

DEPARTMENT OF CIVIL ENGINEERING, IIT DELHI

M.Tech (Rock Engineering and Underground Structures) — CEU

New Structure

Total Credits = 48

1. Programme Core (PC) Lecture/Practical Credits (excluding project) = 18 (12L+6P)
2. Credits for the M.Tech. Project (excluding core/practical courses) = 18 (6+12)
3. Programme Elective (PE) Course Credits = 12 (4*3 = 12)

Semester-wise Structure

I st Semester	II nd Semester	Summer Semester	III rd Semester	IV th Semester
(Sem. Credits)	(Sem. Credits)	(Sem. Credits)	(Sem. Credits)	(Sem. Credits)
CVL710	CVL712		CVD810	CVD811
CVL711	CVL713		PE-4	
CVP710	CVP810			
PE-1	PE-2			
	PE-3			
Total = 12 Credits	Total = 15 Credits		Total = 9 Credits	Total = 12 Credits

List of Program Core Courses (PC):

1. CVL710 - Engineering Properties of Rocks and Rock Masses
2. CVL711 - Structural Geology
3. CVL712 - Slopes and Foundations
4. CVL713 - Analysis and Design of Underground Structures
5. CVP710 - Rock Mechanics Laboratory 1
6. CVP810 - Rock Mechanics Laboratory 2
7. CVD810 - Major Project Part-1
8. CVD811 - Major Project Part-2

List of Program Electives (PE):

1. CVL704 - Finite Element Method in Geotechnical Engineering
2. CVL714 - Field Exploration and Geotechnical Processes
3. CVL715 - Excavation Methods and Underground Space Technology
4. CVL716 - Environmental Rock Engineering
5. CVL810 - Emerging Topics in Rock Engg and Underground Structures
6. CVL811 - Numerical and Computer Methods in Geomechanics
7. CVD710* - Minor Project
8. CVS810 - Independent Study

***CVD710 may be considered as core course in place of CVP810, for Part-Time Students**

Major Changes: Based on the feedback and the requirement of the industry, the courses have been modified/restructured to take into account the present need of the industry as well as recent developments. Significant self-study component is introduced through restructuring. A new elective course has been added in the list of electives.

MINOR PROJECT TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	MINOR PROJECT
3.	L-T-P structure	0 - 0 - 6
4.	Credits	3
5.	Course number	CVD710
6.	Status (<i>category for program</i>)	PROGRAMME ELECTIVE

7.	Pre-requisites (course no./title)	NONE
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8.	Supersedes any existing course	NONE
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9.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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10.	FACULTY WHO WILL SUPERVISE PROJECT STUDY ALL GEOTECHNICAL SECTION FACULTY	
11.	Will the PROJECT SUPERVISION require any visiting faculty?	MAY BE INVITED ON REQUEST BY FACULTY SUPERVISOR/STUDENT

12.	PROJECT objective (<i>about 50 words</i>): (1) TO EXPLORE A PRESCRIBED PROBLEM BASED ON LABORATORY AND/OR NUMERICAL MODELLING BASED APPROACHES (2) TO EXPLORE DESIGN METHODOLOGIES IN THE AREA OF ROCK ENGINEERING AND UNDERGROUND STRUCTURES	
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13. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	SPECIFIC TO THE PROBLEM TAKEN UP FOR THE STUDY	OPEN

14. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

RELEVANT, CONTEXTUAL RESEARCH ARTICLES, REPORTS AND BOOKS

15. Resources required for the STUDY (*itemized & student access requirements, if any*)

19.1	Software	YES
19.2	Hardware	YES
19.3	PRESENTATION aides (videos, etc.)	YES
19.4	Laboratory	YES
19.5	Equipment	YES
19.6	Classroom infrastructure	NO
19.7	Site visits	MAY BE REQUIRED AS PART OF THE STUDY

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	FINITE ELEMENT METHOD IN GEOTECHNICAL ENGINEERING
3.	L-T-P structure	3 - 0 - 0
4.	Credits	3
5.	Course number	CVL704
6.	Status (<i>category for program</i>)	PE

7.	Pre-requisites (course no./title)	NIL
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	Less than 10%, This course will be offered also for Geotechnical and Geoenvironmental Engineering students.
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	NIL

9.	Not allowed for (indicate program names)	Approval from course coordinator required for registration
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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11.	Faculty who will teach the course Prof. K. S. Rao, Prof. M. Datta, Prof. G.V. Ramana, Prof. J. T. Shahu, Dr. R. Ayothiraman Dr. B. Manna, Dr. T. Chakraborty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): The students would learn 1. the formulation and steps in finite element methods, solution algorithms 2. the application of finite element method in geotechnical and rock engineering 3. the application of commercial packages in finite element simulation	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Introduction. Steps in FEM. Variational Methods, Stress-deformation analysis: One-, Twodimensional formulations; Three-dimensional formulations;	
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	Boundary conditions; Solution algorithms; Descretization; use of FEM2D Program and Commercial packages. Analysis of foundations, dams, underground structures and earth retaining structures. Analysis of flow (seepage) through dams and foundations. Consolidation Analysis, Linear and non-linear analysis. Insitu stresses. Sequence construction and excavation. Joint/interface elements. Infinite elements. Dynamic analysis. Evaluation of material parameters for linear and non-linear analysis, Recent developments.
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15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	Introduction. Steps in FEM, Variational methods;	4
2	Stress-deformation analysis: One-, Two-dimensional formulations; Three-dimensional formulations;	5
3	Boundary conditions; Solution algorithms; Discretization;	5
4	Use of FEM2D Program and Commercial packages.	3
5	Analysis of foundations, dams, underground structures and earth retaining structures.	5
6	Analysis of flow (seepage) through dams and foundations, Consolidation analysis.	5
7	Linear and non-linear analysis.	3
8	In situ stresses. Sequence construction and excavation.	3
9	Joint/interface elements. Infinite elements.	3
10	Dynamic analysis.	3
11	Evaluation of material parameters for linear and non-linear analysis,	2
12	Recent developments	1
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
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COURSE TOTAL (14 times 'P')		

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

1. Daryl L. Logan, A First Course in the Finite Element Method, Cengage Learning, 2010.
2. Robert D. Cook and David S. Malkus. Concepts and Applications of Finite Element Analysis, 4th Edition. Wiley and Sons.
3. Desai, C.S. and Kundu T. Introductory Finite Element Method. CRC Press, 2001.
4. K.J. Bathe. Finite Element Procedures. Prentice Hall, 1982.
5. Desai, C.S. and Abel, J.F. Introduction to Finite Element Method. Van Nostrand Reinhold, New York, 1972.
6. Naylor, D.J. and Pande, G.N. Finite Elements in Geotechnical Engineering. Pineridge Press, 1981.

