M. TECH. IN DAM SAFETY AND REHABILITATION

(After incorporating suggestions of the IAPC meeting held on December 28, 2020, suggestions of associated faculty, suggestions of faculty colleagues across the Institute on Faculty Discuss and IAPC meeting held on January 11, 2021)

BACKGROUND

India has 5334 large dams in operation and about 411 large dams are under construction. In addition to the large dams, there are more than 90,000 small and medium dams in the country. These dams have been built to ensure water safety, which in turn, is essential for the food and energy security of the country. The recorded history of dam construction in the country dates back to the 11^{th} century when Veeranam dam was constructed in Central India and since then the dams are being built for the storage of water. In addition to this, there are numerous dams all over the world. IIT Roorkee is playing a major role in the design and execution of these dams since its inception in 1847.

The safety of these dams is of utmost importance. Many of the existing dams are very old and need rehabilitation. Keeping these concerns in view, Ministry of Water Resources, River Development & Ganga Rejuvenation through Central Water Commission initiated the DRIP project in April 2012 with the assistance of World Bank. IIT Roorkee is the academic partner in this programme and has entered in MoU with Central Water Commission in September 2017. This project is coming to an end in March 2021.

Keeping the importance of the dams in view and to cover more number of dams in the project, phase II and phase III of the DRIP programme have been approved by Ministry of Jal Shakti, Government of India on October 29, 2020.

Dam Safety Bill 2019 was introduced in Lok Sabha on July 29, 2019, and was passed on August 2, 2019. The bill provides for the surveillance, inspection, operation, and maintenance of all specified dams across the country. The bill is likely to be passed by Rajya Sabha soon.

During the concurrence of the Dam Safety Bill, Government India desired that apex institutions in the country should be approached to start a regular course in the dam safety management at the post-graduation level. Accordingly, in pursuance to this, Secretary, DoWR, RD&GR requested

Secretary, Department of Higher Education, Ministry of HRD for this. The Chairman, CWC also requested to the academic partners of DRIP in June 2019.

IIT Roorkee kept a close eye on these developments and constituted a 4-member committee, consisting of Prof N.K. Goel, Prof. M.L. Sharma, Prof. Zulfequar Ahmad, and Prof. M.L. Kansal, in December 2019 to draft the proposal for the establishment of the International Centre for Dams at IIT Roorkee and start a M. Tech. programme in Dam Safety and Rehabilitation with effect from July 2021.

A meeting through video conferencing was held on May 27, 2020, under the Chairmanship of the Additional Secretary, D/o WR, RD & GR, Ministry of Jal Shakti to discuss about the matters related to the experience of IIT Roorkee with ongoing DRIP, plan for the introduction of Postgraduate programme in Dam Safety Management and establishment of a Centre of Excellence (CoE) in Dam Engineering. This meeting was attended by Director, IIT Roorkee and Prof. N.K. Goel. The intent of IIT Roorkee to establish the Centre for dams and start of the M. Tech. programme on Dam safety and Rehabilitation was reiterated in the meeting.

The committee had a series of meetings and after receiving the inputs from Central Water Commission finalised its proposal for the establishment of the 'International Centre for the dams' at IIT Roorkee and start of M. Tech programme in Dam safety and Rehabilitation and sent it to the Departments of Civil Engineering, Hydrology, Earthquake and WRDM for consideration and inputs for the M. Tech. Programme. The proposal for the Establishment of the Centre was also sent to the CWC and the World Bank for consideration and providing inputs for the finalisation of the proposal in October 2020.

A number of suggestions were received from the Departments of Civil, EQ, Hydrology and WRDM. The present proposal incorporates the suggestions received till date. The requirements, structure and the syllabus of different subjects of the programme are given in the next section.

Who can Attend the Programme

The programme will be meant for the sponsored officers of state implementing agencies of DRIP programme and other agencies within India and abroad with relevant experience of 2 years and fresh GATE qualified candidates having valid GATE score.

Eligibility for sponsored Candidates

1. Graduation/ Post Graduation degree in Civil/ Mechanical/ Earthquake/ Hydrology/ Water Resources Engineering/ equivalent;
2. Post-graduation degree in Physics/ Mathematics/ Geology/ Geophysics; Environmental Engineering/ equivalent;
3. Any other degree acceptable to the State Implementing agencies for regular appointment in the dam safety wings.

Eligibility for GATE qualified Candidates

1. Graduation engineering degree in Civil/ Mechanical engineering / equivalent;
2. Post-graduation degree in Geology/ Geophysics; equivalent;

Number of seats:

30 with a minimum of 5 seats for GATE qualified candidates.

Faculty

The programme will be jointly delivered by the faculty members of IIT Roorkee and the national and international experts. The national and International experts have been proposed with the delivery of the programme as the number of subjects proposed to be dealt with are new and the faculty members of IIT Roorkee need to develop the expertise of delivering the programme independently over a period of next five years through continuous interaction with international experts and exposure visits.

Financial Support:

The programme shall be supported by Ministry of Jal Shakti under DRIP phase II and III and the World Bank.

Reference Material:

A number of guidelines have been prepared by CPMU of CWC in consultation with National and International subject matter specialists during the last 6 years. These guidelines document the best National and International practices in the area. The M. Tech. programme will give the participants enough exposure to follow these guidelines and implement the best practices in the field. So far, the following 14 guidelines have been prepared and are available online.

1. Guidelines for developing Emergency action plans for dams, February 2016;
2. Guidelines for safety inspections of dams, January 2018;
3. Guidelines for instrumentation of large dams, January 2018;
4. Guidelines for preparing operation and maintenance manual for dams, January 2018;
5. Guidelines for mapping flood risks associated with dams, January 2018;
6. Manual for rehabilitation of large dams, January 2018;
7. Inspection Manual for Dam Field Engineers After Seismic Events, Ichari Dam, Uttarakhand, January 2018;
8. Technical Specifications of Hydro-meteorological, Geodetic, Geotechnical and Seismic Instruments, January 2018;
9. Guidelines for Assessing and Managing Risks Associated with Dams; February 2019;
10. Handbook for Assessing and Managing Reservoir Sedimentation, February 2019;
11. Inspection Manual for Dam Field Engineers after Seismic Events, Maithon Dam, Damodar Valley Corporation, Jharkhand, February 2019;
12. Guidelines for Classifying the Hazard Potential of Dams, November 2020;
13. Operational Procedures for Assessing and Managing Environmental Impacts in Existing Dam Projects, November 2020;
14. Manual for Assessing Structural Safety of Existing Dams, November 2020.

Apart from the above guidelines, few more guidelines have been prepared by other organisations:

1. Guidelines for community-based ecotourism development, WWF International, 2001;
2. Guidelines for maintaining longitudinal connectivity through dams, 2017;
3. ICOLD, “Selecting Seismic Parameters for Large Dams, Guidelines”, Bulletin 148 Committee on Seismic Aspects of Dam Design, International Commission on Large Dams (ICOLD), Paris, 2014;

4. National Disaster Management Guidelines, 2007;

COURSE OBJECTIVES, STRUCTURE AND THE SYLLABUS

Course Objectives

The course objective is to train the sponsored officers to deal with the complete life cycle of the dam and take up the challenges of safety and rehabilitation of the older dams and the design of new dams. To develop analytical, operational, and sectoral understanding, M. Tech. students will be exposed to a plethora of courses related to dam safety which would enhance the qualitative and quantitative research methodology, policy aspects, and skills to device appropriate solutions.

INTERNATIONAL CENTRE OF EXCELLENCE FOR DAMS
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

Program Code: **XXX M.Tech. (Dam Safety and Rehabilitation)**
Department: **International Centre of Excellence for Dams**
Year: **I**
Model: **2**

Teaching Scheme					Contact Hours/Week			Exam Duration	
S.No.	Subject Code	Course Title	Subject Area	Credits	L	T	P	Theory	Practical
Semester-I (Autumn)									
1.	DSC-501	Hydrologic Safety Evaluation of Dams	PCC	3	2	1	0	-	-
2.	DSC-503	Reservoir Sedimentation and Silt Management	PCC	3	2	0	2	-	-
3.	DSC-505	Seepage through Dams	PCC	3	2	0	2	-	-
4.	DSC-507	Geotechnical safety evaluation of Dams	PCC	3	2	0	2	-	-
5.	DSC-509	Seismic Hazard Assessment for dams	PCC	3	2	0	2	-	-
6.		Social Science Course	SSC	2	-	-	-	-	-
		Total		**17**					
Semester-II (Spring)									
1.		Program Elective-I	PEC	3	-	-	-	-	-
2.		Program Elective-II	PEC	3	-	-	-	-	-
3.		Program Elective-III	PEC	3	-	-	-	-	-
4.		Program Elective-IV	PEC	3	-	-	-	-	-
5.		Program Elective-V	PEC	3	-	-	-	-	-
6.		Science, Technology, and Advanced Research-tools	STAR	3	-	-	-	-	-
7.	DSC-700	Seminar	SEM	2	-	-	-	-	-
		Total		**20**					

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INTERNATIONAL CENTRE OF EXCELLENCE FOR DAMS
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

Program Code: **XXX M.Tech. (Dam Safety and Rehabilitation)**
Department: **International Centre of Excellence for Dams**
Year: **II**
Model: **2**

Teaching Scheme					Contact Hours/Week			Exam Duration	
S.No.	Subject Code	Course Title	Subject Area	Credits	L	T	P	Theory	Practical
Semester-I (Autumn)									
1	DSC-691	Internship Social Activity	ISA	5	-	-	-	-	-
2	DSC-701A	Thesis Stage-I	THESIS	10	-	-	-	-	-
		Total		**15**					
Semester-II (Spring)									
1	DSC-701B	Thesis Stage-II	THESIS	14	-	-	-	-	-
		Total		**14**					

Summary				
Semester	**1**	**2**	**3**	**4**
Semester-wise Total Credits	17	20	15	14
Total Credits	**66**			

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M.Tech. (Dam Safety and Rehabilitation)

