



CE603PC: FOUNDATION ENGINEERING

COURSE PLANNER

I. COURSE OVERVIEW:

Civil Engineers are required to construct structures on the soil. The loads coming onto these structures, along with the self-weight, have to be safely transmitted to the soil beneath it. A geotechnical engineer must be able to design a footing in such a way that soil below it will not fail there will not be any excessive settlements in the soil. This foundation course in civil engineering is intended to introduce to concepts of types of soils present in nature, properties of soil on which the load carrying capacity of the soil depends. For this, the concept of (a) types of soil present in nature and their properties which in turn effect the load carrying capacity of soil, (b) shear strength of the soils, (c) settlement reduction by compaction and consolidation are covered in depth.

II. PREREQUISITE(S):

| Level | Credits | Periods | Prerequisite |
|-------|---------|---------|---------------------------------------|
| UG | 4 | 4 | Engineering Mechanics, soil mechanics |

III. COURSE OBJECTIVES:

The course should enable the students to:

| | |
|----|---|
| 1. | To Plan Soil exploration programme for civil Engineering Projects |
| 2. | To check the stability of slopes. |
| 3. | To determine the lateral earth pressures and design retaining walls |
| 4. | To determine the Bearing capacity of Soil |
| 5. | To design pile group foundation. |

IV. COURSE OUTCOMES:

Students, who complete the course, will have demonstrated the ability to do the following:

| Course Outcomes | Description | Bloom's Taxonomy Levels | Program Outcomes, Program Specific Outcomes |
|-----------------|--|-------------------------------|---|
| CO1 | Understand the principles and methods of Geotechnical Exploration | L3: Applying | PO1, PO2, PO3, PSO1, PSO3 |
| CO2 | Decide the suitability of soils and check the stability of slopes | L2: Understand, L4: Analyzing | PO2, PO3, PO4, PO6, PSO1. |
| CO3 | Calculate lateral earth pressures and check the stability of retaining walls | Understand, applying | PO1, PO2, PO3, PSO1, PSO3 |
| CO4 | Analyse and design the shallow and deep foundations | design | PO1, PO2, PO3, PSO1, PSO3 |



V. HOW PROGRAM OUTCOMES ARE ASSESSED:

| Program outcomes | | Level | Proficiency assessed by |
|------------------|---|-------|-------------------------|
| PO1 | Engineering knowledge: To Apply the knowledge of mathematics, science, engineering fundamentals/principals, and civil engineering to the solution of complex engineering problems encountered in modern engineering practice. | 1 | Assignments |
| PO2 | Problem analysis: Ability to Identify, formulate, review research literature, and analyze complex engineering problems related to Civil Engineering and reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences. | 2.5 | Exercise, Exams |
| PO3 | Design/development of solutions: Design solutions for complex engineering problems related to Civil Engineering and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations. | 3 | Exercise |
| PO4 | Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions. | 1 | Discussion, Seminars |
| PO5 | Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations. | - | Discussion, Seminars |
| PO6 | The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the Civil Engineering professional engineering practice. | 1 | Discussions |
| PO7 | Environment and sustainability: Understand the impact of the Civil Engineering professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development. | - | ----- |
| PO8 | Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice. | - | ----- |
| PO9 | Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings. | - | ----- |
| PO10 | Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions. | - | ----- |



| | | | |
|------|--|---|------------------------|
| PO11 | Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments. | - | ----- |
| PO12 | Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change. | - | Prototype, Discussions |

VI. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

| Program outcomes | | Level | Proficiency assessed by |
|------------------|---|-------|--------------------------|
| PSO 1 | ENGINEERING KNOWLEDGE: Graduates will be able to apply technical knowledge in drawing, analysis, design, laboratory investigations and construction aspects of civil engineering | 2.5 | Lectures and Assignments |
| | infrastructure, along with good basics in mathematics, basic sciences and technical communication. | | |
| PSO 2 | BROADNESS AND DIVERSITY: Graduates will be able to summarize and can demonstrate about societal, economical, environmental, health and safety factors involved in infrastructural development, and shall work within multidisciplinary teams with competence in modern tool usage. | - | Tutorials |
| PSO 3 | SELF-LEARNING AND SERVICE: Graduates will be able to pursue lifelong learning and professional development to face the challenging and emerging needs of our society, ethically and responsibly. | 1 | Seminars and Projects |

0-None

2 -Supportive

3 – Highly Related



VII. SYLLABUS:

UNIT – I

SOIL EXPLORATION: Need – methods of soil exploration – boring and sampling methods – penetration tests – plate load test– planning of soil exploration programme, Bore logs and preparation of soil investigation report.

UNIT – II

SLOPE STABILITY: Infinite and finite earth slopes – types of failures – factor of safety of infinite slopes – stability analysis by Swedish slip circle method, method of slices, Bishop's Simplified method of slices

– Taylor's Stability Number- stability of slopes of earth dams under different conditions.

UNIT – III

EARTH PRESSURE THEORIES: Active, Passive and at rest soil pressures Rankine's theory of earth pressure – earth pressures in layered soils – Coulomb's earth pressure theory.

RETAINING WALLS: Types of retaining walls – stability of gravity and cantilever retaining walls against overturning, sliding and, bearing capacity, filter material for drainage.

UNIT – IV

SHALLOW FOUNDATIONS - Types - choice of foundation – location and depth - safe bearing capacity – shear criteria – Terzaghi's, and IS code methods - settlement criteria – allowable bearing pressure

based on SPT N value and plate load test – allowable settlements of structures.