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19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	Available
19.2	Hardware	Available
19.3	Teaching aides (videos, etc.)	Black board, OHP, PPT, Videos and site visits
19.4	Laboratory	NA
19.5	Equipment	NA
19.6	Classroom infrastructure	Black board and PPT Projector required
19.7	Site visits	YES

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	Up to 20%
20.2	Open-ended problems	Up to 15%
20.3	Project-type activity	Up to 15%
20.4	Open-ended laboratory work	Up to 10%
20.5	Others (please specify)	Self study up to 20%

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	ENGINEERING PROPERTIES OF ROCKS AND ROCK MASSES
3.	L-T-P structure	3 - 0 - 0
4.	Credits	3
5.	Course number	CVL710
6.	Status (<i>category for program</i>)	PC

7.	Pre-requisites (course no./title)	NIL
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	Less than 10%
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	NIL

9.	Not allowed for (indicate program names)	Approval from course coordinator required for registration
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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11.	Faculty who will teach the course Prof. K. S. Rao, Prof. M. Datta, Prof. G.V. Ramana, Prof. J. T. Shahu, Dr. R. Ayothiraman, Dr. B. Manna, Dr. T. Chakraborty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): The students would learn 1. the physical and mechanical behavior of intact rock and rock mass 2. simple elastic and elastoplastic constitutive models used in rock mechanics 3. concepts of rock mass rating and rock classification	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Introduction. Rock materials, Physical properties, Strength behaviour in uniaxial compression, tension and triaxial state. Laboratory testing methods. Stress-strain relationships. Factors influencing strength. Failure mechanism. Anisotropy. Failure criteria, Coulomb, Mohr's, Griffiths and Modified Griffiths criteria and Empirical criteria. Brittle – ductile transition, Post failure behaviour. Strength and deformation behaviour of discontinuities. Rockmass behaviour, Shear strength of jointed rocks, roughness, peak and residual strengths. Strength criteria for rockmass. Intact and rockmass classifications, Terzaghi,	
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	RQD, RSR, RMR and Q classifications, Rating, Applications. Creep and cyclic loading. Weathered rocks. Flow through intact and fissured rocks. Dynamic properties
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15. Lecture Outline (*with topics and number of lectures*)

Module no.	Topic	No. of hours
1	Introduction. Rock materials, Physical properties, Strength behaviour in uniaxial compression, tension and triaxial state.	5
2	Laboratory testing methods. Stress-strain relationships.	4
3	Factors influencing strength. Failure mechanism. Anisotropy.	4
4	Failure criteria, Coulomb, Mohr's, Griffiths and Modified Griffiths criteria and Empirical criteria.	4
5	Brittle – ductile transition, Post failure behaviour.	3
6	Strength and deformation behaviour of discontinuities.	4
7	Rockmass behaviour, Shear strength of jointed rocks, roughness, peak and residual strengths. Strength criteria for rockmass.	5
8	Intact and rockmass classifications, Terzaghi, RQD, RSR, RMR and Q classifications, Rating, Applications.	5
9	Creep and cyclic loading. Weathered rocks.	2
10	Flow through intact and fissured rocks.	3
11	Dynamic properties	3
12		
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
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COURSE TOTAL (14 times 'P')		

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

1. Goodman, R. E. Introduction to Rock Mechanics. John Wiley and Sons, 1989.
2. John Jaeger and N. G. Cook. Fundamentals of Rock Mechanics. Wiley-Blackwell. 2007.
3. Ramamurthy, T. Engineering in Rocks for Slopes, Foundations and Tunnels. Prentice Hall India, 2007.
4. Vutukuri, V.S., Lama, R.D. and Saluja, S.S. Handbook on Mechanical Properties of Rocks. Vol. 1, Trans Tech. Publications, 1974.
5. Zhang Lianyang. Engineering Properties of Rocks. Elsevier, 2005.
6. Bieniawski, Z.T.. Engineering Rock Mass Classifications. John Wiley and Sons, 1989.

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19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	Available
19.2	Hardware	Available
19.3	Teaching aides (videos, etc.)	Black board, OHP, PPT, Videos and site visits
19.4	Laboratory	NA
19.5	Equipment	NA
19.6	Classroom infrastructure	Black board and PPT Projector required
19.7	Site visits	YES

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	Up to 10%
20.2	Open-ended problems	Up to 10%
20.3	Project-type activity	Up to 10%
20.4	Open-ended laboratory work	Up to 10%
20.5	Others (please specify)	Self study component up to 15%

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	STRUCTURAL GEOLOGY
3.	L-T-P structure	3 - 0 - 0
4.	Credits	3
5.	Course number	CEL711
6.	Status (<i>category for program</i>)	PC

7.	Pre-requisites (course no./title)	NIL
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	Less than 10%
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	NIL

9.	Not allowed for (indicate program names)	Approval from course coordinator required for registration
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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11.	Faculty who will teach the course Prof. K. S. Rao, Prof. M. Datta, Prof. G.V. Ramana, Prof. J. T. Shahu, Dr. R. Ayothiraman, Dr. B. Manna, Dr. T. Chakraborty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): The students would learn 1. different rock types 2. structural geological features of rocks and its mapping 3. problems encountered in rock mechanical design due to the geological features	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Origin, interior and composition of the earth. Rock cycle, Igneous, Metamorphic and Sedimentary rocks. Rock structures. Plate tectonics, Continental drift and sea floor spreading. Geological time scale. Layered formations, Attitude, true and apparent dips, topographic maps, outcrops. Measurement of attitude of formations. Folds, types of folds, classification, field study of folds, mechanics of folds, causes of folding. Joints, rock mass concept, Joint description and classification. Three point problems, Depth and	
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	thickness problems. Faults, mechanics of faulting, normal, reverse and thrusts, faults. Lineations. Foliations, Schistosity. Fault problems. Stereographic projection methods, Use of DIPS software, presentation of geological data and analysis, Applications, Scan line survey of rock joints in the visit.
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15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	Origin, interior and composition of the earth.	3
2	Rock cycle, Igneous, Metamorphic and Sedimentary rocks. Rock structures., Response of rocks to stress	3
3	Plate tectonics, Continental drift and sea floor spreading. Geological time scale.	2
4	Layered formations, Attitude, true and apparent dips, topographic maps, outcrops.	6
5	Measurement of attitude of formations. Folds, types of folds, classification, field study of folds, mechanics of folds, causes of folding.	7
6	Joints, rock mass concept, Joint description and classification. Three point problems, Depth and thickness problems.	6
7	Faults, mechanics of faulting, normal, reverse and thrusts, faults. Lineations. Foliations, Schistosity.	6
8	Fault problems, Structural Associations.	3
9	Stereographic projection methods,	3
10	Use of DIPS software, presentation of geological data and analysis, Applications,	3
11	Field visit.	
12		
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
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COURSE TOTAL (14 times 'P')		

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

1. Marland Pratt Billings. Structural Geology. Prentice Hall College. 1972.
2. Marshak, S. and Mitra, G. Basic Methods of Structural Geology, Prentice-Hall, 1988.