Program Elective Courses

Teaching Scheme					Contact Hours/Week			Exam Duration	
S.No.	Subject Code	Course Title	Subject Area	Credits	L	T	P	Theory	Practical
1	DSL-501	Assessing and Managing Risks Associated with Dams	PEC	3	2	1	0	3	0
2	DSL-502	Disaster Management and EAPs for dams	PEC	3	2	0	2	3	0
3	DSL-503	Dam Safety Surveillance, Instrumentation and Monitoring	PEC	3	2	1	0	3	0
4	DSL-504	Environmental Monitoring and Impact Assessment of Dams	PEC	3	2	0	2	3	0
5	DSL-505	Earthquake Geotechnical Engineering	PEC	3	2	0	2	3	0
6	DSL-506	Geospatial Techniques for Monitoring of Dams	PEC	3	2	0	2	3	0
7	DSL-507	Hydraulic design of spillways and energy dissipators	PEC	3	2	0	2	3	0
8	DSL-508	Contract and Financial Management	PEC	3	2	1	0	3	0
9	DSL-509	Seismic Safety Evaluation of Dams	PEC	3	2	0	2	3	0
10	DSL-510	Planning and Design of Hydro-Mechanical Components in Dams	PEC	3	2	1	0	3	0
11	DSL-511	Ground Improvement and Geo-synthetics	PEC	3	2	0	2	3	0

M.Tech. (Dam Safety and Rehabilitation)

Science, Technology, and Advanced Research-tools basket

Teaching Scheme					Contact Hours/Week			Exam Duration	
S.No.	Subject Code	Course Title	Subject Area	Credits	L	T	P	Theory	Practical
1	DST-501	Analysis of Dam Instrumentation Data	STAR	3	2	1	0	3	0

Social Sciences Course Basket

S.No.	Subject Code	Course Title	Subject Area	Credits	L	T	P	Theory	Practical
1	DSS-501	Sustainable Tourism around Dams	SSC	2	1	0	2	-	-

*** Revision of syllabus is under process.**

SYLLABI (PROGRAMME COMPULSORY COURSES)

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **INTERNATIONAL CENTRE FOR DAMS**

1. Subject Code: **DS-501** Course Title: **Assessing and Managing Risks Associated with Dams**
2. Contact Hours: **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs): **Theory: 3** **Practical: 0**
4. Relative Weightage: **CWS: 20-35 PRS: 0 MTE: 20-30 ETE: 40-50 PRE: 0**
5. Credits: **4** 6. Semester: **Autumn**
7. Subject Area: **PCC** 8. Pre-requisite: **NIL**
9. Objective: To provide necessary background about the various risk associated with dams and the techniques for dam safety assessment and management
10. Details of Course:

S. No.	Contents	Contact Hours
1	**Overview of Dams Risk Assessment and Management**: Smart Governance and risk management, Risk analysis Formal Framework, Risk-informed decision-making and its importance in an integral Dam Safety Management Program, Dam Safety Program Fundamentals in USA, Spain, Argentina, Brazil etc.	4
2	**Basis for a Risk-Informed Dam Safety Management Program for India:** Dam failure risks worldwide, Dam failure risks in India, Lessons learnt from Risk Assessment and Management worldwide.	6
3	**Initial Risk-Based Screening:** Purpose of a risk-based screening tool, elements of the risk-based screening tool, brief reference to the Hazard Classification in India, dam safety inspections reports and DHARMA. Practical workshop or hands-on exercise.	5
4	**Identification of Failure Modes:** PFMA (Potential Failure Mode Analysis), types of failure modes and loading scenarios, the purpose of the failure mode identification, Identification and classification of Failure Modes, Identification of investigation and surveillance needs, Proposal of risk reduction actions. Practical workshop or hands-on exercise.	5

5	**Semi-Quantitative Risk Analysis:** Introduction, scope, and limitations of a semi-quantitative risk analysis (Failure probability categories Vs. Consequences categories), Prioritization of new studies or instrumentation. Practical workshop or hands-on exercise.	4
6	**Quantitative Risk Assessment**: Introduction, scope and limitations. Incremental Risk Concept, Failure modes structure, Risk model input data, Levels of Detail in Risk Calculation input data, Event tree concept and calculation examples, Common Cause Adjustment, Risk Calculation in dam systems, Risk Representation (FN and FD Graphs). Uncertainty analysis in risk calculations. Practical workshop or hands-on exercise.	6
7	**Risk Evaluation (Quantitative Risk Assessment):** Introduction, scope and limitations on Risk Evaluation process. Tolerability Guidelines Worldwide (ANCOLD, USBR, USACE, other countries/agencies), Proposal and justification of Tolerability Guidelines for India, Definition and prioritization of risk reduction actions, Risk reduction principles, Relation between quantitative risk models and DRIP Guidelines. Practical workshop or hands-on exercise.	5
8	**Portfolio Risk Management:** Introduction, Risk-informed decision-making inputs, risk-informed decision-making process (conditioning aspects). Structure of Reports on Dam Safety Risk Assessment. Practical workshop or hands-on exercise.	3
9	**Risk Governance:** Introduction, Capacity building, Risk Communication, Overall Regulatory Framework, Review and quality assurance, Other Factors Affecting Decision Making- Climate Change, Inter-State Issues etc. **Institutional Framework in Dam Safety**: Perspective of Institutional framework in Switzerland, USA, Australia; Existing Dam Safety Monitoring Mechanism in India-Dam Safety Organization (DSO), National Committee on Dam Safety (NCDS), National Committee on Seismic Design Parameters (NCSDP); Dam Safety Legislation in India-Historical Development, Important Provisions of the Dam Safety Bill 2019.	4
Total		42

11. Suggested Books:

S. No.	**Name of Authors/Books/Publisher**	**Year of Publication**
1.	Zhang L., Peng M., Chang D. and Xu Y., "Dam Failure Mechanisms and Risk Assessment", John Wiley & Sons	1976
2.	Hartford D. N. and Baecher G. B., "Risk and Uncertainty in Dam Safety", Thomas Telford, Ltd	2004
3.	Raftery J., Loosemore M. and Reilly C., "Risk Management in Projects", United Kingdom: Tayor & Francis	2006
4.	Rodríguez Valladares M., "Overview of Credit Risk Portfolio Management", (n.p.): FT Press Delivers	2011

5.	"Risk Analysis, Dam Safety, Dam Security and Critical Infrastructure Management". Netherlands: CRC Press	2011
6.	Solozhentsev E., "Risk Management Technologies: With Logic and Probabilistic Models", Netherlands: Springer Netherlands	2012
7.	"Hydrology of Disasters", Netherlands: Springer Netherlands	2012
8.	Iverson D., "Strategic Risk Management: A Practical Guide to Portfolio Risk Management", Germany: Wiley	2013
9.	Wagner R., "The Handbook of Project Portfolio Management", United Kingdom: Taylor & Francis	2018
10.	"Guidelines Assessing and Managing Risks Associated with Dams", DRIP, DoWR, MoJ, GoI, New Delhi	2019

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NAME OF DEPTT. /CENTRE: **INTERNATIONAL CENTRE FOR DAMS**

1. Subject Code: **DS-502** Course Title: **Basics of Disaster Management and its implementation Concepts**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs): **Theory: 3** **Practical: 0**

4. Relative Weightage: **CWS: 20-35 PRS: 0 MTE: 20-30 ETE: 40-50 PRE: 0**

5. Credits: **4** 6. Semester: **Autumn**

7. Subject Area: **PCC** 8. Pre-requisite: **NIL**

9. Objective: To provide the basics of disaster management and implementation of various concepts to the dam by various modelling and mapping etc.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Overview of Disaster Management and Flood Mapping:** Disaster management cycle, Disaster Management Policies in India. Potential Uses of Flood Mapping in brief, Tiered Flood Modelling and Mapping Approach in India.	4
2	**Flood Risk Associated with Dams:** Types of Dams, Dam Failure concept, Estimation of consequences.	8
3	**Disaster Mitigation:** Warning and evacuation, do's and dont's about disaster, damage survey for designing aid package, detailed survey for reconstruction, repair and retrofitting, post disaster survey, long term measures, codal practices.	5
4	**Remote Sensing and Geographic Information Systems (GIS) applied to Emergency Preparedness and flood Mapping:** Techniques, uses, importance, Planning the Mapping Process, Geographical Information System (GIS), GIS Software, Practical workshop or hands-on exercises	5
5	**Dam Hazard Classification Framework in India:** CWC Guidelines; Assessment of the Area Affected by Dam break; Failure Scenarios, Classification of the Dams in India Based on Hazard Potential; Potential	4

	Consequences Index Definition and Calculation Process (Additive-weighting scheme), Potential Implications of Hazard Potential Classification; Requirement for Emergency Action Plans (EAP) and their revision. Practical workshop or hands-on exercises.	
6	**Emergency Action Plans Preparation:** Emergency management Organisation (Stakeholders), Relationship of the EAP document and the O&M manual. Establishment of emergency response protocols/procedures, Notification Flowcharts, levels of alerts and associated thresholds, preparedness actions/protocols, local evacuation plan [shelters, evacuation routes, warning time], communications networks, emergency resources and equipment. Practical workshop or hands-on exercises.	8
7	**Emergency Action Plans Implementation:** Stakeholder's Consultation Meeting (discussion-based exercise), mock-drill or table top exercise for EAP testing and improvement. Design of an incident management system, types, and design process of a warning system network in the flood plain. Integration of the Dam EAP with the District/State Disaster Management Plan. Practical workshop or hands-on exercises.	5
8	**Environmental Management:** Introduction; Existing Policies and Legal Framework; Procedure for Environment, Forest and Wildlife Clearances; EIA Procedure; Environmental Management and Control; External Funding Agency's Policy and Requirements on Environmental and Social Safeguards	3
Total		42

11. Suggested Books:

S. No.	Name of Authors/Books/Publisher	Year of Publication
1.	"National Disaster Management Guidelines", Government of India	2007
2.	Baas S., "Disaster Risk Management Systems Analysis: A Guide Book", Italy: Food and Agriculture Organization of the United Nations	2008
3.	"Swaziland Disaster Risk Reduction National Action Plan", 2008 to 2015. Eswatini: Swaziland Government	2008
4.	MacDonald W. and Ritchie L. A., "Enhancing Disaster and Emergency Preparedness, Response, and Recovery Through Evaluation: New Directions for Evaluation", Number 126, United Kingdom: Wiley	2010
5.	Dwivedi O., "India's Environmental Policies, Programmes and Stewardship". United Kingdom: Palgrave Macmillan UK	2016
6.	Huggel C. and Singh R., "Climate Change, Extreme Events and Disaster Risk Reduction: Towards Sustainable Development Goals", Germany: Springer International Publishing	2017
7.	"Environmental Modelling with GIS and Remote Sensing", United Kingdom: Taylor & Francis	2017
8.	Esmail M., and Abdalla R., "WebGIS for Disaster Management and Emergency Response", Germany: Springer International Publishing	2018
9.	"Emergency and Disaster Management: Concepts, Methodologies, Tools, and Applications", United States: IGI Global	2018