UNIT - V

PILE FOUNDATION: Types of piles – load carrying capacity of piles based on static pile formulae – dynamic pile formulae – Pile Capacity through SPT results - pile load tests - load carrying capacity of

pile groups in sands and clays – Settlement of pile groups – negative skin friction

TEXT BOOKS:

1. Basic and Applied Soil Mechanics by Gopal Ranjan & ASR Rao, New age International Pvt. Ltd, NewDelhi
2. Principals of Geotechnical Engineering by Braja M. Das, Cengage LearningPublishers.



REFERENCES:

1. Soil Mechanics and Foundation Engineering by VNS Murthy, CBS Publishers and Distributors.
2. Geotechnical Engineering Principles and Practices by Cuduto, PHI International.
3. Analysis and Design of Substructures – Swami Saran, Oxford and IBH Publishing company Pvt Ltd (1998).
4. Geotechnical Engineering by S. K. Gulhati & Manoj Datta – Tata Mc.Graw Hill Publishing company New Delhi. 2005.
5. Bowles, J.E., (1988) Foundation Analysis and Design – 4th Edition, McGraw-Hill Publishing company, New York.

GATE SYLLABUS:

- Foundation Engineering: Sub-surface investigations- scope, drilling bore holes, sampling, penetration tests, plate load test. Earth pressure theories, effect of water table, layered soils. Stability of slopes-infinite slopes, finite slopes. Foundation types-foundation design requirements. Shallow foundations-bearing capacity, effect of shape, water table and other factors, stress distribution, settlement analysis in sands & clays. Deep foundations – pile types, dynamic & static formulae, load capacity of piles in sands & clays, negative skin friction

IES SYLLABUS:

- Foundation Engineering: Types of foundations, Selection criteria, bearing capacity, settlement, laboratory and field tests; Types of piles and their design and layout, Foundations on expansive soils, swelling and its prevention, foundation on swelling soils.



VIII. COURSE PLAN:

| Lecture No. | Unit No. | Topics to be covered | Link for PDF | Course learning outcomes | Teaching Methodology | Reference |
|-------------|----------|---------------------------------------|---|---|----------------------|-----------|
| 1 | 1 | Introduction to Soil Exploration | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNgwYuanZZ2VruWP4ycNH?usp=sharing | Learn how soil Exploration are performed | Chalk and Talk | T1,T2, T3 |
| 2 | | | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNgwYuanZZ2VruWP4ycNH?usp=sharing | | Chalk and Talk | |
| 3 | | Methods of soil Exploration | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNgwYuanZZ2VruWP4ycNH?usp=sharing | Learn how the soil exploration are done using different methods | Chalk and Talk | T1,T2, T3 |
| 4 | | Student Presentation | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNgwYuanZZ2VruWP4ycNH?usp=sharing | Able to communicate | Chalk and Talk | |
| 5 | | Types of Boring | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNgwYuanZZ2VruWP4ycNH?usp=sharing | Understand different types of boring methods | Chalk and Talk | T1,T2, T3 |
| 6 | | | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNgwYuanZZ2VruWP4ycNH?usp=sharing | | Chalk and Talk | |
| 7 | | Soil Sampling methods | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNgwYuanZZ2VruWP4ycNH?usp=sharing | Analyze Soil sampling methods for different types of soils | Chalk and Talk | T1,T2, T3 |
| 8 | | Student Presentation | | | Chalk and Talk | |
| 9 | | Soil Sampling methods | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNgwYuanZZ2VruWP4ycNH?usp=sharing | | Chalk and Talk | |
| 10 | | Standard Penetration test (SPT) Learn | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNgwYuanZZ2VruWP4ycNH?usp=sharing | how to perform SPT | Chalk and Talk | T1,T2, T3 |
| 11 | | Plate Load test | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNgwYuanZZ2VruWP4ycNH?usp=sharing | | Chalk and Talk | T1,T2, T3 |



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| | | | P4ycNH?usp=sharing | | | |
| 12 | | Student Presentation | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | | Chalk and Talk | |
| 13 | | In-situ test using a pressure meter | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | Learn how to perform in-situ test using pressure meter | Chalk and Talk | T1,T2, T3 |
| 14 | | Planning & Preparation of Soil investigation report Understand Planning & Preparation of Soil investigation report Understand | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | how to prepare planning & preparation of Soil investigation | Chalk and Talk | T1,T2, T3 |
| 15 | 2 | Introduction to infinite and finite earth slopes | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | Understand basic concepts of earth slopes | Chalk and Talk | T1,T2, T3 |
| 16 | | Student Presentation | | | Chalk and Talk | |
| 17 | | Types of failures | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | Analyze types of failures for infinite and finite slopes | Chalk and Talk | T1,T2, T3 |
| 18 | | FOS of infinite slopes | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | Learn how to identify FOS for infinite slopes | Chalk and Talk | T1,T2, T3 |
| 19 | | | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | | Chalk and Talk | |
| 20 | | Student Presentation | | Learn how to find Stability of slopes by Swedish arc Method | Chalk and Talk | T1,T2, T3 |
| 21 | | Stability Analysis by Swedish arc Method | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | | Chalk and Talk | |
| 22 | | Method of Slices for Analysis of finite slopes | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | Learn how to find Stability of slopes by using Method of Slices for Analysis of finite slopes | Chalk and Talk | T1,T2, T3 |
| 23 | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | | Chalk and Talk | | | |