3. Priest, S.D. Hemispherical Projection Methods in Rock Mechanics, George Allen & Unwin (Publishers) Ltd., 1985.
4. Ramsay, J.G. and Huber, M.I. The Techniques of Modern Structural Geology, Academy Press, London, 1987
5. B.E. Hobbs, W. Means and P.F. Williams An Outline of Structural Geology, Wiley Int. Edition, 1976
6. R.J. Twiss and E.M. Moores Structural Geology, W.H. Freeman and Co, 2007.

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	Available
19.2	Hardware	Available
19.3	Teaching aides (videos, etc.)	Black board, OHP, PPT, Videos and site visits
19.4	Laboratory	NA
19.5	Equipment	NA
19.6	Classroom infrastructure	Black board and PPT Projector required
19.7	Site visits	YES

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	Up to 30%
20.2	Open-ended problems	Up to 20%
20.3	Project-type activity	Up to 10%
20.4	Open-ended laboratory work	Up to 20%
20.5	Others (please specify)	Self study component up to 20%

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	SLOPES AND FOUNDATIONS
3.	L-T-P structure	3 - 0 - 0
4.	Credits	3
5.	Course number	CVL712
6.	Status (<i>category for program</i>)	PC

7.	Pre-requisites (<i>course no./title</i>)	NIL
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	Less than 20%, Slopes and Retaining Structures
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	NIL

9.	Not allowed for (<i>indicate program names</i>)	Approval from course coordinator required for registration
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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11.	Faculty who will teach the course Prof. K. S. Rao, Prof. M. Datta, Prof. G.V. Ramana, Prof. J. T. Shahu, Dr. R. Ayothiraman, Dr. B. Manna, Dr. Tanusree Chakraborty	
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12.	Will the course require any visiting faculty?	No
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13.	Course objective (<i>about 50 words</i>): The students would learn 1. the types of rock slope failure and stability analysis of rock slopes. 2. bearing capacity of foundations on rock. 3. use of available codes and standards in design of slopes and foundations on rock.	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Introduction, Short-term and long-term stability. Influence of ground water, Seismic effects. Types of rock slope failures. Infinite slopes, Circular and non-circular slip surface analysis, Stability charts. Plane failure analysis. Wedge failure analysis analytical, Stereographic methods. Buckling and toppling	
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	failures, Rock falls, Landslides. Foundations: Bearing capacity, settlement and stress distribution in intact and layered rocks. Foundations of dams. Deep foundations. Tension foundations, Codal provisions. Foundation improvement. Use of appropriate software packages.
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15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	Introduction, Short-term and long-term stability.	5
2	Influence of ground water, Seismic effects.	4
3	Types of rock slope failures, Infinite slopes,	4
4	Circular and non-circular slip surface analysis, Stability charts.	4
5	Plane failure analysis.	3
6	Wedge failure analysis analytical,	4
7	Stereographic methods.	4
8	Buckling and toppling failures, Rock falls, Landslides.	5
9	Foundations: Bearing capacity, settlement and stress distribution in intact and layered rocks.	2
10	Foundations of dams. Deep foundations.	3
11	Tension foundations, Codal provisions.	3
12	Foundation improvement. Use of appropriate software packages.	1
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
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2		
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COURSE TOTAL (14 times 'P')		

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

1. Evert Hoek, Jonathan D. Bray. Rock Slope Engineering: Third Edition. 1981
2. Duncan C. Wyllie and Chris Mah. Rock Slope Engineering: Fourth Edition. CRC Press, 2004.
3. Richard E. Goodman, Foundations on Rock, 2007.
4. Duncan Wyllie. Foundations on Rock. Chapman and Hall, 1990.
5. Goodman, R.E. Introduction to Rock Mechanics. John Wiley, 1980.
6. Anderson, M.G. and Richards, K.S.: Slope Stability, John Wiley, 1987.

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	Available
19.2	Hardware	Available
19.3	Teaching aides (videos, etc.)	Black board, OHP, PPT, Videos and site visits
19.4	Laboratory	NA
19.5	Equipment	NA
19.6	Classroom infrastructure	Black board and PPT Projector required
19.7	Site visits	YES

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	Up to 20%
20.2	Open-ended problems	Up to 15%
20.3	Project-type activity	Up to 15%
20.4	Open-ended laboratory work	Up to 15%
20.5	Others (please specify)	Self study component up to 20%

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	ANALYSIS AND DESIGN OF UNDERGROUND STRUCTURES
3.	L-T-P structure	3 - 0 - 0
4.	Credits	3
5.	Course number	CVL713
6.	Status (<i>category for program</i>)	PC

7.	Pre-requisites (course no./title)	NIL
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	Less than 10%
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	NIL

9.	Not allowed for (indicate program names)	Approval from course coordinator required for registration
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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11.	Faculty who will teach the course Prof. K. S. Rao, Prof. M. Datta, Prof. G.V. Ramana, Prof. J. T. Shahu, Dr. R. Ayothiraman, Dr. B. Manna, Dr. T. Chakraborty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): The students would learn 1. analysis of underground structures in rock and soil using elastic and elastoplastic stress-strain behavior of rock and soil, respectively. 2. design of underground structure using empirical, analytical and numerical approaches 3. use of codes and standards in design of underground structures	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Introduction. Types and classification of underground openings. Factors affecting design. Design methodology. Functional aspects. Size and shapes. Support systems. Codal provisions. Analysis: Stresses and deformations around openings, Stresses and deformations around tunnels and galleries with composite lining due to internal pressure, Closed form solutions, BEM, FEM. Design : Design based on analytical methods; Empirical methods based on	
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	RSR, RMR, Q systems; Design based on Rock support interaction analysis; Observational method- NATM, Convergence-confinement method. Design based on Wedge failure and key block analysis. Design of Shafts and hydraulic tunnels. Stability of excavation face and Tunnel portals. Use of appropriate software packages.
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15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	Introduction. Types and classification of underground openings.	2
2	Factors affecting design. Design methodology.	4
3	Functional aspects. Size and shapes. Support systems. Codal provisions.	3
4	Analysis: Stresses and deformations around openings,	8
5	Stresses and deformations around tunnels and galleries with composite lining due to internal pressure,	5
6	Closed form solutions, BEM, FEM.	4
7	Design : Design based on analytical methods;	4
8	Empirical methods based on RSR, RMR, Q systems;	4
9	Design based on Rock support interaction analysis;	2
10	Observational method- NATM, Convergence-confinement method.	2
11	Design based on Wedge failure and key block analysis. Design of Shafts and hydraulic tunnels.	2
12	Stability of excavation face and Tunnel portals. Use of appropriate software packages.	2
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
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COURSE TOTAL (14 times 'P')		