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **INTERNATIONAL CENTRE FOR DAMS**

1. Subject Code: **DS-503** Course Title: **Hydrologic Safety Evaluation of Dams**
2. Contact Hours: **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs): **Theory: 3** **Practical: 0**
4. Relative Weightage: **CWS: 20-35 PRS: 0 MTE: 20-30 ETE: 40-50 PRE: 0**
5. Credits: **4** 6. Semester: **Autumn**
7. Subject Area: **PCC** 8. Pre-requisite: **Nil**
9. Objective: To provide the knowledge and aspects of Hydrologic Evaluations for dam safety.
10. Details of Course:

S. No.	Contents	Contact Hours
1	**Design Flood Analysis**: Design flood estimation by Hydro-meteorological approach: Concept of Unit hydrograph, design storm, depth estimation from PMP Atlas, clock hour correction, areal reduction factor, Storm transposition, Location Adjustment Factor (LAF), Barrier Adjustment Factor (BAF), Transposition Adjustment Factor (TAF), Moisture Maximization Factor (MMF), loss rate, base flow, time distribution coefficient, HEC-HMS model	8
2	**Design flood estimation by flood frequency approach:** Statistical tests on flood data, stationary and non-stationary flood frequency analysis, computation of return period floods, Goodness of fit tests	8
3	**Channel routing**: Hydrological and hydraulic channel routing	4
4	**Reservoir routing**: Modified Pul's and other applicable methods	3
5	**Dam Breach Modelling:** Parameters estimation methodologies, Breach outflow routing (Upstream Flood Routing methodologies, Downstream Flood Routing methodologies, two-dimensional depth averaged models, one-dimensional models and coupled 2D-1D models, Modelling Software available), Practical workshop or hands-on exercises for three different levels of detail in dam breach modelling (Tier I, II and III)	8
6	**Reservoir Rule Curve:** Consistency check of inflow data, computation of percentile and dependable flow, derivation of rule curve, conservation rule curve, upper rule curve, testing of rule curve for different dependable flows	5

7	**Hydrological safety under changing climate**: Climate change, Changes in precipitation domain and its impact of inflows.	6
Total		42

11. Suggested Books:

S. No.	Name of Authors/Books/Publisher	Year of Publication
1.	"Statistical Distributions for Flood Frequency Analysis", WMO operational hydrology report no. 33.	1989
2.	"Design Flood Estimation Manual", Central Water Commission, New Delhi	2000
3.	Haan C. T., "Statistical Methods in Hydrology", Wiley Publication, 378 pages	2002
4.	Hosking, J.R.M. and Wallice J.R. "Regional Frequency Analysis- An Approach Based on L-Moments", Cambridge University Press.	2005
5.	"Guide to hydrological practices", World Meteorological Organization (WMO)	2008
6.	Boes R. M. and Schleiss A. J., "Dams and Reservoirs Under Changing Challenges", Netherlands: CRC Press	2011
7.	AghaKouchak A., Easterling D., Hsu K., Schubert S. and Sorooshian S. (Eds.), "Extremes in a changing climate: detection, analysis and uncertainty (Vol. 65)", Springer Science & Business Media	2012
8.	Beven, K.J. "Rainfall-Runoff Modelling: The Primer", 2nd Edition, Wiley-Blackwell	2012
9.	Zhang J., Zhang L. and Wang R., "Dam Breach Modelling and Risk Disposal: Proceedings of the First International Conference on Embankment Dams (ICED 2020)", Germany: Springer International Publishing	2020
10.	Xu Y., Zhang L., Chang D. and Peng M., "Dam Failure Mechanisms and Risk Assessment", Singapore: Wiley	2016
11.	"Flood Evaluation and Dam Safety", United States: CRC Press	2018

NAME OF DEPTT. /CENTRE: **INTERNATIONAL CENTRE FOR DAMS**

1. Subject Code: **DS-504** Course Title: **Sediment Management in Reservoirs**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

2. Contact Hours: **L: 3** **T: 1** **3** **P: 0**

3. Examination Duration (Hrs): **Theory: 3** **Practical: 0**

4. Relative Weightage: **CWS: 20-35 PRS: 0 MTE: 20-30 ETE: 40-50 PRE: 0**

5. Credits: **4** 6. Semester: **Spring**

7. Subject Area: **PCC** 8. Pre-requisite: **NIL**

9. Objective: To provide the background of sedimentation in reservoirs, its assessment and measurement, various options to manage sedimentation of the reservoir.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Sediment Management; Magnitude of the Problem	2
2	**Erosion and Sedimentation in Drainage Basins:** Weathering and Erosion Processes, sediment properties, modes of sediment transport, mathematical models, Sediment Delivery Ratio, Rates of Erosion and Delivery, Human Impact on Sediment Yield, Impact of Natural Events, Measurement of Sediment Load	8
3	**Reservoir Sedimentation Process:** Hydrological and Hydraulic Processes, Erosion, Transport and Sedimentation, Sources and Processes, Morphological Processes, Sediment Size, Entrainment, Suspension, Suspended Material Load, Bed Material Load, Unit Weight of Deposits, Delta Formation	5
4	**Reservoir sedimentation:** Computation of sediment yield, trap efficiency, distribution of sediment in reservoir, new zero elevation	5
5	**Predictive Methods for Reservoir Sedimentation:** Measurement and Monitoring Techniques, Empirical and Analytical Methods, Physical Modelling, Satellite, UAV and USV, Post-Processing and Analysis Tools for Topo-Bathymetric Data, Computational Modelling	6
6	**Mitigation of Reservoir Siltation:** Erosion and Sedimentation Control, Sediment Routing, Sediment Removal, Structural and Non-Structural Adaptive Measures, Watershed Management, Check Dams, Sediment Bypassing,	6

	Sediment Flushing, Sediment Sluicing, Density Current venting, Sediment Dredging	
7	**Reservoir Sedimentation in India:** National Records and Regulation of Dams in India, Indian Standard Code, Guidelines and Compendium on Reservoir Sedimentation, Reservoir Sediment Management in India, Sedimentation Data and Observation in Selected Reservoirs, Sediment Management in Indian Reservoirs: Good Practices and Problems, published Indian case studies from journals	6
8	Reservoir sedimentation- International Practices	4
Total		42

11. Suggested Books:

Sl. No.	**Name of Authors/Books/Publisher**	**Year of Publication**
1.	Annandale G.W., "Reservoir sedimentation", Elsevier, New York	1987
2.	Morris G. L. and Fan J., "Reservoir sedimentation handbook: design and management of dams, reservoirs, and watersheds for sustainable use", McGraw Hill Professional	1998
3.	Garde R.J. and Raju K., "Mechanics of Sediment Transportation and Alluvial Streams Problems", Taylor & Francis	2006
4.	"Reservoir Sediment Management Hardcover"-Illustrated, CRC Press, 1st edition	2011
5.	Tigrek S. and Aras T., "Reservoir sediment management", CRC Press, Taylor & Francis Group, Boca Raton	2012
6.	Bhattacharyya K. and Singh V. P., "Reservoir Sedimentation: Assessment and Environmental Controls", CRC Press, Taylor & Francis Group, Boca Raton	2019
7.	"Handbook for Assessing and Managing Reservoir Sedimentation", DRIP, DoWR, MoJ, GoI	2019

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **INTERNATIONAL CENTRE FOR DAMS**

1. Subject Code: **DS-505** Course Title: **Dam Safety Surveillance Instrumentation and Monitoring**
2. Contact Hours: **L: 2** **T: 1** **P: 2/2**
3. Examination Duration (Hrs): **Theory: 3** **Practical: 0**
4. Relative Weightage: **CWS: 15-30 PRS: 20 MTE:15-25 ETE: 30-40 PRE: 0**
5. Credits: **4** 6. Semester: **Spring**
7. Subject Area: **PCC** 8. Pre-requisite: **NIL**
9. Objective: To provide the concepts of dam inspection, monitoring etc. and explore the theory and practical knowledge for the dam safety surveillance instrumentation.
10. Details of Course:

S. No.	Contents	Contact Hours
1	**Dam Safety Inspection Program:** Types, preparing for an Inspection**,** Inspecting Embankment Dams**,** Concrete and Masonry Dams**,** Spillways, Outlets and Mechanical Equipment, Inspecting General Areas**,** Visual Inspection using remotely Operated Vehicles (ROVs), Use of Remotely Operated Underwater Vehicles (ROVs), Use of Unmanned Aerial Vehicles (UAVs)	4
2	**Documenting an Inspection:** Method, Checklist, Field Sketches, Photographs, Monitoring Data, Global Positioning Sensors (GPS), Inspection Notes, Visual Inspection Documentation, Writing an Inspection Report, Comprehensive Inspection Report.	8
3	**Comprehensive Dam Safety Review:** Procedures, Details to be provided to DSRP before inspection, Composition of DSRP, Reports of Comprehensive Safety Evaluation, Roles and the Responsibilities of Dam Safety Review Panel, Empanelment of Members of DSRP	5
4	**Instrumentation and Monitoring:** Monitoring Frequency, Measurement of Seepage and Leakage, Movement, Types of Movement, Reservoir / Tail water Elevations, Staff Gauge, Precipitation, Local Seismic Activity, Stress and Strain, Types of Pressure (Stress) Measuring Devices, Temperature, Critical Physical Data to be monitored, Data Evaluation. **Instrumentation System Planning: Embankment Dams:** Instrumenting Existing Embankment Dams, Monitoring Seepage and Water Pressure, Monitoring Soil Stresses, Indian Standards Instrumentation System Planning,	5

