - Principles of assessment of weathering and durability - Diagnosis of construction failures - Dealing with cracks - Materials for Repair, Preparation of surface and strengthening techniques - Corrosion damage of reinforced concrete - repair and prevention measures - Surface deterioration, Efflorescence, causes, prevention and protection - Surface coatings and painting - Water proofing – Grouting - Strengthening of existing structures - Special repairs, maintenance, inspection and planning, Budgeting and management - Case Studies.

References:

1. Peter H. Emmons (1993), Concrete Repair and Maintenance Illustrated, RSMeans Company, Kingston, MA.
2. Handbook on repair and Rehabilitation of RCC buildings, Central Public works Department, Government of India, New Delhi, 2002.
3. ACI 546R-04 Concrete Repair Guide, American Concrete Institute, Detroit, Michigan, 2004.
4. ACI 562M-13, Code Requirements for Evaluation, Repair, and Rehabilitation of Concrete Buildings and Commentary, American Concrete Institute, Detroit, Michigan, 2013.

CE-757 Remote Sensing of thermal radiation

Revision of basic radiometry definitions, thermal radiation laws, Earth's thermal radiation, atmospheric effects, concepts of emissivity and land surface temperature (LST), Emissivity and LST retrieval techniques for single and multi-channel thermal sensors, Sea Surface Temperature (SST), retrieval of LST from passive microwave radiometry, combining thermal infrared and passive microwave radiometry.

Spatiotemporal resolution tradeoff, disaggregation and data fusion for improving the spatiotemporal resolutions of thermal sensors.

Surface energy balance equation and its relation to thermal remote sensing, applications of thermal remote sensing in hydrology, hydrometeorology, urban studies, vegetation monitoring and agriculture.

References:

1. H. Tang and Z.L. Li, Quantitative Remote Sensing in the Thermal Infrared: Theory and Applications, Springer, 2014.
2. Glenn Hulley and Darren Ghent (Editors), Taking the temperature of the Earth - Steps towards Integrated Understanding of Variability and Change, Elsevier, 2019.
3. Claudia Kuenzer and Stefan Dech (Editors), Thermal Infrared Remote Sensing: Sensors, Methods, Applications, Springer, 2013