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

1. Hoek, E., Brown, E. Underground excavations in rock, CRC Press, 1980.
2. Leonard Obert, Wilbur I. Duvall, Rock mechanics and the design of structures in rock, Wiley, 1967.
3. Poulos, H.G. and Davis, E.H.: Elastic Solutions for soil and rock mechanics. John Wiley & Sons, 1974.
4. Bieniawski, Z.T. Rock mechanics in mining & tunnelling. A.A. Balkema, 1984.
5. Szechy, K. The art of tunnelling, Akadémiai Kiadó, 1973.
6. Goodman, R.E. Introduction to Rock Mechanics. John Wiley, 1980.

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19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	Available
19.2	Hardware	Available
19.3	Teaching aides (videos, etc.)	Black board, OHP, PPT, Videos and site visits
19.4	Laboratory	NA
19.5	Equipment	NA
19.6	Classroom infrastructure	Black board and PPT Projector required
19.7	Site visits	YES

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	Up to 20%
20.2	Open-ended problems	Up to 15%
20.3	Project-type activity	Up tp 15%
20.4	Open-ended laboratory work	Up to 10%
20.5	Others (please specify)	Self study component up to 15%

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	FIELD EXPLORATION AND GEOTECHNICAL PROCESSES
3.	L-T-P structure	3 - 0 - 0
4.	Credits	3
5.	Course number	CVL714
6.	Status (<i>category for program</i>)	PE

7.	Pre-requisites (course no./title)	NIL
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	Less than 10%
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	NIL

9.	Not allowed for (indicate program names)	Approval from course coordinator required for registration
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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11.	Faculty who will teach the course Prof. K. S. Rao, Prof. M. Datta, Prof. G.V. Ramana, Prof. J. T. Shahu, Dr. R. Ayothiraman, Dr. B. Manna, Dr. T. Chakraborty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): The students would learn 1. field exploration techniques in rock engineering, 2. insitu stresses and its measurement 3. different geotechnical processes in rock engineering for rock stabilization.	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Surface and sub surface exploration methods. Aerial and remote sensing techniques, Geophysical methods, electrical resistivity, seismic refraction, applications. Rock drilling, Core samplers, Core boxes, Core orientations. Logging, stratigraphic profile, scan line survey. Laboratory tests, report. Stresses in rocks. Stress anisotropy and stress ratio. Stress relief and compensation techniques, USBM, door stopper cells, flat jack, hydrofrac, strain rosette and dilatometers. Deformability, plate load, pressure tunnel and bore hole tests. Strength tests, insitu compression, tension and direct shear tests.	
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	Pull out tests. Borehole extensometers, piezometers, embedment gauges, inclinometers, Slope indicators, packer tests for insitu permeability, Codal provisions. Ground improvement techniques. Compaction, Grouting, Types of grouts, technique, Rheological models. Viscous and viscoplastic flows. Spherical and radial flows, Shotcrete, Ground anchors, Rock bolts.
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15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Surface and sub surface exploration methods. Aerial and remote sensing techniques,	3
2	Geophysical methods, electrical resistivity, seismic refraction, applications.	3
3	Rock drilling: percussion, rotary drilling, drill bits. Core samplers, Core boxes, Core orientations.	2
4	Logging, stratigraphic profile, scan line survey, classification. Planning of laboratory tests, report.	2
5	Stresses in rocks, gravity, tectonics, residual, thermal and induced stresses. Stress anisotropy and stress ratio. Stress relief and compensation techniques, USBM, door stopper cells, flat jack, hydrofrac, strain rosette and dilatometers. Soft and rigid inclusions.	5
6	Deformability, plate load, pressure tunnel and bore hole tests. Strength tests, insitu compression, tension and direct shear tests. Pull out tests. Borehole extensometers, piezometers, embedment gauges, inclinometers, Slope indicators, packer tests for insitu permeability, Codal provisions.	6
7	Ground improvement techniques, assessment.	2
8	Compaction of disintegrated and weathered rocks.	3
9	Grouting, type of grouts, suspensions, solutions and resins, Rheological models. Viscous and viscoplastic flows. Spherical and radial flows. Groutability. Grouting techniques, materials, equipment, specifications, evaluation and quality control. Case histories,	6
10	Shotcrete, method and materials, factors. Fibre reinforced shotcrete.	1
11	Ground anchors, principles of reinforcement, Cable anchors. Dewatering techniques, classification, assessment of insitu permeability, filter criteria and design of wells, Codal provisions.	4
12	Rock bolts, mechanism, mechanical, friction, grouted tensioned and untensioned bolts. Design of bolts. Installation. Equipment. Testing.	5
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

1. Clayton, C. R. I., Matthews, M. C. and Simons, N. E. Site Investigation. Second Edition, Wiley-Blackwell, 1995.
2. Kearey, P. and Brooks, M. An Introduction to Geophysical Exploration. Blackwell Scientific Publishers, London, 1991.
3. Hausmann, M.R. (1990). Engineering principles of ground modification. McGraw Hill.
4. Moseley, M.P. and Kirsch, K. (1993). Ground improvement. Spon press, Taylor and Francis.
5. Simons, N, Menzies, B. and Mathews, M. (2002). A short course on geotechnical site investigation. Thomas Telford.
6. Bengt Stillborg. Professional Users Handbook for Rock Bolting. Trans Tech Publications. 1986.
7. J. Patrick Powers and Arthur B. Corwin. Construction Dewatering and Groundwater Control : New Methods and Applications, 3rd Edition, 2007.
8. Amadei, B. and Stephansson, O. Rock Stress and its Measurement. Chapman and Hall, London, 1997.