	Instrumentation System Planning: Seismic Monitoring, Instrumentation of Existing Dam	
5	**Hydro-Meteorological Instrumentation:** Measurement, Recording, Installation, Data validation, Errors in measurement of rainfall, temperature, relative humidity, wind speed, evaporation, snowfall, water level, suspended load etc.	4
6	**Instrumentation Data Collection and Management:** Introduction, Data Collection, Manual Data Collection, Stand Alone Data loggers, Real time Monitoring Networks, Advantages and Disadvantages, Data Management and Presentation, Database software, Data Processing, Data Maintenance, Data Presentation, Critical Data Analysis.	8
7	**Monitoring Data Organization and Analysis:** Introduction, Design Aspects, Numerical Modelling, Back Analysis for Calibration, Dynamic Loading, Dynamic Analysis, Monitoring Data Analysis, The Purposes of Monitoring Data Analysis, Automatic Data Acquisition, Evaluation of Measurement Data, Data analysis and Evaluation Summary	5
8	**Automation of Instrumentation:** Power for remote equipment, Vandalism, Lightning protection, Notification protocols, Data Acquisition and Management	3
Total		42

11. Suggested Books:

Sl. No.	**Name of Authors/Books/Publisher**	**Year of Publication**
1.	Bartholomew C. L. and Murray B. C., "Embankment dam instrumentation manual", US Department of the Interior, Bureau of Reclamation	1987
2.	Dunnicliff J., "Geotechnical instrumentation for monitoring field performance", John Wiley & Sons	1993
3.	Penman A.D.M., Saxena K.R. and Varma V.M., "Instrumentation, Monitoring and Surveillance: Embankment, Dams", Hardcover, Routledge	1999
4.	"Guidelines for instrumentation and measurements for monitoring dam performance", ASCE Task Committee on Instrumentation and Dam Performance	2000
5.	Roth J. J. and Hughes W., "Dam Maintenance and Rehabilitation II". CRC Press	2010
6.	"Guidelines for instrumentation of large dams" GoI, CWC, Central Dam Safety Organization, New Delhi	2018

7.	"Guidelines for preparing operation and maintenance manual for dams", CWC, DoWR, MoJ, GoI, New Delhi	2018
8.	"Guidelines for safety inspections of dams", CWC, DoWR, MoJ, GoI, New Delhi	2018
9.	Penman A. D., "Instrumentation, monitoring and surveillance: embankment dams", Routledge	2018
10.	"Monitoring Dam Performance: Instrumentation and Measurements", United States: American Society of Civil Engineers	2018
11.	Technical Specifications of Hydro-meteorological, Geodetic, Geotechnical and Seismic Instruments	2018

SYLLABI (ELECTIVE COURSES)

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **INTERNATIONAL CENTRE FOR DAMS**

1. Subject Code: **DS-511** Course Title: **Seepage through Dams**
2. Contact Hours: **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs): **Theory: 3** **Practical: 0**
4. Relative Weightage: **CWS: 20-35 PRS: 0 MTE: 20-30 ETE: 40-50 PRE: 0**
5. Credits: **4** 6. Semester: **Both**
7. Subject Area: **PEC** 8. Pre-requisite: **NIL**
9. Objective: To develop the understanding of basic principles and concepts of Seepage and its control in Dams.
10. Details of Course:

S. No.	Contents	Contact Hours
1	Importance of seepage in dam safely and rehabilitation, Types and causes of seepage through various types of Dams	4
2	Fundamentals of seepage through porous media, Darcy's law, seepage velocity, Dupuits theory, Seepage charts, Phreatic lines, Flow nets, Determination of free surface and seepage discharge through dams for isotropic and anisotropic media. Flow net for earth dam under steady/transient seepage condition, the stability of dams	10
3	Seepage Analysis, Boundary conditions, numerical techniques and modelling tools, Phreatic line with and without filter, stability conditions	5
4	Seepage through main body of various types of dams; Measurement of seepage water in galleries, Various methods of seepage control, Selection of core materials, Drainage of embankments, Design criteria of filters, Use of geo-textiles, Seepage Control through Embankments, Foundations	7
5	Seepage through bottom of reservoir area; various types of geological formations in the bed; identification techniques to know the seepage from the beds, Dam Grouting, Design and installation of grout curtains	6
6	Seepage detection, control and monitoring, Plan and design of various dams and adopt suitable measures for its safety	6
7	Practical examples and site visits	4
Total		42

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **INTERNATIONAL CENTRE FOR DAMS**

1. Subject Code**: DS-512** Course Title**: Assessment and Management of Environmental issues in Reservoirs**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs): **Theory: 3** **Practical: 0**

4. Relative Weightage: **CWS: 20-35 PRS: 0 MTE: 20-30 ETE: 40-50 PRE: 0**

5. Credits: **4** 6. Semester: **Both**

7. Subject Area: **PEC** 8. Pre-requisite: **NIL**

9. Objective: To provide background of ecosystem, environment, legal issues, guidelines etc. and necessary practices and application on environmental issues in reservoirs.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Water quality issues:** Impact of reservoir on water flow; Impacts on thermal regime; Water chemistry; Sedimentation; Nutrient enrichment; Water pollution; Emission of greenhouse gases; Climate change; Hydrological and water quality impacts; Soil and landscape changes; Agro-economic issues; Human health impacts.	7
2	**Ecosystem resilience issues:** Concept of an Ecosystem; importance of biological diversity; Destruction in ecosystem; Impacts on organisms and biodiversity; Influence in primary production; Effects on aquatic ecosystems; Value of ecosystem goods and services; Social and cultural impacts	8
3	**Assessment of carbon footprints in dams**	2
4	**Guidelines and Standard Codes:** Introduction; National and international legislative frameworks, codes; Future challenges.	5
5	**EIA methods and Tools:** Introduction; basic principles of EIA for reservoir; Development of scope; Mandate and study design; Base line survey; Methodology for EIA; Economic approaches; Environmental Impact Statement (EIS) preparation; temporal and spatial scales; socio-environmental factors; Planning and reservoir management; case studies.	8
6	**Environmental Clearances:** Introduction; Requirement for environmental clearances; Procedure for environmental clearances; Analysis of alternatives	5
7	**Legal Issues:** Introduction; Policy, legal and regulatory compliance; Statutory clearance approval and permissions	5

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **INTERNATIONAL CENTRE FOR DAMS**

1. Subject Code: **DS-513** Course Title: **Earthquake Geotechnical Engineering**
2. Contact Hours: **L: 3** **T: 1** **P: 2/2**
3. Examination Duration (Hrs): **Theory: 3** **Practical: 0**
4. Relative Weightage: **CWS: 15-3 PRS: 20 MTE: 15-25 ETE: 30-40 PRE: 0**
5. Credits: **4** 6. Semester: **Both**
7. Subject Area: **PEC** 8. Pre-requisite: **NIL**
9. Objective: The objective is to introduce the potential consequences of strong earthquakes on dam site areas for Design, construct and maintain the safety and evaluation.
10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Earthquakes, characteristics and distribution, tectonic features of the earth, geo-tectonic divisions of the Indian continent, geologic hazards perception. Background and lessons learnt from damages in past earthquakes.	3
2	**Earthquakes in Different Geological Set-Ups:** Geological structures and deformation pattern, inter and intra – continent set up, convergent zones, divergent margins, trenches, thrusts and faults. Earthquake implication of structural discontinuities, the impact of the neo-tectonic activity.	3
3	**Mapping:** Coordinate and coordinate systems; geographical and map projection system, 2D and 3D data transformation, types of maps, scales, map sheet numbering systems and uses, types of maps, introduction to topographical and geological maps, thematical maps, geological sections, data processing, analysis and presentation techniques.	2
4	**Wave Propagation:** Waves in semi-infinite media – one-, two- and three-dimensional wave propagation; Attenuation of stress waves – material and radiation damping; Dispersion, waves in a layered medium.	2
5	**Dynamic Soil Properties:** Stress & strain conditions, the concept of stress path; Measurement of seismic response of soil at low and high strain, using laboratory tests; Cyclic triaxial, cyclic direct simple shear, resonant column,	4

	shaking table, centrifuge and using field tests - standard penetration test, plate load test, block vibration test, SASW/MASW tests, cross borehole; Evaluation of damping and elastic coefficients; Stress-strain behaviour of cyclically loaded soils; Effect of strain level on the dynamic soil properties; Equivalent linear and cyclic nonlinear models; Static and dynamic characteristics of soils.	
6	**Ground Response Analysis:** Introduction-, one-, two- and three-dimensional analyses; Equivalent and nonlinear finite element approaches; Introduction to soil-structure interaction.	2
7	**Liquefaction:** Introduction, pore pressure, liquefaction related phenomena – flow liquefaction and cyclic mobility: Factors affecting liquefaction, liquefaction of cohesionless soils and sensitive clays, liquefaction susceptibility; State Criteria –CVR line, SSL, FLS; **Evaluation of liquefaction potential:** characterization of earthquake loading and liquefaction resistance, cyclic stress ratio, Seed and Idriss method; Effects of liquefaction.	3
8	**Earth Pressure:** Active and passive earth pressures; Terzaghi's passive wedge theory, numerical methods, earth pressure measurements.; Seismic design of retaining walls: types, modes of failures, static pressure, seismic response (including M-O Method), seismic displacement, design considerations.	2
9	**Seismic Slope Stability:** Types of earthquake-induced landslides; Evaluation of slope stability – stability analysis with dynamic loading, friction circle method, effective and total stress methods of analysis, factor of safety, yield acceleration, damage potential, displacement analysis, effect of saturated and submerged conditions, FEM analysis of slope stability.	3
10	**Remote Sensing in Earthquake Geology:** Basic concepts of satellite imaging of ground, types of satellite data in identifying the tectonic features, recognising characteristics of earthquake deformation features, SAR interferometry for earthquake deformation studies; Application of GPS for mapping;	4
Total		28

List of Experiments: Processing of pre and post-earthquake satellite images, Collection of data using GPS and mapping, Use of SAR interferometry for surface displacement measurement, Liquefaction Resistance of Soil using Vibration Table, Shear Velocity Profile using MASW, N values of cohesionless soils using SPT, c and Φ of soil using direct shear/triaxial tests, Liquefaction resistance of soil using cyclic triaxial test apparatus, Determination of dynamic properties using laboratory tests; Shear velocity profile using cross-bore test; Model Testing on Small Geotechnical Centrifuge.