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| 24 | | Student Presentation | | | Chalk and Talk | T1,T2, T3 |
| 25 | | Bishop's Simplified method | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | Learn how to find Stability of slopes by Taylor's Stability number | Chalk and Talk | T1,T2, T3 |
| 26 | | Taylor's Stability number | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | | Chalk and Talk | |
| 27 | | Stability of slopes of earth dam under different conditions | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | Understand basic concepts of Stability of slopes of earth dam under different conditions | Chalk and Talk | T1,T2, T3 |
| 28 | | Student Presentation | | | Chalk and Talk | |
| 29 | 3 | Introduction to earth pressure theories | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | Understand concepts of earth pressure theories for stability of Retaining walls | Chalk and Talk | T1,T2, T3 |
| 30 | | Rankine's earth pressure theories | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | Understand concepts of earth pressure theories for stability of Retaining walls | Chalk and Talk | T1,T2, T3 |
| 31 | | | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | | Chalk and Talk | |
| 32 | | Columb's earth pressure theories | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | Learn the concept of Rankine's earth pressure theories for stability of Retaining walls | Chalk and Talk | T1,T2, T3 |
| 33 | | Student Presentation | | | Chalk and Talk | |
| 34 | | Columb's earth pressure theories | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | Learn the concept of Rankine's earth | Chalk and Talk | T1,T2, T3 |



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| | | | P4ycNH?usp=sharing | pressure theories for stability of Retaining walls | | |
| 35 | | | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNgwYuanZZ2VruWP4ycNH?usp=sharing | | Chalk and Talk | |
| 36 | | Culman's graphical method | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNgwYuanZZ2VruWP4ycNH?usp=sharing | Understand the concept of Culman's graphical method for the stability of Retaining Structures | Chalk and Talk | T1,T2, T3 |
| 37 | | Student Presentation | | Learn how to Analyze different types of Retaining Walls | Chalk and Talk | T1,T2, T3 |
| 38 | | Introduction and types of Retaining walls | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNgwYuanZZ2VruWP4ycNH?usp=sharing | | Chalk and Talk | |
| 39 | | Stability of Retaining walls against overturning, Sliding, bearing capacity. | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNgwYuanZZ2VruWP4ycNH?usp=sharing | Learn how to find Stability of Retaining walls against overturning, Sliding, bearing capacity | Chalk and Talk | T1,T2, T3 |
| 40 | | | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNgwYuanZZ2VruWP4ycNH?usp=sharing | | Chalk and Talk | |
| 41 | | Student Presentation | | Learn how drainage of Backfill soil play role for the stability slopes | Chalk and Talk | T1,T2, T3 |
| 42 | | Drainage for Backfill introduction to reinforced earth walls. | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNgwYuanZZ2VruWP4ycNH?usp=sharing | | Chalk and Talk | |
| 43 | 4 | Introduction to Shallow foundations | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNgwYuanZZ2VruWP4ycNH?usp=sharing | Understand concepts of types of Foundations based on their depths | Chalk and Talk | T1,T2, T3 |
| 44 | | | | | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNgwYuanZZ2VruWP4ycNH?usp=sharing | |
| 45 | | | Student Presentation | | Learn how the depth of foundation play a role in bearing capacity of soils | Chalk and Talk |



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| 46 | | Depth of foundation | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | | Chalk and Talk | |
| 47 | | Safe bearing capacity | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | | Chalk and Talk | |
| 48 | | Terzaghi Method, Skempton Method | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | Learn how to find safe bearing capacity of Soil | Chalk and Talk | T1,T2, T3 |
| 49 | | Student Presentation | | Understand the concept of how to find the bearing capacity of soil by Terzaghi Method | Chalk and Talk | T1,T2, T3 |
| 50 | | Plate load test | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | Understand the concept of how to find the bearing capacity of soil by Meyerhof Method | Chalk and Talk | T1,T2, T3 |
| 51 | 5 | Types of piles | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | Understand the concept of how to find the bearing capacity of soil by Skempton Method | Chalk and Talk | T1,T2, T3 |
| 52 | | load carrying capacity of pile groups in sands and clays | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | Learn IS Code methods for finding bearing capacity of soils | Chalk and Talk | T1,T2, T3 |
| 53 | | Student Presentation | | Understand the concept how to find the safe bearing pressure based on N- Value | Chalk and Talk | T1,T2, T3 |
| 54 | | Settlement of pile groups, negative skin friction | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | Understand the concept how to find the allowable bearing pressure & Settlements | Chalk and Talk | T1,T2, T3 |
| 55 | | Introduction to Well foundation and there | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNngwYuanZZ2VruWP4ycNH?usp=sharing | Learn how to perform Plate Load | Chalk and Talk | T1,T2, T3 |



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| | | types, Different shapes of wells | P4ycNH?usp=sharing | test | | |
| 56 | | Components of Wells, Sinking of Wells | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNgwYuanZZ2VruWP4ycNH?usp=sharing | Learn types of piles | Chalk and Talk | T1,T2, T3 |
| 57 | | Student Presentation | | Learn load capacity of piles on different formulae | Chalk and Talk | T1,T2, T3 |
| 58 | | Measures for rectification of tilts and Silts | https://drive.google.com/drive/folders/1gNbTE8eMzdYZNgwYuanZZ2VruWP4ycNH?usp=sharing | Learn capacity of pile | Chalk and Talk | T1,T2, T3 |

IX. MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:

| Course Objectives | Program Outcomes | | | | | | | | | | | | Program Specific Outcomes | | |
|-------------------|------------------|------|------|------|------|------|------|------|------|-------|-------|-------|---------------------------|-------|-------|
| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 | PO 8 | PO 9 | PO 10 | PO 11 | PO 12 | PSO 1 | PSO 2 | PSO 3 |
| I | 2 | 3 | 3 | - | - | - | - | - | - | - | - | - | 2 | -- | 2 |
| II | - | 2 | 3 | 2 | - | 2 | - | - | - | - | - | - | 3 | - | - |
| III | | 2 | 2 | 3 | | | | | | | | | | | |
| IV | 2 | 2 | 1 | | | | | | | | | | 2 | 2 | |
| Average | 1 | 2.5 | 3 | 1 | - | 1 | - | - | - | - | - | - | 2.5 | - | 1 |