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	Available
19.2	Hardware	Available
19.3	Teaching aides (videos, etc.)	Black board, OHP, PPT, Videos and site visits
19.4	Laboratory	NA
19.5	Equipment	NA
19.6	Classroom infrastructure	Black board and PPT Projector required
19.7	Site visits	YES

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	Up to 20%
20.2	Open-ended problems	Up to 15%
20.3	Project-type activity	Up to 15%
20.4	Open-ended laboratory work	Up to 15%
20.5	Others (please specify)	Self study component up to 20%

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	EXCAVATION METHODS AND UNDERGROUND SPACE TECHNOLOGY
3.	L-T-P structure	3 - 0 - 0
4.	Credits	3
5.	Course number	CVL715
6.	Status (<i>category for program</i>)	PE

7.	Pre-requisites (course no./title)	NIL
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	Less than 10%
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	NIL

9.	Not allowed for (indicate program names)	Approval from course coordinator required for registration
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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11.	Faculty who will teach the course Prof. K. S. Rao, Prof. M. Datta, Prof. G.V. Ramana, Prof. J. T. Shahu, Dr. R. Ayothiraman, Dr. B. Manna, Dr. T. Chakraborty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): The students would learn 1. excavation methods for construction of underground structures 2. requirement of different machinery for excavation purposes 3. facility design in under structures 4. hazards associated with underground construction works	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Principles of rock breakage, explosive energy, energy balance, blasting mechanism. Types of explosives, initiators, delay devices, primer and booster selection. Blast hole design. Drilling methods and machines Blast hole timing. Pattern design, open pit and underground blasting, production, estimation and damage criteria of ground vibrations. TBM tunnelling. Factors influencing and evaluation, Excavation mechanics, Boom machines, transverse boom	
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	tunnelling machines and Robins mobile miner. Drag pick cutting, cutting tool materials and wear, disc cutters. Case studies. Tunnels, energy storage caverns, nuclear waste disposal repositories, metros, underground chambers and defence installations. Geological considerations, layout, survey and alignment. Analysis and design methods. Construction methods. Ventilation, provisions, equipment. Control and monitoring system, services, operations and maintenance. Lighting, specifications, maintenance, e, emergency lighting. Power supply and distribution, Water supply and distribution. Safety provisions, localized hazards, fire hazards in highway tunnels, rapid transit tunnels. Surveillance and control system for highway tunnels. Tunnel finish.
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15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Principles of rock breakage, explosive energy, energy balance, blasting mechanism. Types of explosives, initiators, delay devices, primer and booster selection.	4
2	Blast hole design. Drilling methods and machines Blast hole timing. Pattern design, open pit and underground blasting, production, estimation and damage criteria of ground vibrations. Controlled blasting. Directional blasting. Safety aspects. Case histories.	8
3	TBM tunnelling, cutter head, propulsion, shield, erector, spoil remover and backup systems. Factors influencing and evaluation, Excavation mechanics, trapanner, ranging drum shearer, continuous miner twin rotor Marnetta borer, boom machines, transverse boom tunnelling machines and Robins mobile miner. Drag pick cutting, cutting tool materials and wear, disc cutters. Cuttability. Case studies.	10
4	Tunnels, energy storage caverns, nuclear waste disposal repositories, metros, underground chambers and defence installations.	8
5	Geological considerations, layout, survey and alignment. Analysis and design methods.	5
6	Construction methods. Ventilation, provisions, equipment. Control and monitoring system, services, operations and maintenance. Lighting, specifications, maintenance, emergency lighting. Power supply and distribution, Water supply and distribution	4
7	Safety provisions, localized hazards, fire hazards in highway tunnels, rapid transit tunnels. Surveillance and control system for highway tunnels. Tunnel finish, Rehabilitation. Inspection methods, Repairs, Tunnel construction contracting.	3
8		
9		
10		
11		
12		
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

1. Hoek, E., Brown, E. Underground excavations in Rock, CRC Press, 1980.
2. Hoek, E. and Brady, J. D. Rock Slope Engineering, Taylor and Francis, 1981
3. Nick Barton, Tunnel Boring Machines, 2000
4. Hudson and Harrison, Engineering Rock Mechanics, 2012
5. P.P.Ray. Rock Blasting: Effects and Operations, 2005
6. D.Chapmann, N.Metje and A.Stark, Introduction to Tunnel Construction, Spon Press, 2010
7. D.Kolymbas, Tunnelling and Tunnel Mechanics, Springer, 2005

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	Available
19.2	Hardware	Available
19.3	Teaching aides (videos, etc.)	Black board, OHP, PPT, Videos and site visits
19.4	Laboratory	NA
19.5	Equipment	NA
19.6	Classroom infrastructure	Black board and PPT Projector required
19.7	Site visits	YES

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	Up to 10%
20.2	Open-ended problems	Up to 10%
20.3	Project-type activity	Up to 10%
20.4	Open-ended laboratory work	Up to 10%
20.5	Others (please specify)	Self study up to 15%

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	ENVIRONMENTAL ROCK ENGINEERING
3.	L-T-P structure	3 - 0 - 0
4.	Credits	3
5.	Course number	CVL716
6.	Status (<i>category for program</i>)	PE

7.	Pre-requisites (course no./title)	NIL
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	Less than 10%
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	NIL

9.	Not allowed for (indicate program names)	Approval from course coordinator required for registration
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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11.	Faculty who will teach the course Prof. K. S. Rao, Prof. M. Datta, Prof. G.V. Ramana, Prof. J. T. Shahu, Dr. R. Ayothiraman, Dr. B. Manna, Dr. T. Chakraborty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): The students would learn 1. elastic, elastoplastic and brittle behavior of rocks and rock masses under static and dynamic loading 2. the effect of temperature and fluid flow on rocks and rock masses 3. environmetal issues in rock engineering and waste disposal in rock.	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Theory: Stress-strain behaviour of rocks and rock masses: Elastic, elasto-plastic, and brittle, Crack phenomena and mechanisms of rock fracture. Temperature, pressure and water related, problems, Effect of temperature on rock behaviour. Fluid flow through intact and fissured rocks. Time dependent behaviour of rocks: Creep, Viscoelasticity and Viscoplasticity Continuum and discontinuum theories: Equivalent material, Block and Distinct element.	
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	Application: Waste disposal, Radioactive and hazardous wastes, repositories, location and design, VLH, VDH and KBS3 concepts. Waste container, barriers, rock structure, embedment, buffers and seals. Performance assessment, quality control and monitoring. Case histories. Hazardous Earth processes, high ground stresses, rock bursts, subsidence. Karst formations. Landslides and rock falls, slopes stabilization, mitigation, Case studies. Earthquakes, tectonic stresses, creep, ground motions, damage, prediction. Volcanic activity and hazard. Tsunamis. Case studies. Thermal analysis, Thermo-mechanical analysis, thermo-hydro-mechanical analysis. Rock dynamics. Physical modelling.
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15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Stress-strain behaviour of rocks and rock masses: Elastic, elasto-plastic, and brittle,	5
2	Crack phenomena and mechanisms of rock fracture.	3
3	Temperature, pressure and water related, problems, Effect of temperature on rock behaviour.	4
4	Fluid flow through intact and fissured rocks.	3
5	Time dependent behaviour of rocks: Creep, Viscoelasticity and Viscoplasticity	3
6	Continuum and discontinuum theories: Equivalent material, Block and Distinct element.	3
7	Waste disposal, Radioactive and hazardous wastes, repositories, location and design, VLH, VDH and KBS3 concepts. Waste container, barriers, rock structure, embedment, buffers and seals. Performance assessment, quality control and monitoring. Case histories.	8
8	Hazardous Earth processes, high ground stresses, rock bursts, subsidence. Karst formations. Landslides and rock falls, slopes stabilization, mitigation, Case studies.	3
9	Earthquakes, tectonic stresses, creep, ground motions, damage, prediction. Volcanic activity and hazard. Tsunamis. Case studies.	4
10	Thermal analysis, Thermo-mechanical analysis, thermo-hydro-mechanical analysis.	2
11	Rock dynamics.	3
12	Physical modelling.	1
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