11. Suggested Books:

S. No.	Name of Authors/Books/Publisher	Year of Publication
1.	Prakash S., "Soil Dynamics", McGraw Hill Book Company	1981
2.	Mather P.M., "Computer Processing of Remotely Sensed Images", John Wiley	1999
3.	Demers Michael N., "Fundamentals of Geographic Information Systems", John Willey	2000
4.	Gibson P.J. and Power C.H., "Introductory Remote Sensing – Digital Image Processing and applications", Routledge	2000
5.	Kameshwara Rao, N.S.V, "Dynamic Soil Tests & Applications", Wheeler Publications	2000
6.	Ranjan G. and Rao A.S.R., "Basic and Applied Soil Mechanics", New Age Int. Ltd	2000
7.	Day Robert W., "Geotechnical Earthquake Engineering Handbook", McGraw-Hill	2001
8.	Hoffmann-Wellenhoff B., "GPS Theory & Practice", Springer	2001
9.	Kramer S.L., "Geotechnical-Earthquake Engineering", Pearson Education – Indian Low-Price Edition	2004
10.	Chandra A.M. and Ghosh S.K., "Remote Sensing and Geographical Information System", Narosa, Oxford: Alpha Science International	2006
11.	Saran S., "Soil Dynamics & Machine Foundation", Galgotia Publication, New Delhi	2006
12.	Das B. M. and Ramana G.V., "Principles of soil dynamics", Cengage Learning	2011

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **INTERNATIONAL CENTRE FOR DAMS**

1. Subject Code **: DS-514** Course Title**: Study Tour/ Case Studies**
2. Contact Hours: **L: 2** **T: 0** **P: 2**
3. Examination Duration (Hrs): **Theory: 3** **Practical: 0**
4. Relative Weightage: **CWS: 15-30 PRS: 20 MTE:15-25 ETE: 30-40 PRE: 0**
5. Credits: **4** 6. Semester: **Both**
7. Subject Area: **PEC** 8. Pre-requisite: **NIL**
9. Objective: To reinforce the understanding of different physical aspects of dams through the case studies and visits to major national and international dams.
10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Introduction to dams; types of dams; major dams in India and abroad; characteristics of major dams.	2
2	**Case studies:** Case studies on major dams in India and abroad, such as Tehri Dam, Hirakund Dam, Tungabhadra Dam, Bhakra Nangal Dam, Nagarjuna Sagar Dam and Krishnasagar dam	2
3	**Discussions on Detailed Project Report (DPRs) of major dams**: Introduction to DPRs; understanding the different elements of DPRs: survey & investigation, geology, hydrology, structural design, hydro-mechanical design, power generation, cost estimates, etc.; discussions on DPRs	4
4	**Field visits to majors dams**: Visits to some of the dams; visit reports; and discussions. Tehri Dam, Hirakund Dam, Tungabhadra Dam, Bhakra Nangal Dam, Nagarjuna Sagar Dam and Krisnasagar dam	2
5	**Expert lectures:** Lectures by experts from different national and international agencies/institutes on design and operations of dams.	4

6	Provision of the visit to one or cluster of the international dams following the best practices during semester breaks	-
Total		14

11. Suggested References

S. No.	**Name of Authors / Books / Publishers**	**Year of Publication/ Reprint**
1.	Detailed Project Report (DPRs) of major dams	
2.	"Advanced Dam Engineering for Design, Construction, and Rehabilitation", United States: Springer US	1988
3.	Paranjpye V. "Evaluating the Tehri Dam: An Extended Cost Benefit Appraisal", India: Indian National Trust for Art and Cultural Heritage	1988
4.	Weaver K. D., "Dam Foundation Grouting", United States: American Society of Civil Engineers	1991
5.	Jain S. K., Singh V. P. and Agarwal P. K., "Hydrology and Water Resources of India", Germany: Springer Netherlands	2007
6.	Ramanathan K. and Abeygunawardena P., "Hydropower Development in India: A Sector Assessment", Philippines: Asian Development Bank	2007
7.	Scudder T. T., "The Future of Large Dams: Dealing with Social, Environmental, Institutional and Political Costs", Iran: Taylor & Francis	2012
8.	"Dam and Levee Safety and Community Resilience: A Vision for Future Practice", United States: National Academies Press	2012

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **INTERNATIONAL CENTRE FOR DAMS**

1. Subject Code : **DS-515** Course Title : **Geo Mechanics**
2. Contact Hours: **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs): **Theory: 3** **Practical: 0**
4. Relative Weightage: **CWS: 20-35 PRS: 0 MTE: 20-30 ETE: 40-50 PRE: 0**
5. Credits: **4** 6. Semester: **Both**
7. Subject Area: **PEC** 8. Pre-requisite: **NIL**
9. Objective: To provide *mechanical* behaviour of geological materials. The engineering aspects of these studies, or applied *geo-mechanics.*
10. Details of Course:

S. No.	Contents	Contact Hours
1	**Basics of Engineering Geology:** A brief about Earth's Interior and Plate Tectonics; brief about Minerals, Formation of minerals and their Classification; Types of Rock: Igneous, Sedimentary and Metamorphic; Formation of Rocks and Rock Cycle; Classification and Properties of Rocks; Weathering, Erosion and Soil Formation;	4
2	**Structural Geology:** Structural Configuration of Strata: Strike, Dip, Bedding Plane, etc., Types of Fractures: Joints, Faults, Folds, Unconformity; Formation and Classification of Joints, Faults and Folds; Effects of Joints, Faulting, Folding and their Civil Engineering Importance; Shear Zone; Topographic and Geological Maps;	8
3	**Engineering Properties of Rocks:** Engineering Properties of Rocks; Rock Deformation: Hooke's Law, Volumetric Strain, Elastic Moduli; **Types of Rock Stresses:** In-situ Stresses, Induced Stress;	5
4	**Hydrological Studies:** Sources of Ground Water; Aquifer, Aquiclude, Aquitard and Aquifuge; Types of Aquifer: Unconfined and Confined; Permeability of Rock mass and its test; Chemical properties of Ground Water and its effects on Rock Mass; **Geological Exploration:** Bore Holes (Vertical and inclined), Drifts in Abutments; Methods of Drilling;	5
5	**Rock Strength and Rock Mass Strength:** Rock Strength Test and Rock Failure Criteria; Rock Mass Strength and its measurement; Rock Mass Classification: Rock Mass Rating and Norwegian Q System;	4

6	Geophysical Methods and their Suitability; **Geology of Dam sites and Reservoirs -** Importance of Geology in Dam Construction; Types of Dams and bearing of Geology in their selection; Geological considerations in the selection of a Dam Site; Factors affecting the Feasibility of Reservoir Site; Investigation of Reservoir Sites; Geological Considerations and the Stability of the Sides of Reservoirs; Sedimentation in Reservoir and Leakage from Reservoir;	8
7	**Geological Hazards -** Landslides, Subsidence; Slope Stability; Slope Strengthening and Stabilization Effect of Reservoir and Tunnel Construction;	5
8	Numerical and computer methods in Geomechanics.	3
Total		42

11. Suggested Books:

S. No.	**Name of Authors/Books/Publisher**	**Year of Publication**
1.	Desai C. S. and Christian J. T., "Numerical Methods in Geotechnical Engineering" , McGraw-Hill	1977
2.	Goodman R. E., "Introduction to Rock Mechanics", 2nd Edition, Wiley	1988
3.	Hudson J. A. and Harrison J. P., "Engineering rock mechanics: an introduction to the principles", Elsevier	1997
4.	Bell F. G., "Geological Hazards: Their Assessment, Avoidance and Mitigation", United Kingdom: Taylor & Francis	2003
5.	Jager J. C., Cook N. G. W. and Zimmerman R., "Fundamental Rock Mechanics", 4th Edition, Wiley	2007
6.	Peng S. and Zhang J., "Engineering geology for underground rocks", Springer Science & Business Media	2007
7.	Farmer I. W., "Engineering behaviour of rocks", Springer Science & Business Media	2012
8.	Zhang L., "Engineering Properties of Rocks", Germany: Elsevier Science	2016
9.	Wyllie D. and Mah C. W., "Rock Slope Engineering", 5th Edition, CRC Press	2017
10.	Kesavulu N. C., "A Textbook of Engineering Geology", Laxmi Publications	2018
11.	Desai C. S., Prashant A. and Sachan A., "Advances in Computer Methods and Geomechanics: IACMAG Symposium 2019 Volume 1", Germany: Springer Singapore	2020
12.	Pollard D. D. and Martel S. J., "Structural Geology: A Quantitative Introduction", United Kingdom: Cambridge University Press	2020

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **INTERNATIONAL CENTRE FOR DAMS**

1. Subject Code**: DS-516** Course Title**: Geospatial Technologies for Dam Monitoring**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs): **Theory: 3** **Practical: 0**

4. Relative Weightage: **CWS: 20-35 PRS: 0 MTE: 20-30 ETE: 40-50 PRE: 0**

5. Credits: **4** 6. Semester: **Both**

7. Subject Area: **PEC** 8. Pre-requisite: **NIL**

9. Objective: This course will impart the knowledge and application of geospatial technologies in monitoring changes in geomorphological characteristics and structural changes of dams and other hydraulic structures.