0=None 2=Supportive 3=Highlyrelated



X. QUESTION BANK:(JNTUH)

DESCRIPTIVE QUESTIONS: (WITH BLOOMS PHRASES)

UNIT-I

SHORT ANSWER QUESTIONS-

| S.No | Question | LEVEL | Programme Outcome |
|------|---|------------|-------------------|
| 1 | Distinguish between disturbed and undisturbed samples | Understand | 1 |
| 2 | How do you obtain undisturbed samples? | Understand | 2 |
| 3 | What is Boring log? | Understand | 1 |
| 4 | List various methods of soil explorations | Remember | 2 |
| 5 | Explain various methods of drilling holes | Remember | 3 |
| 6 | What is Reconnaissance? What is its use? | Remember | 3 |
| 7 | What is split spoon sampler? Why it is use? | Remember | 3 |
| 8 | Discuss the merits of wash boring method? | Remember | 3 |
| 9 | What is soil exploration? | Remember | 3 |
| 10 | What is the purpose of soil investigation? | Understand | 3 |

LONG ANSWER QUESTIONS-

| S.No | Question | LEVEL | Programme Outcome |
|------|--|------------|-------------------|
| 1 | Explain briefly various methods of soil exploration techniques? | Understand | 3 |
| 2 | Write a short note on Auger Boring? | Remember | 2 |
| 3 | Write a short note on Wash Boring? | Remember | 3 |
| 4 | Write a detailed note on various types of boring techniques? | Remember | 2 |
| 5 | Write a short note on Percussion Drilling? | Understand | 3 |
| 6 | Explain in detail Seismic Refraction Method? | Remember | 2 |
| 7 | Explain in detail SPT test? | Understand | 3 |
| 8 | Explain the various parameters which affect the sampling of soil? | Understand | 3 |
| 9 | Explain briefly various Geophysical methods used for soil Investigation? | Remember | 3 |
| 10 | Explain the need of Soil Exploration | Understand | 3 |



UNIT-2

SHORT ANSWER QUESTIONS-

| S.No | Question | LEVEL | Programme Out come |
|------|---|------------|--------------------|
| 1 | Define Finite Slope. | Remember | 3 |
| 2 | Define Infinite Slope. | Remember | 3 |
| 3 | Name various types of slope failure. | Remember | 3 |
| 4 | What are the causes of failure of slopes? | Remember | 3 |
| 5 | Write brief notes on Taylor's stability number. | Understand | 3 |
| 6 | What are different FOS used in stability of slopes. | Understand | 3 |
| 7 | What is critical height? | Understand | 3 |
| 8 | Explain the assumptions that are made in analysis of the stability of slopes? | Remember | 3 |
| 9 | Discuss various methods for improving the stability of slopes? | Remember | 3 |

LONG ANSWER QUESTIONS-

| S.No | Question | LEVEL | Programme Out come |
|------|---|------------|--------------------|
| 1 | Discuss the stability analysis of infinite slopes in cohesion less soils for no seepage condition. | Remember | 4 |
| 2 | Discuss the stability analysis of infinite slopes in cohesive soils. | Understand | 3 |
| 3 | Discuss the stability analysis of infinite slopes in cohesion less soils with ground water table at the surface of the slope. | Understand | 4 |
| 4 | Explain the stability analysis by Swedish slip circle method and derive the factor of safety. | Remember | 5 |
| 5 | Explain Bishop's simplified method for determination of factor of safety of a finite slope. | Remember | 2 |
| 6 | Explain the basis for Taylor's stability number and the procedure of its use. | Remember | 3 |
| 7 | Explain the method of slices for estimation on factor of safety of finite slopes. | Understand | 4 |
| 8 | Describe the stability of slope of an earthen dam in—suddendrawdown/conditions. | Understand | 2 |
| 9 | Explain stability of earthen dam in full reservoir condition | Remember | 3 |



| | | | |
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| 10 | Discuss in detail different forms of slip surface in finite slopes | Understand | 3 |
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UNIT-3

SHORT ANSWER QUESTIONS-

| S.No | Question | LEVEL | Programme Out come |
|------|---|------------|--------------------|
| 1 | What is Active Earth Pressure? | Understand | 3 |
| 2 | What is Passive Earth Pressure? | Remember | 3 |
| 3 | What is At rest Earth Pressure? | Understand | 3 |
| 4 | Write the assumptions of Rankine's Theory. | Understand | 3 |
| 5 | Write the assumptions of Coulombs Theory. | Remember | 3 |
| 6 | Distinguish between active and passive earth pressures. | Understand | 3 |
| 7 | Write short notes on Culmann's graphical method. | Understand | 3 |
| 8 | What is Rankine's passive earth pressure coefficient? | Understand | 3 |
| 9 | What is Rankine's active earth pressure coefficient? | Remember | 3 |
| 10 | What is lateral earth pressure? | Remember | 3 |