1. R. Pusch. Waste Disposal in Rock. Elsevier. 1994
2. John Jaeger and N. G. Cook. Fundamentals of Rock Mechanics. Wiley-Blackwell. 2007.
3. Randall F. Barron and Brian R. Barron. Design for Thermal Stresses. Wiley, 2011.
4. Catherine O'Sullivan. Particulate Discrete Element Modelling: A Geomechanics Perspective (Applied Geotechnics), CRC Press 2011.
5. Jacob Lubliner. Plasticity Theory (Dover Books on Engineering) 2008.
6. Steven L. Kramer. Geotechnical Earthquake Engineering. Prentice Hall. 1996.

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	Available
19.2	Hardware	Available
19.3	Teaching aides (videos, etc.)	Black board, OHP, PPT, Videos and site visits
19.4	Laboratory	NA
19.5	Equipment	NA
19.6	Classroom infrastructure	Black board and PPT Projector required
19.7	Site visits	YES

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	Up to 20%
20.2	Open-ended problems	Up to 15%
20.3	Project-type activity	Up to 15%
20.4	Open-ended laboratory work	Up to 15%
20.5	Others (please specify)	Self study up to 20%

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	EMERGING TOPICS IN ROCK ENGG AND UNDERGROUND STRUCTURES
3.	L-T-P structure	3 - 0 - 0
4.	Credits	3
5.	Course number	CVL810
6.	Status (<i>category for program</i>)	PE

7.	Pre-requisites (course no./title)	NIL
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	Less than 10%
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	NIL

9.	Not allowed for (indicate program names)	Approval from course coordinator required for registration
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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11.	Faculty who will teach the course Prof. K. S. Rao, Prof. M. Datta, Prof. G.V. Ramana, Prof. J. T. Shahu, Dr. R. Ayothiraman, Dr. B. Manna, Dr. T. Chakraborty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): The students would learn advanced rock mechanical problems and environmetal issues in rock engineering.	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Advanced and state-of-the-art rock engineering topics	
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15. Lecture Outline (*with topics and number of lectures*)

Module no.	Topic	No. of hours
1	Advanced and state-of-the-art rock engineering topics	42
2		
3		
4		
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6		
7		
8		
9		
10		
11		
12		
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

Relevant text books, journal and conference papers and standards.

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	Available
19.2	Hardware	Available
19.3	Teaching aides (videos, etc.)	Black board, OHP, PPT, Videos and site visits
19.4	Laboratory	NA

19.5	Equipment	NA
19.6	Classroom infrastructure	Black board and PPT Projector required
19.7	Site visits	YES

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	Up to 20%
20.2	Open-ended problems	Up to 15%
20.3	Project-type activity	Up to 15%
20.4	Open-ended laboratory work	Up to 10%
20.5	Others (please specify)	Self study up to 20%

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	ROCK MECHANICS LABORATORY 1
3.	L-T-P structure	0 - 0 - 6
4.	Credits	3
5.	Course number	CVP710
6.	Status (<i>category for program</i>)	PC

7.	Pre-requisites (course no./title)	NIL
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	Less than 10%
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	NIL

9.	Not allowed for (indicate program names)	Approval from course coordinator required for registration
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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11.	Faculty who will teach the course Prof. K. S. Rao, Prof. M. Datta, Prof. G.V. Ramana, Prof. J. T. Shahu, Dr. R. Ayothiraman, Dr. B. Manna, Dr. T. Chakraborty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): The students would learn 1. drilling, coring and sample preparation techniques for rock 2. testing procedure for physical and mechanical properties of rocks 3. the engineering behavior of rocks	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Tests and test procedures, Rock samples, Specimen preparation, coring, cutting and lapping. Tolerance limits. Physical Properties: Water absorption, density, specific gravity, porosity, void index, electrical resistivity and sonic wave velocity tests. Mechanical Properties: Uniaxial compression, Point load index and Brazilian strength tests, Elastic properties. Effect of L/D ratio and saturation. Strength anisotropy. Shear tests: Single, double, oblique tests, Punch shear, Triaxial compression tests, Direct shear test. Slake durability and Permeability tests. Compilation of	
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	test data. Classification. Codal provisions.
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15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1		
2		
3		
4		
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6		
7		
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11		
12		
COURSE TOTAL (14 times 'L')		

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	Tests and test procedures, Specimen preparation, coring, cutting and lapping. Tolerance limits.	6
2	Physical Properties: Water absorption, density, specific gravity,	6
3	Porosity, void index,	6
4	Electrical resistivity and sonic wave velocity tests.	6
5	Mechanical Properties: Uniaxial compression, Elastic properties.	12
6	Point load index and Brazilian strength tests,	12
7	Effect of L/D ratio ,Strain rate and saturation.	6
8	Strength anisotropy. Shear tests: Single, double, oblique tests,Punch shear	12
9	Triaxial compression tests, Direct shear test.	12
10	Slake durability and Permeability tests. Compilation of test data. Classification. Codal provisions.	6
COURSE TOTAL (14 times 'P')		84

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

1. Goodman, R. E. Introduction to Rock Mechanics. John Wiley and Sons, 1989.
2. Indian Standard Codes
3. Hoek,Rock Characterisation,ISRM Test Procedures.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	Available
19.2	Hardware	Available
19.3	Teaching aides (videos, etc.)	Black board, OHP, PPT, Videos and site visits
19.4	Laboratory	Available
19.5	Equipment	Available
19.6	Classroom infrastructure	Black board and PPT Projector required
19.7	Site visits	YES

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	Up to 10%
20.2	Open-ended problems	Up to 10%
20.3	Project-type activity	Up to 15%
20.4	Open-ended laboratory work	Up to 20%
20.5	Others (please specify)	Self study component up to 20%

Date:

(Signature of the Head of the Department)