10. Details of Course:

S. No.	Contents	Contact Hours
1	Overview of Geospatial Technologies	2
2	Introduction to optical remote sensing and its applications to surface water changes; Fundamentals of Digital Image Processing	4
3	Introduction to microwave (SAR) remote sensing; InSAR processing and its application to dam monitoring and associated tools/software; Structural Monitoring of Dam Structures using SAR	6
4	Introduction to UAV sensing; various components of UAV; autonomous UAVs; UAV data collection and processing methods; Indian Regulatory Systems for UAV sensing	6
5	Introduction to LiDAR; LiDAR data collection methods; Application of LiDAR technology to dam monitoring	6
6	Introduction to GPS Systems; GPS data collection techniques; Application of GPS to dam monitoring	6
7	Monitoring of Catchment Characteristics using geospatial technologies: Snow covered areas and rain-fed areas	6
8	Monitoring of landslide zones using geospatial technologies and their representation in GIS	3
9	Application of geospatial technologies for land use/cover change monitoring in flood-prone downstream areas of dams and risk assessment	3

Total		42

11. Suggested books:

S. No.	Name of Books/Authors/Publishers	Year of Publication/ Reprint
1.	Burrough P.A. and McDonnel R.A., "Principles of Geographic Information System", Oxford University Press	2000
2.	Joseph G., "Fundamentals of Remote Sensing", India: Universities Press	2005
3.	Nayak S. and Zlatanova S., "Remote Sensing and GIS Technologies for Monitoring and Prediction of Disasters", Germany: Springer Berlin Heidelberg	2008
4.	Richards J.A., "Remote Sensing Digital Image Analysis", Springer	2013
5.	Ferretti A., "Satellite InSAR Data – Reservoir Monitoring from Space", Eage Publications	2014
6.	Thenkabail P.S., "Remote Sensed Data Characterization, Classification, and Accuracies", CRC Press	2016
7.	Shaw R., "Land Use Management in Disaster Risk Reduction: Practice and Cases from a Global Perspective", Japan: Springer Japan	2016
8.	Dong P and Chen Q., "LiDAR Remote Sensing Applications", CRC Press	2018
9.	Shimada M., "Imaging from Spaceborne and Airborne SARs, Calibration, and Applications", Taylor and Francis	2018
10.	Garg P.K., "Introduction to Unmanned Aerial Vehicles", New Age International Publishers	2020

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **INTERNATIONAL CENTRE FOR DAMS**

1. Subject Code **: DS-517** Course Title**: Hydraulic and structural design of dams, spillways and energy dissipators**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs): **Theory: 3** **Practical: 0**

4. Relative Weightage: **CWS: 20-35 PRS: 0 MTE: 20-30 ETE: 40-50 PRE: 0**

5. Credits: **4** 6. Semester: **Both**

7. Subject Area: **PEC** 8. Pre-requisite: **NIL**

9. Objective: To discuss design methodology for dams, spillways and energy dissipators

10. Details of Course:

S. No.	Contents	Contact Hours
1	Introduction to hydraulic structures and their necessity.	2
2	**Embankment Dams:** Types, design considerations, seepage analysis and control, stability analysis, construction techniques	7
2	**Gravity Dams:** Forces acting on failure of a gravity dam, stress analysis, elementary profile, design of gravity dam, other functional features of a gravity dam	7
3	**Spillways:** Types and their design, Ogee spillway, Chute and side spillway, Shaft spillway, Labyrinth and Piano Key Weirs, spillway gates, cavitation, aerators, inflatable rubber weirs, stepped spillway, nappe and skimming flow	7
4	**Energy dissipators:** Necessity, Types and their selection, design of hydraulic jump type stilling basins, Bucket and Flip type energy dissipators, Impact and pipe outlet	9
5	Supercritical flow, oblique jump, supercritical transition	3
6	Hydraulic modelling of spillways and energy dissipators, dimensional analysis, modelling of turbulence, friction, air entrainment etc., scale effects,	3
7.	Life time assessment of dam and associated works	4
Total		42

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication /Reprint
1.	Creager W. P., Justin J. D. W. and Hinds J., "Engineering for Dams, Vol I & Vol II", John Wiley & Sons	1945
2.	Peterka A. J., "Hydraulic design of stilling basins and energy dissipators", USBR Engineering Monographs No. 25	1984
3.	"Design of Small Dams-Third Edition", A Water Resources Technical, Publication - US Bureau of Reclamation	1987
4.	Hager W.H. and Vischer D.L., "Energy Dissipators: IAHR Hydraulic Structures Design Manuals", CRC Press	1992
5.	Varshney R. S., "Engineering for Embankment Dams", Netherlands: A.A. Balkema Publishers.	1995
6.	Varshney R. S., "Hydro Power Structures", Nem Chand & Bros., Roorkee	2001
7.	Khatsuria R. M., "Hydraulics of spillways and energy dissipators", CRC Press	2004
8.	Singh B. and Varshney R. S., "Embankment Dam and Engineering", Nem Chand & Bros, Roorkee	2004
9.	Novak P. and Nalluri C., "Hydraulic Structures", Edition 4, Taylor & Francis	2007
10.	Chanson H., "Energy Dissipation in Hydraulic Structures" Netherlands: CRC Press	2015
11.	Nalluri C., Narayanan R., Novak P. and Moffat A., "Hydraulic Structures", United States: CRC Press	2017

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **INTERNATIONAL CENTRE FOR DAMS**

1. Subject Code: **DS-518** Course Title: **Ground Improvement and Geosynthetics**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs): **Theory: 3** **Practical: 0**

4. Relative Weightage: **CWS: 20-35 PRS: 0 MTE: 20-30 ETE: 40-50 PRE: 0**

5. Credits: **4** 6. Semester: **Both**

7. Subject Area: **PEC** 8. Pre-requisite: **NIL**

9. Objective: To introduce the ground improvement techniques and geo-synthetics for the dam safety, repair and rehabilitation.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Basics:** Principles of ground improvement, Types/Classification of ground improvement techniques. Mechanical modification, Types of compaction techniques, Properties of compacted soil. Hydraulic modification, dewatering systems, preloading and vertical drains, electro-kinetic dewatering, chemical modification, modification by admixtures, stabilization using industrial wastes, grouting, soil reinforcement principles,	06
2	**Methods of stabilizations:** – Mechanical – Admixture (Cement/Lime) - Bituminous - Chemical. Types of admixture stabilisation- Grouting (permeation grouting, compaction grouting, jet grouting), Deep Soil Mixing, Mass Soil Stabilisation, Cutter Soil Mixing. Grouting: - basic functions- permeation-compaction-hydro fracture, classification of grouts- grout ability ratio- properties of grouts - viscosity, stability, fluidity, rigidity, thixotropy, permanence Grouting applications : - seepage control in soil and rock under dams- seepage control in soil for cut off walls – stabilization grouting for underpinning. Properties of admixture stabilised soils, Design of hydraulic cut-off walls, grout curtains.	10
3	**Geosynthetics:** Properties of geosynthetics and its testing, applications of geosynthetics in bearing capacity improvement, slope stability, retaining walls, embankments on soft soil, and pavements, filtration, drainage and seepage control with geosynthetics, geosynthetics in landfills, soil nailing and other	08

	applications of geosynthetics. improvement of ground using geomembranes, geocells, geonets, geotubes	
4	**Reinforced earth: -** Mechanism- types of reinforcing elements- reinforcement-soil interaction –applications- reinforced soil structures with vertical faces. Design of reinforced earth retaining walls, reinforced earth embankments structures	06
5	**Advances** in ground improvement technologies- thermal stabilisation, biotechnical stabilization, hydroseeding etc.	02
6	**Case Studies:** Different case studies in India and around the world in the field of Ground Improvement and Geosynthetics.	10
Total		42

11. Suggested Books:

S. No.	**Name of Authors/Books/Publisher**	**Year of Publication**
1.	"Reinforced Soil Engineering: Advances in Research and Practice", Switzerland: Taylor & Francis	2003
2.	Indraratna B., Chu J., Hudson H.A., "Ground Improvement- Case Histories", Elsevier	2005
3.	Saran S., "Reinforced Soil and Its Engineering Applications", I.K. International	2005
4.	Shukla S.K. and Yin J. H., "Fundamentals of Geosynthetic Engineering", Taylor & Francis	2006
5.	Rao G.V., "Geosynthetics – An Introduction", Sai Master geo-environmental services	2007
6.	Kitazume M., and Terashi M., "The Deep Mixing Method", CRC Press	2012
7.	Koerner R.M., "Designing with Geosynthetics", Sixth Edition, Xlibris Corporation	2012
8.	Kirsch K. and Bell A., "Ground Improvement", Third Edition, CRC Press	2013
9.	Mittal S., "An Introduction to Ground Improvement Engineering", Medtech	2013
10.	Denies N., and Huybrechts N., "Handbook- Soil mix walls, Design and Execution", First Edition, CRC Press	2018
11	"Ground Improvement Techniques and Geosynthetics: IGC 2016 Vol (2)", Germany: Springer Singapore,	2018
12.	Huat B. B., Anggraini V., Prasad A. and Kazemian S., "Ground Improvement Techniques", Netherlands: CRC Press	2019

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **INTERNATIONAL CENTRE FOR DAMS**

1. Subject Code : **DS-519** Course Title : **Contract and Financial Management**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs): **Theory: 3** **Practical: 0**

4. Relative Weightage: **CWS: 20-35 PRS: 0 MTE: 20-30 ETE: 40-50 PRE: 0**

5. Credits: **4** 6. Semester: **Both**

7. Subject Area: **PEC** 8. Pre-requisite: **NIL**

9. Objective: To ensure and aware to the contract and financial management over respective obligations as efficiently and effectively as possible for the dam safety evaluation.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Contract Management:** Formation, Standard bid documents, tender and award of tenders, Online contracts, mistake and auctions, Breach and termination of contract, Impossibility of performance (force majeure clause), Forfeitures, loss and damages, Delays and liquidated damages, Risk, loss and indemnities, Condition, warranty, merchantability and quality of goods, Transportation, delivery, and Incoterms, Letters of credit, bank guarantee, and performance guarantee, Jurisdiction of courts, arbitration and dispute resolution, Confidentiality clauses and exemption/exclusion clauses, Contracts and taxation.	4
2	**Financial Management, Financial Analysis:** Introduction, uses, M&A, Private Equity, Equity Research, Career Opportunities, Skills Required	8
3	**Financial Statement Preparation:** Balance Sheet, Profit and Loss and Cash Flow, Revenues and Expenses, Consolidated Accounts, Tangible Assets, Goodwill, Depreciation	5
4	**MS Excel:** Spreadsheet Vocabulary, Logical & Statistical Functions, Data Validation, Custom List, Goal Seek, Scenarios, Data Manipulation, Pivot Tables and Macros	5
5	**Accounting Basics:** The Accounting Process, Accounting & Book-Keeping, Financial Terminologies, Accounting Concepts, the Accounting Cycle, Hindalco: Walk Through of Financial Statements	4

6	**Ratio Analysis:** Introduction to Ratio Analysis, Objectives of Ratio Analysis, Dupont Analysis, Types of Ratios, Simple Consolidation, Preparing Consolidated Statements	8
7	**Financial Modelling:** Create a Basic IB Financial Model, Types of Data & Variables, Growth Rates and Proportions, BEDMAS Principle	5
8	Forecasting and Modelling	3
Total		42