LONG ANSWER QUESTIONS-

| S.No | Question | LEVEL | Programme Out come |
|------|---|------------|--------------------|
| 1 | Describe briefly Rankine's earth pressure theory. | Understand | 3 |
| 2 | Describe briefly Coulombs earth pressure theory. | Understand | 3 |
| 3 | Distinguish the Rankine's and Coulomb's theories for computation of earth pressure and suggest the suitability of these methods. | Remember | 3 |
| 4 | Explain briefly Culmann's Graphical Method. | Understand | 3 |
| 5 | What is the effect of submergence on active and passive earth pressures? | Understand | 3 |
| 6 | A gravity retaining wall of height 3 m with uniform thickness (i.e. rectangular in cross section) of 1.20m is constructed in RRM with a unit weight of 24 kN/m ³ . The average properties of soil from top to bottom of wall includes $c = 0\text{kN/m}^2$; $\phi = 30^\circ$. Analyze the stability of wall against overturning when the entire backfill is Moist with a unit weight of 18kN/m ³ ii. Submerged(consider the saturated unit weight in submerged conditions as 9.80kN/m ³) | Understand | 3 |
| 7 | A retaining wall with a smooth vertical back retains sand backfill for a depth 6m. The backfill has a horizontal surface and the properties of backfill material is $c =$ | Remember | 3 |



| | | | |
|----|---|------------|---|
| | 0 kN/m^2 ; $\phi' = 28^\circ$, $\gamma = 16 \text{ kN/m}^3$, $\gamma_{\text{sat}} = 20 \text{ kN/m}^3$. Calculate total force acting on wall. | | |
| 8 | A retaining wall with a smooth vertical back retains sand backfill for a depth 6m. The backfill has a horizontal surface and the properties of backfill material is $c = 0 \text{ kN/m}^2$; $\phi' = 28^\circ$, $\gamma = 16 \text{ kN/m}^3$, $\gamma_{\text{sat}} = 20 \text{ kN/m}^3$. If the backfill supports a UDL of 25 kN/m^2 . Calculate total force acting on wall. | Understand | 3 |
| 9 | A retaining wall with a smooth vertical backfill is 10 m high and retains a two layers of sand backfill with following properties 0-5 m depth $c' = 0 \text{ kN/m}^2$; $\phi' = 30^\circ$, $\gamma = 18 \text{ kN/m}^3$ 5-10 m depth $c' = 0 \text{ kN/m}^2$; $\phi' = 34^\circ$, $\gamma = 20 \text{ kN/m}^3$. Draw the active earth pressure distribution assuming that WT is well below base of the wall. | Understand | 3 |
| 10 | A retaining wall 8 m high with smooth vertical back, retains a clay backfill with $c' = 15 \text{ kN/m}^2$; $\phi' = 15^\circ$, $\gamma = 18 \text{ kN/m}^3$. Calculate the total active thrust on the wall assuming that tension cracks may develop to the full depth. | Remember | 3 |

UNIT-4

SHORT ANSWER QUESTIONS-

| S.No | Question | LEVEL | Programme Out come |
|------|---|------------|--------------------|
| 1 | What is bearing capacity? | Remember | 3 |
| 2 | What is difference between ultimate bearing capacity and Safe bearing capacity? | Understand | 3 |
| 3 | What is net safe bearing capacity? | Understand | 3 |
| 4 | Write Terzaghi ultimate bearing capacity equation for continuous footing. | Remember | 3 |
| 5 | Write Terzaghi ultimate bearing capacity equation for square footing. | Understand | 3 |
| 6 | What is settlement of footing as per plate load test? | Understand | 3 |
| 7 | What are the various types of settlements in foundations? | Remember | 3 |
| 8 | Define foundation | Remember | 3 |
| 9 | Write Terzaghi ultimate bearing capacity equation for rectangular footing. | Remember | 3 |
| 10 | Define end bearing pile. | Understand | 3 |



LONG ANSWER QUESTIONS-

| S.No | Question | LEVEL | Program me Out come |
|------|--|------------|---------------------|
| 1 | Design a strip footing for load bearing wall transmitting a force of 200kN/m proposed to be laid at a depth of 1.50m below the G.L on a $c-\phi$ soil with $c=40$ kPa and $\phi=20^\circ$, $\gamma=17$ kN/m ³ . Given $N_C=11.80$, $N_q=3.90$, $N_\gamma=1.70$ | Remember | 3 |
| 2 | A 2m wide square footing is laid at a depth of 1.2 m below the G.L on a $c-\phi$ soil with $c=40$ kPa and $\phi=20^\circ$, $\gamma=17$ kN/m ³ . Given $N_C=11.80$. $N_q=3.90$, $N_\gamma=1.70$. Using Terzaghi's theory, compute the ultimate bearing capacity (q) when the GWT is, 5 m below G.L At GL 2 m below G.L | Remember | 3 |
| 3 | Determine the ultimate bearing capacity of a strip footing, 1.5 m wide, with its base at a depth of 1m, resting on a dry sand stratum take $\gamma_d=17$ kN/m ³ , $c'=0$ kPa and $\phi=38^\circ$. Use Terzaghi theory | Understand | 3 |
| 4 | Determine the ultimate bearing capacity of a footing, 1.5 m wide, with its base at a depth of 1m, resting on a dry sand stratum take $\gamma_d=17$ kN/m ³ , $c'=0$ kPa and $\phi=38^\circ$. Use bearing capacity factors recommended by Meyerhof. Ignore Embedment effect. | Remember | 4 |
| 5 | Determine the ultimate bearing capacity of a strip footing, 1.5 m wide, with its base at a depth of 1m, resting on a sand stratum take $\gamma_d=17$ kN/m ³ , $c'=0$ kPa and $\phi=32^\circ$. Use Terzaghi theory | Understand | 2 |
| 6 | What are the effects of Effects of pile driving? | Understand | 3 |
| 7 | Explain how the Group capacity of piles can be found by different Methods | Understand | 2 |
| 8 | What is the load carrying of the pile group in sands and clays? | Remember | 3 |
| 9 | What is the load carrying capacity of the pile in cohesion less soil? | Remember | 2 |
| 10 | Estimate the settlement of Pile group | Understand | 3 |
| 11 | Estimate the settlement of foundation by plate load test. | Remember | 2 |