MAJOR PROJECT TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	MAJOR PROJECT I
3.	L-T-P structure	0 - 0 - 12
4.	Credits	6
5.	Course number	CVD810
6.	Status (<i>category for program</i>)	PROGRAMME CORE
7.	Pre-requisites (course no./title)	EARNED PROGRAMME CORE CREDITS AND MINIMUM OF 24 CREDITS BY THE END OF FIRST YEAR
8.	Supersedes any existing course	CED 851
9.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
10.	FACULTY WHO WILL SUPERVISE PROJECT STUDY ALL GEOTECHNICAL SECTION FACULTY	
11.	Will the PROJECT SUPERVISION require any visiting faculty?	MAY BE INVITED ON REQUEST BY FACULTY SUPERVISOR/STUDENT
12.	PROJECT objective (<i>about 50 words</i>): (1) TO INITIATE STUDENTS INTO RESEARCH ON WELL DEFINED OR OPEN ENDED PROBLEMS (2) TO FOSTER/PROMOTE UNDERSTANDING OF IDENTIFIED PROBLEM DOMAINS BASED ON LABORATORY AND/OR NUMERICAL MODELLING BASED APPROACHES (3) TO DEVELOP THEORETICAL FORMULATIONS OF SPECIFIC CONTEXTUAL PHYSICAL PROCESSES (4) TO DEVELOP IMPROVED DESIGN METHODOLOGIES IN THE AREA OF ROCK ENGINEERING AND UNDERGROUND STRUCTURES	

13. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	SPECIFIC TO THE PROBLEM TAKEN UP FOR THE STUDY	OPEN

14. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

RELEVANT, CONTEXTUAL RESEARCH ARTICLES, REPORTS AND BOOKS

15. Resources required for the STUDY (*itemized & student access requirements, if any*)

19.1	Software	YES
19.2	Hardware	YES
19.3	PRESENTATION aides (videos, etc.)	YES
19.4	Laboratory	YES
19.5	Equipment	YES
19.6	Classroom infrastructure	NO
19.7	Site visits	MAY BE REQUIRED AS PART OF THE STUDY

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	ROCK MECHANICS LABORATORY 2
3.	L-T-P structure	0 - 0 - 6
4.	Credits	3
5.	Course number	CVP810
6.	Status (<i>category for program</i>)	PC

7.	Pre-requisites (<i>course no./title</i>)	CVP710: ROCK MECHANICS LABORATORY 1
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	Less than 20%, Rock Lab 1
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	NIL

9.	Not allowed for (<i>indicate program names</i>)	Approval from course coordinator required for registration
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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11.	Faculty who will teach the course Prof. K. S. Rao, Prof. M. Datta, Prof. G.V. Ramana, Prof. J. T. Shahu, Dr. R. Ayothiraman, Dr. B. Manna, Dr. T. Chakraborty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): The students would learn 1. the significance of experiments on rock for field problems 2. the usage of rock stress-strain response and physical properties of rock in practical rock engineering design 3. planning, designing, cost calculation and execution steps of projects in and on rock	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Project planning, Schedule and cost assessment, DPR and GD for Major projects, Field visit, Sample collection, Scanline survey and seismic survey,, Rock characterization, Determination of physical and mechanical properties of rocks, Analysis of slopes using GEOSLOPE and Analysis of tunnels using	
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	Phase2, both using the material properties determined through laboratory tests.Design of slopes and tunnels.
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15. Lecture Outline (*with topics and number of lectures*)

Module no.	Topic	No. of hours
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COURSE TOTAL (14 times 'L')		

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	Field visit, Sample collection, Scanline survey	6
2	Physical properties of rocks	9
3	Rock characterization through uniaxial and triaxial tests	18
4	Rock characterization through direct shear tests	15
5	Analysis of slopes using GEOSLOPE, Analysis of tunnels using Phase2 using the material properties determined through laboratory tests.	18
6	Design of slopes, tunnels and Underground structures.	18
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COURSE TOTAL (14 times 'P')		84

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

1. Goodman, R. E. Introduction to Rock Mechanics. John Wiley and Sons, 1989.
2. Indian Standard Codes and ASTM codes.
3. GEOSLOPE and Phase2 Software Manuals
4. Hoek, E., Brown, E. Underground excavations in rock, CRC Press, 1980.
5. Hoek, E. and Bray, J. Rock Slope Engineering, 4th Ed. Spon Press. 2004.

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	Available
19.2	Hardware	Available
19.3	Teaching aides (videos, etc.)	Black board, OHP, PPT, Videos and site visits
19.4	Laboratory	Available
19.5	Equipment	Available
19.6	Classroom infrastructure	Black board and PPT Projector required
19.7	Site visits	YES

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	Up to 30%
20.2	Open-ended problems	Up to 20%
20.3	Project-type activity	Up to 50%
20.4	Open-ended laboratory work	Up to 20%
20.5	Others (please specify)	Self study component up to 30%

Date:

(Signature of the Head of the Department)

INDEPENDENT STUDY TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	INDEPENDENT STUDY
3.	L-T-P structure	0 - 3 - 0
4.	Credits	3
5.	Course number	CVS810
6.	Status (<i>category for program</i>)	PROGRAMME ELECTIVE

7.	Pre-requisites (course no./title)	NONE
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8.	Supersedes any existing course	NONE
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9.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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10.	FACULTY WHO WILL SUPERVISE PROJECT STUDY ALL GEOTECHNICAL SECTION FACULTY	
11.	Will the PROJECT SUPERVISION require any visiting faculty?	MAY BE INVITED ON REQUEST BY FACULTY SUPERVISOR/STUDENT
12.	PROJECT objective (<i>about 50 words</i>): TO STUDY AN IDENTIFIED RESEARCH AREA AND PREPARE A REPORT ON THE STATE OF THE ART	

13. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	SPECIFIC TO THE PROBLEM TAKEN UP FOR THE STUDY	OPEN

14. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

RELEVANT, CONTEXTUAL RESEARCH ARTICLES, REPORTS AND BOOKS

15. Resources required for the STUDY (*itemized & student access requirements, if any*)

19.1	Software	YES
19.2	Hardware	YES
19.3	PRESENTATION aides (videos, etc.)	YES
19.4	Laboratory	YES
19.5	Equipment	YES
19.6	Classroom infrastructure	NO
19.7	Site visits	MAY BE REQUIRED AS PART OF THE STUDY

Date:

(Signature of the Head of the Department)

MAJOR PROJECT TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	MAJOR PROJECT II
3.	L-T-P structure	0 - 0 - 24
4.	Credits	12
5.	Course number	CVD811
6.	Status (<i>category for program</i>)	PROGRAMME CORE