11. Suggested Books:

S. No.	Name of Authors/Books/Publisher	Year of Publication
1.	Hughes W. and Champion R, "Construction contracts: law and management", Routledge	2007
2.	Juan D. A., "Fundamentals of Accounting: Basic Accounting Principles Simplified for Accounting Students", United States: Author House	2007
3.	Fletcher S. and Gardner C., "Financial Modelling in Python", Germany: Wiley	2010
4.	Netscher P., "Successful Construction Project Management: The Practical Guide", Createspace Independent Pub	2014
5.	Roy M., "Microsoft Excel 2018: Learn Excel Basics with Quick Examples" United States: Create Space Independent Publishing Platform	2018
6.	Syrstad T. and Jelen B. "Microsoft Excel 2019 VBA and Macros" (n.p.): Pearson Education	2018
7.	Jelen B. and Syrstad T., "Microsoft Excel 2019 VBA and Macros (Business Skills)", Microsoft Corpn	2019
8.	Raina V. K., "Raina's Construction and Contract Management Vol.1", Shroff	2020

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **INTERNATIONAL CENTRE FOR DAMS**

1. Subject Code : **DS-520** Course Title : **Sustainable Tourism around Dams**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs): **Theory: 3** **Practical: 0**

4. Relative Weightage: **CWS: 20-35 PRS: 0 MTE: 20-30 ETE: 40-50 PRE: 0**

5. Credits: **4** 6. Semester: **Both**

7. Subject Area: **PEC** 8. Pre-requisite: **NIL**

9. Objective: To explore the opportunities, *sustainable tourism across* the world and awareness for dam safety.

10. Details of Course:

S. No.	Contents	Contact Hours
1	Understanding the concepts of Sustainability, Sustainable Development, Sustainable tourism	4
2	Socio-cultural problems related to dams- Social problems of displaced people, Strategies for integration of local people into mainstream tourism, Skill up-gradation as an essential mechanism for success of sustainable tourism	8
3	Understanding dam Tourism as a tool to enhance socio-economic and environmental aspects, Techno-Economics aspects of Dam sustainability, Tools and methodology for determining economic sustainability of dams	5
4	Understanding feasibility report for Dam tourism, components of feasibility reports	5
5	Concept of Sustainable Tourism around dams, issues and challenges	4
6	Challenges and limitations of sustainable tourism around dams in India	8
7	Current state of tourism around dams in India Best case studies of sustainable tourism around dams in India and world	3
8	Discussion and possible line of action for the dams in the purview of the Implementing Agencies	3
9	Risk Associated with tourism around dams; awareness and management	2
Total		42

11. Suggested Books:

S. No.	Name of Authors/Books/Publisher	Year of Publication
1.	Stevens J. E., "Hoover Dam: An American Adventure", University of Oklahoma Press.	1990
2.	"Guidelines for community-based ecotourism development", WWF International	2001
3.	Prasad K., "Water resources and Sustainable Development: challenges of 21st century", Shipra Publications	2003
4.	Narasaiah M. L., "Water and sustainable tourism", Discovery Publishing House	2005
5.	Bansal S. P. and Gautam P., "Sustainable Tourism Development: A Himalayan Experience", India: Indus Publishing Company	2007
6.	Schleiss A. J. and Boes R. M. (Eds.), "Dams and reservoirs under changing challenges", CRC press	2011
7.	Bass S. and Dalal-Clayton B., "Sustainable development strategies: a resource book", Routledge	2012
8.	Sharma N. and Flügel W. A., "Applied geoinformatics for sustainable integrated land and water resources management (ILWRM) in the Brahmaputra River basin", Springer India	2015

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **INTERNATIONAL CENTRE FOR DAMS**

1. Subject Code : **DS-521** Course Title: **Earth Retaining Structures and Dams**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs): **Theory: 3** **Practical: 0**

4. Relative Weightage: **CWS: 20-35 PRS: 0 MTE: 20-30 ETE: 40-50 PRE: 0**

5. Credits: **4** 6. Semester: **Both**

7. Subject Area: **PEC** 8. Pre-requisite: **NIL**

9. Objective: The objective is to introduce the various earth retaining structures design and its analysis by various software.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Basic Concept/ Design:** Classification of Dam Types, Physical Factors governing Selection of Type, General Arrangement, Area Capacity Curve, Fixation of different hydraulic Levels and Capacities	4
2	**Diversion Arrangement:** Design of Coffer Dams, Design of Diversion Tunnels, Design of Diversion Channels	8
3	**Spillways:** Types of Spillways (Ogee, Sluice, Side Channel, Chute channel, Conduit and Tunnel, Morning Glory etc.), Hydraulics, Profiles and Spillway Capacity, Types of Energy Dissipation Arrangement (EDA) (Stilling Basin, Bucket type etc.), Design of EDAs	5
4	**Foundation Design:** Embankment: Treatment of foundation, Cut off trenches, Toe Drains and Pressure relief wells etc., Concrete Dam: Consolidation Grouting, Curtain Grouting etc., Other suitable foundation measures for other type of dams and barrages	5
5	**Stability Analysis:** Forces/ Loads to be considered, Different load cases, Factors of safety in different conditions, Allowable stress/ deformation conditions	4
6	**Design of other structures:** Free board calculations and conditions for different types of dams, Piers, Spillway bridges, Different Galleries, Stair Case/ Lift, Control Room, Retaining walls, Dam Toe Power House etc	8
7	Construction Methods and suitable treatments for Concrete Dams/ RCC Dams/ CFRD Dams/ Arch Dams, Earth/ Embankment Dams/ Rock fill Dams,	5

	Barrages, Specific Studies such as Thermal Analysis etc., Physical & Numerical Model Studies	
8	**Software analysis:** Different software and their detailed applications, Analysis of all the above designs using Softwares.	3
Total		42

11. Suggested Books:

S. No.	**Name of Authors/Books/Publisher**	**Year of Publication**
1.	"Treatise on Dams", United States: U.S. Department of the Interior, Bureau of Reclamation, [Commissioner's Office]	1950
2.	"Design of gravity dams: design manual for concrete gravity dams", Bureau of Reclamation United States	1976
3.	Hoek E. and Brown E.T., "Underground Excavation in Rocks", The Institution of Mining and Metallurgy, London	1980
4.	Saran S., "Reinforced soil and its engineering applications", IK International Pvt Ltd	2005
5.	Weaver K. D. and Bruce D. A., "Dam Foundation Grouting", revised and expanded edition, American Society of Civil Engineers, ASCE Press, New York, 504	2007
6.	Desai Y. M. and Shah A. H., "Finite Element Method with Applications in Engineering", India: Pearson Education India	2011
7.	Saran S., "Analysis and design of foundations and retaining structures subjected to seismic loads", IK International Publish	2012
8.	Clayton C. R., Woods R. I. and Milititsky J., "Earth pressure and earth-retaining structures". CRC press	2013
9.	Zhang C., "Seismic Safety Evaluation of Concrete Dams: A Nonlinear Behavioral Approach", Netherlands: Elsevier Science & Technology Books	2014
10.	Mohammad A. R., "Nonlinear Finite Element Analysis of Earthen Dam", Germany: Lap Lambert Academic Publishing GmbH KG	2015

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **INTERNATIONAL CENTRE FOR DAMS**

1. Subject Code : **DS-522** Course Title: **Seismic Safety of Embankment Dams**
2. Contact Hours: **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs): **Theory: 3** **Practical: 0**
4. Relative Weightage: **CWS: 20-35 PRS: 0 MTE: 20-30 ETE: 40-50 PRE: 0**
5. Credits: **4** 6. Semester: **Both**
7. Subject Area: **PEC** 8. Pre-requisite: **NIL**
9. **Objective:** To cover the issues pertaining to earth and rock-fill dams under seismic loads and their analysis using classical and contemporary approaches.
10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction to Earth and Rock-fill Dams:** Introduction to dams; Characteristics of embankment dams; Differences between embankment dam and other types of dams; Components of embankment dam, functions and suitable materials; Zones of an embankment dam; Types of embankment dams: Homogeneous, Zoned and Diaphragm type dams; Influence of inclined and vertical core; Composite dams; Site selection for an embankment dam: Geology and seismicity of dam site, Reservoir rim and basin, Construction materials, Suitable spillway location, Submergence aspects, and Construction infrastructure;	6
2	**Case Studies Related to Dam Failures:** Performance of embankment dams in past earthquakes; Causes of dam failure: Non-Earthquake conditions, and Earthquake conditions; Different modes of dam failures; Inferences from various case studies: Teton dam, Machchhu dam failure, Hebgen dam, Los Angeles dam, San Fernando dam, and Sheffield Dam.	3
3	**Stability Analysis of Dams:** Effective and total stress methods of analysis; Analysis by Fellinius, Spencer, Bishop, Spencer method, Morgenstern price methods; Seismic slope stability methods: Inertial slope stability methods, Pseudostatic analysis, Displacement analysis; Pseudo-static analysis by Friction-circle, Fellinius and Bishop's methods; Factor of safety, yield accelerations and damage potential under saturated and submerged conditions; Displacement analysis by Newmark and Makdisi-Seed methods; Different loading cases for dam stability analysis: End of the construction, Partial submergence, Sudden drawdown, Steady state seepage, Sustained rainfall, and Earthquake; Slope protection measures	8

4	**FEM for Dam Analysis:** Application of FEM, Dam-foundation interaction; Identification of zones of hydraulic fractures and cracks; Nonlinear analysis, Tangent stiffness, Secant stiffness methods and No-tension analysis; Inertial and Weakening slope stability analysis; Modelling aspects: Element size, Domain size, Boundary conditions. Computer applications: Software to compute static & dynamic stresses induced, Deformations & displacements resulted, and Zones of liquefaction within the dam; Dynamic analysis of dams with examples;	8
5	**Seismic Performance Criteria for Large Embankment Dams:** Background; Integral dam safety concept; Seismic hazard a multi-hazard; Primary factors to consider in seismic design: Regional factors, Local factors; Selection of earthquakes for analysis; Seismic evaluation requirements; Seismic input parameters for analysis; The conceptual and constructional criteria for seismic-resistant fill dams	3
6	**Design Response Spectra – Generation of Time History:** Introduction, Standard code of practices; Synthesis of uncorrelated accelerograms: Modification of recorded accelerograms in time-domain, Modulated sum of harmon, Superposition of narrow-band time histories, Parametric time series modelling, Modification of recorded time history in frequency domain, Ground motion synthesis in frequency-domain; Spatially correlated accelerograms: Modelling of spatial variation, Method of spectral factorization, Method of principal components.	4
7	**Reservoir Rim and Basin Stability:** Causes and effects of rim stability, methods for assessing rim and basin stability: Earthquake induced landslide activity, Different types of earthquake induced landslides and their assessment methods.	3
8	**Assessment of Seepage Pressures:** Seepage in earth and rockfill dams and their foundations, Different methods of seepage assessment; Standard analytical solutions for seepage problems, Piping and Liquefaction; Estimation of pore pressure by flow net and its construction: Confined flow and Unconfined flow; FEM analysis for the estimation of seepage pressures.	4
9	**Guidelines for the Seismic Design and Construction of Embankment Dams:** Different codal provisions: Core, Shell, Cut-off wall, Cut-off Barrier, Transition Zones and Transition Filters; Internal drainage system; Protective layers for erosion control; Free board; Parapet wall; Riprap;	3
Total		42

List of Experiments:

1. Demonstration of GeoStudio
2. Stability assessment of an existing dam suing SLOPE/W
3. Seismic stability assessment of an existing dam using QUAKE/W
4. Assessment of seepage pressures using SEEP/W.
5. Generation of spectrum compatible time histories.
6. Deconvolution of time histories to obtain base input motions.
7. Dynamic stability assessment of a model dam using shake table experiment.