UNIT-5

SHORT ANSWER QUESTIONS-

| S.No | Question | LEVEL | Programme Out come |
|------|---|------------|--------------------|
| 1 | What is open caisson? | Understand | 2 |
| 2 | What is Pneumatic caisson? | Understand | 2 |
| 3 | What are the forces acting on well foundation? | Understand | 2 |
| 4 | Write the equation for allowable bearing pressure for well in cohesion less soil. | Understand | 2 |
| 5 | Define scouring | Remember | 2 |
| 6 | What is well cap? | Understand | 2 |
| 7 | What is Cutting Edge? | Understand | 2 |
| 8 | Name various Components of Well. | Remember | 2 |
| 9 | Write a note on floating caisson foundation. | Understand | 2 |
| 10 | How well foundations are classified? | Remember | 2 |

LONG ANSWER QUESTIONS-

| S.No | Question | LEVEL | Programme Out come |
|------|---|------------|--------------------|
| 1 | Describe various types of caisson foundations and comment on their ability. | Remember | 2 |
| 2 | Explain in detail the procedure of sinking of well foundations. | Understand | 3 |
| 3 | Describe the component parts of a Pneumatic Caisson with a neat sketch. | Understand | 2 |
| 4 | What is a 'Floating Caisson'? How is its stability checked? What are the merits and demerits of a Floating Caisson when compared with other types? | Remember | 3 |
| 5 | Describe various types of caisson foundations and comment on their ability. | Remember | 2 |
| 6 | A cylindrical well of external diameter 6 m and internal diameter 4 m is sunk to a depth 16 m below the maximum scour level in a sand deposit. The well is subjected to a horizontal force of 1000kN acting at a height of 8m above the scour level. Determine the total allowable equivalent resisting force due to earth pressure, assuming that (a) the well rotates about a point above the base, and (b) the well rotates about the base. Assume $\gamma' = 10 \text{ kN/m}^3$, $\phi = 30^\circ$, and factor of safety against passive resistance = 2. Use Terzaghi's approach. | Remember | 2 |



| | | | |
|---|--|------------|---|
| 7 | A square footing carries a load of 1000 kN. The depth of footing is 2 m. The properties of soil are $C = 10$ kPa and $\Phi = 48^\circ$, $\gamma = 19.5$ kN/m ³ . Determine the size of footing for FOS = 3 against shear failure. What will be changes in size of footing? If WT rises to G.L. Give that $N_c = 42$, $N_q = 39$ and $N_\gamma = 45$. | Understand | 2 |
| 8 | A circular well of 4.5 m external diameter and 0.75m steining thickness embedded to a depth of 12 m in a sandy soil deposit. The properties of soil are $\gamma_{sat} = 30$ kN/m ³ , $\phi = 30^\circ$. The well is subjected to a resultant horizontal force of 500 kN and a moment of 400 kN-m at the scour level. Determine the allowable total equivalent resisting force due to the earth pressure. A FOS = 2 may be adopted for soil resistance. Determine the magnitude and point of maximum Bending moment at well steining. | Remember | 2 |
| 9 | Design a strip footing for a load bearing wall transmitting a force of 200 kN/m proposed to be laid at a depth of 1.5 m below GL on C- Φ soil with $C = 40$ kPa, $\Phi = 20^\circ$, $\gamma = 17$ kN/m ³ given that $N_c = 11.8$, $N_q = 3.9$ and $N_\gamma = 1.7$. | Remember | 2 |

XI. OBJECTIVE QUESTIONS: JNTUH

UNIT-I:

- A soil has the bulk density and water content respectively are 22 kN/m³ and 10%, then its dry density in kN/m³ will be
(a) 2.0 (b) 1.9 (c) 1.8 (d) 1.7
- The void ratio of a soil
(a) Cannot be more than unity (b) will be between 0 and 1
©can exceed unity but practically may not be too high (d) can be, practically, any value
- In a unit phase diagram, the following quantity is taken as unity
(a) volume of water (b) total volume of soil
(b) (c) volume of solids (d) weight of solids
- For a medium dense soils, the density index in per cent will be
(A) less than 35 (b) 35 to 65 (c) 65 to 85 (d) greater than 85
- A plane inclined at an angle ' φ ' to the horizontal at which the soil is expected to stay in the absence of any lateral support, is known as _____.
- The major principal stress in an element of cohesion-less soil within the backfill of a retaining wall is- _____.
- Failure of the stability of slopes, generally occurs along _____.
- A pile is being driven with a drop hammer weighing 1800 kg and having a free fall of 1.00 m. If the penetration with last blow is 5 mm, the load carrying capacity of the pile, -according to the Engineering News formula, is _____.
- The Westergaard analysis is used for _____.
- The angle between the directions of the failure and the major principal plane, is equal to _____.



UNIT-II:

1. The most active clay mineral in respect of inducing shrinkage and swelling in soils is
(A) Illite (b) calcite (c) kalonite (d) montmorillonite
2. Toughness index of soil is the ratio of
(a) Consistency index to flow index (b) flow index to plasticity index
©liquidity index to flow index (d) plasticity index to flow index
3. From a grain size distribution curve, the particle sizes obtained corresponding to 60% and 10% finer are 1.6 mm and 0.4 mm respectively, then the uniformity coefficient of soil will be
(a) 8 (b) 6 (c) 4 (d) 2
4. A clay soil has a liquid limit of 60% and plasticity index 35%, then the soil will be classified as
(a)CL (b) CH (c) ML (d) MH
5. Factor of safety against sliding of slope, is the ratio of _____.
6. If the failure of a finite slope occurs through the toe, it is known as _____.
7. Backfill with a sloping surface exerts a total active pressure on the wall of height H acts at _____.
8. Failure of the stability of slopes generally occurs along _____.
9. The angle that Coulomb's failure envelope makes with the horizontal is called _____.
10. Bishop's method of stability analysis assumes _____.