7.	Pre-requisites (course no./title)	STUDENT SHOULD HAVE CLEARED MAJOR PROJECT PART I
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8.	Supersedes any existing course	CED852
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9.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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10.	FACULTY WHO WILL SUPERVISE PROJECT STUDY ALL GEOTECHNICAL SECTION FACULTY	
11.	Will the PROJECT SUPERVISION require any visiting faculty?	MAY BE INVITED ON REQUEST BY FACULTY SUPERVISOR/STUDENT

12.	PROJECT objective (<i>about 50 words</i>): (1) TO INITIATE STUDENTS INTO RESEARCH ON WELL DEFINED OR OPEN ENDED PROBLEMS (2) TO FOSTER/PROMOTE UNDERSTANDING OF IDENTIFIED PROBLEM DOMAINS BASED ON LABORATORY AND/OR NUMERICAL MODELLING BASED APPROACHES (3) TO DEVELOP THEORETICAL FORMULATIONS OF SPECIFIC CONTEXTUAL PHYSICAL PROCESSES (4) TO DEVELOP IMPROVED DESIGN METHODOLOGIES IN THE AREA OF ROCK ENGINEERING AND UNDERGROUND STRUCTURES	
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13. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	SPECIFIC TO THE PROBLEM TAKEN UP FOR THE STUDY	OPEN

14. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

RELEVANT, CONTEXTUAL RESEARCH ARTICLES, REPORTS AND BOOKS

15. Resources required for the STUDY (*itemized & student access requirements, if any*)

19.1	Software	YES
19.2	Hardware	YES
19.3	PRESENTATION aides (videos, etc.)	YES
19.4	Laboratory	YES
19.5	Equipment	YES
19.6	Classroom infrastructure	NO
19.7	Site visits	MAY BE REQUIRED AS PART OF THE STUDY

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	NUMERICAL AND COMPUTER METHODS IN GEOMECHANICS
3.	L-T-P structure	2 - 0 - 2
4.	Credits	3
5.	Course number	CVL811
6.	Status (<i>category for program</i>)	PE

7.	Pre-requisites (course no./title)	CVL704; Any course on Finite Element Method
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	Less than 10%
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	NIL

9.	Not allowed for (indicate program names)	Approval from course coordinator required for registration
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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11.	Faculty who will teach the course Prof. K. S. Rao, Prof. M. Datta, Prof. G.V. Ramana, Prof. J. T. Shahu, Dr. R. Ayothiraman, Dr. B. Manna, Dr. T. Chakraborty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): The students would learn 1. numerical modeling and solution techniques of geotechnical boundary value problems 2. simple and advanced constitutive models for soil and rock, model integration and its implementation in finite element and finite difference programs 3. numerical integration of load-displacement, seepage, consolidation and heat conduction equations 4. finite element and finite difference programming techniques.	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Introduction to Numerical Methods, ODEs, PDEs, Equation solution techniques, Root finding techniques, Fourier Series, Types of geotechnical boundary value problems, Numerical modeling, Numerical solution schemes,	
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	pros and cons, Programming tools- FORTRAN, MATLAB, MATHCAD, Development of programming flowchart. Simplified and advanced constitutive models and their calibration: Elastic Models, Elasto-plastic Models, Formulation of Elasto-Plastic Stiffness Matrix, Governing equations of elastoplasticity, Rock and Soil constitutive models. Integration of stress-strain equations, Concepts of verification and validation, Selection of model input parameters, Integration of load-displacement relations, Integration of seepage, consolidation and heat conduction equations, Sturm–Liouville problem, Solution of seepage, consolidation, heat conduction and Sturm-Liouville equations using finite difference and finite element programming methods, Comparison with commercially available software results.
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15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction to Numerical Methods, ODEs, PDEs, Equation solution techniques, Root finding techniques, Fourier Series	3
2	Types of geotechnical boundary value problems, Numerical modeling, Numerical solution schemes, pros and cons	3
3	Simplified and advanced constitutive models and their calibration: Elastic Models, Elasto-plastic Models, Formulation of Elasto-Plastic Stiffness Matrix, Governing equations of elastoplasticity, Rock and Soil constitutive models.	8
4	Numerical implementation: Integration of stress-strain equations, numerical integration schemes-explicit and implicit, Concepts of verification and validation, Selection of model input parameters,	4
5	Integration of load-displacement relations, numerical integration schemes-explicit and implicit, numerical implementation	4
6	Integration of seepage, consolidation and heat conduction equations, Sturm–Liouville problem	4
7	Analytical solutions of representative geotechnical problems in contrast to their numerical modeling/solution	2
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12		
COURSE TOTAL (14 times 'L')		28

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	Programming tools- FORTRAN, MATLAB, MATHCAD.	2
2	Development of Programming Flowchart	2
3	Integration of stress-strain equations, numerical integration schemes-explicit and implicit, Concepts of verification and validation, Selection of model input parameters,	4
4	Integration of load-displacement relations, numerical integration schemes-explicit and implicit, numerical implementation	3
5	Finite difference method and examples: Programming solution of Seepage and Steady State Heat Conduction Equations, Consolidation and Transient Heat Conduction Equations	6
6	Finite element method and examples: Programming solution of Seepage and Steady State Heat Flow Equations, Consolidation and Transient Heat Conduction Equations	8
7	Analytical solutions of representative geotechnical problems in contrast to their numerical modeling/solution	1
8	Commercially available geotechnical software and examples, capabilities and limitations of software.	2
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10		

COURSE TOTAL (14 times 'P')	28
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18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

1. Chapra, R. Canale, Numerical Methods for Engineers, McGraw-Hill Science/Engineering/Math; 6 edition, 2009.
2. L. Hinton, and D. Owen. Finite Element Programming, Academic Press. 1980.
3. J. C. Simo and T. J. R. Hughes, Computational Inelasticity, Springer, 2000.
4. B. Dasgupta, Applied Mathematical Methods, Pearson, 2006.
5. F. B. Hildenbrand, Methods of Applied Mathematics, Dover Publications Inc.; 1992.
6. Daryl L. Logan, A First Course in the Finite Element Method, Cengage Learning; 5 edition 2011

19. Resources required for the course (itemized & student access requirements, if any)

19.1	Software	Available
19.2	Hardware	Available
19.3	Teaching aides (videos, etc.)	Black board, OHP, PPT, Videos and Computers
19.4	Laboratory	Available
19.5	Equipment	Available
19.6	Classroom infrastructure	Black board, PPT Projector and computers required
19.7	Site visits	No

20. Design content of the course (Percent of student time with examples, if possible)

20.1	Design-type problems	Up to 20%
20.2	Open-ended problems	Up to 15%
20.3	Project-type activity	Up to 20%
20.4	Open-ended laboratory work	Up to 20%
20.5	Others (please specify)	Self study up to 20%

Date:

(Signature of the Head of the Department)