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	"Embankment Stability Analysis, Preliminary Design: Proposed Indian Creek Dam, North Dakota", United States: Soil Exploration Company	1974
2.	"IS 7894, Code of practice for stability analysis of earth dams", Bureau of Indian Standard (BIS), New Delhi, India	1975 (Reaffirmed 2002)
3.	Prakash S., "Soil Dynamics", McGraw Hill Book Company	1981
4.	Zienkiewicz O. C. and Morgan K., "Finite Elements and Approximation", John Wiley & Sons	1983
5.	Kramer S.L., "Geotechnical-Earthquake Engineering", Pearson Education – Indian Low-Price Edition	2004
6.	Singh, B. and Varshney, R.S., "Embankment Dam Engineering", Nem Chand & Brothers.	2004
7.	Akin J.E., "Finite Element Analysis with Error Estimators", Elsevier Publications	2005
8.	Bandyopadhyay J. N., "Design of Concrete Structures", India: PHI Learning	2008
9.	"Earthquake-Induced Landslides: Proceedings of the International Symposium on Earthquake-Induced Landslides, Kiryu, Japan, 2012", Germany: Springer Berlin Heidelberg	2012
10.	"Selecting Seismic Parameters for Large Dams, Guidelines, Bulletin 148 Committee on Seismic Aspects of Dam Design", International Commission on Large Dams (ICOLD), Paris	2014
11.	Al-Labban S. N., "Seepage and Stability Analysis of the Earth Dams Under Drawdown Conditions by Using the Finite Element Method", United States: University of Central Florida	2018

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **INTERNATIONAL CENTRE FOR DAMS**

1. Subject Code: **DS-523** Course Title: **Concepts of Planning and Design of Hydro-Mechanical Components in Dams**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs): **Theory: 3** **Practical: 0**

4. Relative Weightage: **CWS: 20-35 PRS: 0 MTE: 20-30 ETE: 40-50 PRE: 0**

5. Credits: **4** 6. Semester: **Both**

7. Subject Area: **PEC** 8. Pre-requisite: **NIL**

9. Objective: To introduce the basic concepts of Planning and Design of hydro-mechanical components of the Dam.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction & Types of Gates:** Brief history of development, Gates components, main applications, types and classification.	4
2	**Selection of Hydraulic Gates:** Selection criteria of Hydraulic gates,	8
3	**Hydraulic Gates Design & Weight Estimation:** Hydrostatic, load cases, allowable stresses, design of skin plate, horizontal beams, embedment, gate weight estimation	5
4	**Hydro-dynamic Forces:** Hydro-dynamic forces (down pull, uplift, cavitation etc.), aeration, modeling, etc.	5
5	**Gate Operating Systems:** Gate operating forces, hoists (Hydraulic & mechanical).	4
6	**Materials, Fabrication, Erection, Testing& Commissioning etc.:** Materials, rubber seals, fabrication, transportation & erection materials, fabrication transportation, erection, testing & commissioning**.**	8
7	**Hydraulic Gates for Dam Safety:** Operation & maintenance of hydraulic Gates, rehabilitation, inspection, operation & maintenance, automation, etc. Recent trends & developments in Hydraulic gates engineering**.**	5
8	Practical Examples/ Workshops	3
Total		42

11. Suggested Books:

S. No.	Name of Authors/Books/Publisher	Year of Publication
1.	Singh B. and Varshney R. S., "Hydropower Structures", Nem Chand & Bros., Roorkee	1977
2.	"Safety of Existing Dams: Evaluation and Improvement", United States: National Academy Press	1983
3.	Nigam P. S., "Handbook on Hydro Electric Engg", Nem Chand & Bros., Roorkee	1985
4.	"Small Hydro Stations" (Publication No. 175), Central Board of Irrigation and Power, New Delhi	2008
5.	"Dam and Levee Safety and Community Resilience: A Vision for Future Practice", United States: National Academies Press	2012
6.	"Standards/Manual/Guidelines for small Hydro Development", IIT Roorkee	2013
7.	Erbisti P. C., "Design of Hydraulic Gates, 2nd Edition", Netherlands: Taylor & Francis	2014
8.	Chen S., "Hydraulic Structures", Belgium: Springer Berlin Heidelberg	2015
9.	Ascila R. and Hartford D. N. D., "Operational Safety of Dams and Reservoirs: Understanding the Reliability of Flow-control Systems", United Kingdom: ICE Publishing	2016
10.	"Guidelines for Preparing Operation and Maintenance Manual for Dams", DRIP, MoWR, New Delhi	2018
11.	Sur S. K., "A Practical Guide to Construction of Hydropower Facilities", United States: CRC Press	2019

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **INTERNATIONAL CENTRE FOR DAMS**

1. Subject Code: **DS-524** Course Title: **Engineering Seismology and Hazard analysis of Dams**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs): **Theory: 3** **Practical: 0**

4. Relative Weightage: **CWS: 20-35 PRS: 0 MTE: 20-30 ETE: 40-50 PRE: 0**

5. Credits: **4** 6. Semester: **Both**

7. Subject Area: **PEC** 8. Pre-requisite: **NIL**

9. Objective: To provide the concepts of engineering seismology, seismological instrumentation, reservoir induced seismicity, seismic hazard assessment.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction**: Scope of seismology; Definitions of important terms; Causes of earthquakes and their classifications; Earthquake effects on ground and structures, Plate tectonics- continental drift, types and characteristics of various plate margins; Earthquake catalogue and seismicity of the earth; Major earthquakes in the world; Important Indian earthquakes	10
2	**Wave Propagation and Instrumentation**: Theory of elasticity; Body and surface waves; Local site effects; Seismic phases; Internal structure of earth; Reference models, Earthquake intensity, Earthquake magnitude, frequency magnitude relations, Earthquake recordings - principles and theory of seismograph; Real time warning system; International monitoring system (IMS); Local seismological networks, strong motion networks and their engineering importance.	8
3	**Seismic Hazard Assessment:** Definitions- seismic hazard, disaster and risk; Probabilistic and deterministic approach; Earthquake occurrence models; Seismotectonic modeling and type of sources; Estimation of maximum magnitude, maximum credible earthquake, design basis earthquake; Frequency magnitude relationship; Poissonian and Non Poissonian models; Ground motion prediction equations; Uncertainties in seismic hazard assessment and their quantification; Return periods and strong motion exceedance rates; Site-specific design earthquake parameters; Case studies.	8
4	**Geophysical Methods**: Seismic methods; Well logging; Steady state Rayleigh method; Spectral analysis of surface waves-SASW and MASW methods;	6

	Ground penetrating radar, bedrock profiling. Quantification of Site Effects: Experimental methods; Microearthquake- standard spectral ratio method & horizontal to vertical spectral ratio method; Microtremors - absolute spectra, SSR method & H/V ratio; Empirical relations; Analytical method; 1D ground response of layered medium	
5	**Site-specific Ground Motion Estimation:** Empirical Green's function; Numerical methods; Basic concept, recent developments; Domain method, boundary method & hybrid method; Effects of nonlinearity on ground motion	5
6	**Seismic Microzonation:** PSHA and DSHA; Seismic microzonation of mega cities, scales used in seismic microzonation; Recent developments and case studies.	5
Total		42

11. Suggested Books:

S. No.	**Name of Authors/Books/Publisher**	**Year of Publication**
1.	Gupta H., "Reservoir Induced Earthquakes", Netherlands: Elsevier Science	1992
2.	Lay T. and Wallace T. C., "Modern Global Seismology", United States: Elsevier Science	1995
3.	Bertero V. V., "Earthquake Engineering: From Engineering Seismology to Performance-Based Engineering", Ukraine: CRC Press	2004
4.	"Earthquake Early Warning Systems", Germany: Springer Berlin Heidelberg	2007
5.	Shearer P. M., "Introduction to Seismology", Cambridge University Press	2009
6.	Mayne P. W. and Coutinho R. Q., "Geotechnical and Geophysical Site Characterization 4", Netherlands: CRC Press	2012
7.	Gupta H. and Rastogi, "Dams and Earthquakes", Netherlands: Elsevier Science	2013
8.	Wysession M. and Stein, S., "An Introduction to Seismology, Earthquakes, and Earth Structure", Germany: Wiley	2013
9.	Shroder J. F. , "Earthquake Hazard, Risk and Disasters", United Kingdom: Elsevier Science	2013
10.	Lai C. G., Rix G. J., Strobbia C. and Foti S., "Surface Wave Methods for Near-Surface Site Characterization", United Kingdom: Taylor & Francis	2014
11.	Beer M., "Encyclopaedia of Earthquake Engineering", Germany: Springer Berlin Heidelberg	2015
12.	Murru M., Console R., Falcone G. "Earthquake Occurrence: Short- and Long-term Models and Their Validation", United Kingdom: Wiley	2017
13.	"Monitoring Dam Performance: Instrumentation and Measurements", United States: American Society of Civil Engineers	2018
14.	Chopra A. K., "Earthquake Engineering for Concrete Dams: Analysis, Design, and Evaluation", United Kingdom: Wiley	2020

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