UNIT-III:

1. The textural classification of soil is based on
(a) Grain size (b) soil plasticity
(c) Both grain size and plasticity (d) gain size and water content
2. When a soil sample is dried below the shrinkage limit, then its volume
(a) Decreases (b) increases (c) remains unchanged (d) becomes zero
1. The Westergaard analysis is used for
(a) Sandy soil (b) cohesive soil (c) stratified soil (d) clayey soil
2. Pressure bulb is defined as
(a) contour joining the equal radius (b) contour joining the equal areas
©contour joining the equal latitudes (d) contour joining the equal stress intensity
3. The active earth pressure of the soil is proportional to _____.
4. The passive earth pressure of the soil is proportional to _____.
5. At rest earth pressure is give as _____
6. The lateral earth pressure on the retaining wall is proportional to _____ of the soil.
7. According to Coulomb's wedge theory, the active earth pressure slides the wedge _____.
8. Rankines's theory of active earth pressure assumes _____.
9. Table raises to the Ground surface
(a) 75% (b) 50% (c) 25% (d) None
7. The Allowable soil pressure for foundation in cohesive soil is
(a)Settlements (b) bearing capacity (c) a & b (d) neither a nor b

UNIT-IV:

1. The ratio of OMC of modified compaction to standard compaction is
(a) some times less than 1 (b) always less than 1
©Some times greater than 1 (d) always greater than 1
2. Zero air void line and 100% saturation line both are
(a) Equal (b) not equal (c) no relation (d) none of these
3. The ratio of compaction energy of modified compaction to the standard compaction is
1.89 (b) 4.89 (c) 3.89 (d) 2.89
4. A clay sample has its liquid limit as 60%, then the compression index of clay in undisturbed state is



- (a) 0.45 (b) 0.35 (c) 0.4 (d) 0.3
5. Under-reamed piles are generally _____ piles.
 6. Minimum depth of footing carrying a heavy load is calculated by the formula _____.
 7. The ultimate settlement of a soil is directly proportional to _____.
 8. Allowable bearing capacity for a foundation depends on _____.
 9. Terzaghi's general bearing capacity formula for strip footing is _____.
 10. In the plate loading test the bearing capacity of soil, the size of bearing plate should be _____.

UNIT-V:

1. A soft clay deposit of 10 m is underlain by sandy soil and overlain by hard impervious soil. The maximum drainage path is
(a) 5m (b) 40 m (c) 20 m (d) 10 m
2. The slope of void ratio and effective normal stress plot is called as
(a) Compression index (b) coefficient of compressibility
(c) Coefficient of consolidation (d) coefficient of volume compressibility
3. In an unconfined compression test the unconfined compression stress of clay found is 100 kPa, then the undrained shear strength of clay is
(a) 25 kPa (b) 50 kPa (c) 100 kPa (d) 200 kPa
4. A cohesion less soil is subjected to a triaxial testing at a confining pressure of 100 kPa and failed at a deviator stress of 200 kPa. The angle of internal friction of sample is
(a) 30° (b) 45° (c) 60° (d) 90°
5. Contact pressure beneath a rigid footing resting on cohesive soil is more at _____.
6. A grillage foundation is _____.
7. The maximum load carried by a pile, when it continues to sink without further increase in load is known as _____.
8. Number of piles required to support a column is _____.
9. If the failure of a finite slope occurs through the toe, it is known as _____.
10. The maximum shear stress occurs on the filament which makes an angle with the horizontal plane equal to _____.

GATE:

1. For very dense sand the 'N' value is=
(a) 30 to 40 (b) <30 (c) <50 (d) >50
2. The standard penetration test is useful to measure
(a) Shear strength of soft clays (b) Shear strength of sands
(c) Consistency of clays (d) none
3. More common methods of advancing a bore hole is=____
(a) Rotary drilling (b) Wash boring (c) Continuous flight augers (d) Percussion drilling
4. Which of the following will have a finite slope?
(a) Embankment (b) Earth dam (c) Canals (d) All of the above
5. Taylor's stability number 'Sn' is
(a) $C / FC \gamma H$ (b) C/rH (c) $CH / FC \gamma$ (d) $C2 / FC \gamma H$
6. The factor of safety of an infinite slope in a sand deposit is found to be 1.732. The angle of Shear resistance of the sand is 30° . The average slope of the sand deposit is given by
(a) $\sin^{-1}(0.333)$ (b) $\cos^{-1}(0.252)$ (c) $\tan^{-1}(0.333)$ (d) $\cot^{-1}(0.621)$
7. Coulomb's theory is applicable for



- (a) Homogeneous soils (b) Non homogeneous soils
© Smooth retaining walls only (d) Soils which have angle of internal friction only.
8. If ' μ ' is Poisson's ratio of a soil, then the coefficient of earth pressure at rest is
(a) $\mu/1-\mu$ (b) $1-\mu/\mu$ (c) $\mu/1+\mu$ (d) $1+\mu/\mu$
9. Gravity-type retaining wall primarily mobilizes active earth pressure by
(a) The free deflection at the top (b) the free deflection at the base
© Uniform translation (d) sudden overturning.
10. _____ formula is used in solid and semi solid gravity walls
(a) Rankine's (b) Mohr's (c) Coulomb's (d) none

IES:

1. The standard penetration test is useful to measure
(a) Shear strength of soft clays (b) strength of sands & Clays
(c) Consistency of clays (d) none of above.
2. For an undisturbed sample, the area ratio of the samples should be
(a) Zero (b) 10% or less (c) 10% to 20% (d) more than 20%
3. The method of slices for the stability of slope
(a) Can be used for stratified soils.
(b) Can be used when seepage occurs and the pore pressure exists within the soil.
(c) Gives the factor of safety based on moments and not the forces. (d) All the above.
4. Taylor's stability charts are based on the total stresses using the
(a) Friction circle method (b) method of slices
© $\phi_u = 0$ analysis (d) none of the above
5. The inclination of the failure plane behind a vertical wall in the passive pressure case is inclined to the horizontal at
(a) $45^\circ - \phi/2$ (b) $45^\circ - \phi$ (c) $45^\circ + \phi/2$ (d) $45^\circ + \phi$
6. The yield of a retaining wall required to reach plastic equilibrium in active case is
(a) more than that in the passive case (b) less than that in the passive case
(c) Equal to that in the passive case. (d) None of above.
7. The minimum allowable factor of safety against sliding in the case of a cantilever retaining wall is
(a) 2.0 (b) 3.0 (c) 1.50 (d) 2.50
8. In the case of a counter fort retaining wall, the toe slab acts as a
(a) Cantilever (b) continuous slab (c) simply supported slabs (d) none of above.
9. Counterfort retaining walls are more suitable than cantilever retaining walls for
(a) smaller heights (b) greater heights (c) Both (d) None
10. _____ develops at the base of the retaining wall when the resultant strikes outside the middle-third.

XIII. WEBSITES:

- www.igs.org.in/
- nptel.iitm.ac.in/
- en.wikipedia.org/wiki/Geotechnical_engineering
- www.foundationengineering.com.au/
- www.cdeep.iitb.ac.in/.../Civil%20Engineering/Foundation_Engineering/



- www.geoengineer.org/
- www.issmge.org/
- www.geotechnicalinfo.com/
- www.ejge.com/GVL/
- <http://www.asce.org>
- <http://www.icivilengineer.com>
- <http://www.construction-guide.in>

XIV. EXPERT DETAILS:

- Datta Manoj
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Areas of Interest: Geoenvironment, Landfills, Ash Ponds, Tailings, Ground improvement, Slope Stability, Dams, Offshore Geotechnology.
- Ramana G.V.
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Areas of Interest: Geoenvironmental Engineering, Geotechnical Earthquake Engineering, Waste Mechanics, Ground Improvement.
- Sharma K.G.
[Ph.D. (Univ. of Wales, UK)], Professor
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Areas of Interest: Rock Mechanics, Soil and Foundation Engineering, Constitutive Modelling, Dam Foundations, Underground Structures, Slope Stability, Computational Methods.
- Ayothiraman R.
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Areas of Interest: Soil Dynamics and Earthquake Engineering, Pile Foundations, Deep Excavations in Urban Areas, Problematic Soils and Ground Improvement.
- Chakraborty Tanusree (Ms)
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Areas of Interest: Foundation Engineering, Blast Loading in Soil, Soil Plasticity and Constitutive Modeling, Soil-Structure Interaction and Underground Construction in Soil and Rock.



XV. JOURNALS:

| | | |
|-----------|--|------|
| | civil.iisc.ernet.in/~geotech/journals.htm | |
| | http://www.ejge.com/Index_ejge.htm | |
| | www.igs.org.in/ | |
| | www.igi-global.com/journal/...journal-geotechnical...engineering/1145 | |
| | ascelibrary.org/journal/jggef | |
| 0970-1141 | Thesis Digest on civil Engineering | 1987 |
| 0973-8061 | International Engineering and Technology Journal of Civil and Structure | 2007 |
| 0975-5314 | International journal of civil engineering | 2009 |
| 0975-6744 | Journal of information knowledge and research in civil engineering | 2009 |
| 0976-6308 | International journal of civil engineering and technology | 2010 |
| 2249-426X | International Journal of Civil Engineering and Applications | 2011 |
| 2249-8753 | Recent Trends in Civil Engineering and Technology | 2011 |
| 2277-5986 | World Research Journal of Civil Engineering | 2011 |
| 2277-7032 | International Journal of Structural and Civil Engineering | 2012 |
| 2278-9987 | International Journal of Civil Engineering (IJCE) | 2012 |
| 2319-6009 | International Journal of Structural and Civil Engineering Research | 2012 |
| 2320-723X | International Journal of Advanced Research in Civil, Structural, Environmental and Infrastructure Engineering and Developing | 2013 |

XVI. LIST OF TOPICS FOR STUDENT SEMINARS:

1. Effects of Damping Ratio of Restoring force Device on Response of a Structure
2. Resting on Sliding Supports with Restoring Force Device
3. Enhancing the performance under close-in detonations with polymer reinforced CRC
4. Equilibrium based evaluation of stress distribution
5. Evaluation of stress distribution in bolted steel angles under tension
6. Evolution of Concrete Skyscrapers: from Ingalls to Jinmao

XVII. CASE STUDIES / SMALL PROJECTS:

1. Earthquake vibration control using modified frame-shear wall
2. Advanced Earthquake Resistant Techniques
3. Seismic isolation devices
4. Energy dissipation devices for seismic design.
5. Reservoir induced seismicity
6. Failure of foundation due to earthquake.

