زانکۆی پۆلیتەکنیکی هەولێر
ERBIL POLYTECHNIC UNIVERSITY

Kurdistan Region Government
Ministry of Higher Education
and Scientific Research
Erbil Polytechnic University

Module (Course Syllabus) Catalogue

2022-2023

College/ Institute	Erbil Polytechnic University	
Department	Highway Engineering Technique Department	
Module Name	Foundations Analysis & Design	
Module Code	FAD704	
Degree	Technical Diploma ☐ Bachelor ✓ High Diploma ☐ Master ☐ PhD ☐	
Semester	7th	
Qualification	M.Sc. Structural Engineering	
Scientific Title	Assistant Lecturer	
ECTS (Credits)	6	
Module type	Prerequisite ☐ Core ✓ Assist. ☐	
Weekly hours	4 hours	
Weekly hours (Theory)	(4) hr Class	(108) Total hrs Workload
Weekly hours (Practical)	(None)hr Class	(None)Total hrs Workload
Number of Weeks	15	
Lecturer (Theory)	Ali J. Nouri Al – Barazanchi	
E-Mail & Mobile NO.	ali.nouri@epu.edu.iq – 07706416969	
Lecturer (Practical)	None	
E-Mail & Mobile NO.		
Websites		

Course Book

Course Description	Increase student knowledge and learn the principles and practices for the investigation, design, contracting, and construction of shallow, intermediate, and deep foundations, including remediation of soft, wet, expansive, and frost-prone soils. After attending this course, student shall have a firm grasp of the background and design specifics necessary to compete in this industry, including industry-leading information on the principles and practices of foundation design for buildings, transportation infrastructure, utilities, and industrial facilities. Understand practical emerging technologies including advanced design techniques for pressuremeter-supported foundation design; aggregate piers; auger cast, helical, and micro piles; and design for lateral loads, frost heave, and wet/dry cycles.
Course objectives	• Understand the importance of geotechnical investigation in foundation design • Apply analytical skills to solving problems in foundation design • Understand the basic requirements of international codes for foundation design • Appreciate the interaction between soils and structures • Identify the key geotechnical and structural issues in foundation design • Appreciate the range of foundation types available and their application • Select an appropriate foundation system for a structure • Appreciate the practical problems of design and detailing when designing foundations • Introduce the student to certain case studies
Student's obligation	a. To attend the classes regularly with minimum absence. b. To participate actively in the class discussion and Q&A session c. Study on daily basis to digest the class material d. To write note off-handouts e. Prepared for sudden Quizzes f. Vet through the references provided by the lecturer and to solve as much as possible of homework and exercises for the subjective materials. g. Prepare the assignment and the seminar as instructed by the lecturer.
Required Learning Materials	Students at this stage with the workload assigned technical for the subject are not required to scatter their attention with bunch of sources. Students are encouraged to thoroughly study the refence given by the lecturer and to vet through available cyber data related to the subject and this shall include the concrete technology worked examples and all those are support with construction site visit for the students to appreciate and monitor closely the application of the theoretical concept in construction.

<table>
<tr><th rowspan="14">Evaluation</th><th colspan="2">Task</th><th>Weight (Marks)</th><th>Due Week</th><th>Relevant Learning Outcome</th></tr>
<tr><td colspan="2">Paper Review</td><td colspan="3">None for B.SC.</td></tr>
<tr><td rowspan="6">Assignments</td><td>Homework</td><td>10</td><td>Weekly</td><td>Application for subject by subject</td></tr>
<tr><td>Class Activity</td><td>2</td><td>Weekly</td><td>Participate in syllabus learning</td></tr>
<tr><td>Report</td><td>8</td><td>4th & 8th</td><td>Concentrate on certain subject of the module and cover its technical aspects</td></tr>
<tr><td>Seminar</td><td>8</td><td>6th & 10th</td><td>Individual or in group for subjects within the module but out of the syllabus</td></tr>
<tr><td>Essay</td><td></td><td></td><td></td></tr>
<tr><td>Project</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Quiz</td><td>8</td><td></td><td></td></tr>
<tr><td colspan="2">Lab.</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Midterm Exam</td><td>24</td><td>7th</td><td></td></tr>
<tr><td colspan="2">Final Exam</td><td>40</td><td>14th & 15th</td><td></td></tr>
<tr><td colspan="2">Total</td><td>100</td><td></td><td></td></tr>
<tr><th>Specific learning outcome:</th><td colspan="5">By the end of the current course, the student shall be able to learn the major activities related to the foundation analysis and design which is the part the makes the backbone for any constructional project. The student would be able to put a scenario for the soil investigations works, assess the subsoil bearing capacity, decide on the proper foundation for the structure, calculate the anticipated settlement, design the foundations (concrete wise for shallow foundations (Spread, Continuous, Strip and Raft) and deep (Piled) foundations, soil treatment for strengthening and retaining structure. The most effect matter the student learn in this course is to decide on safe and most economical foundation system for the subjective projects.</td></tr>
<tr><th>Course References:</th><td colspan="5">▪ Foundation Analysis and Design: Joseph E. Bowles
▪ Principles of Foundation Engineering: Braja M. Das
▪ Shallow foundations bearing capacity and settlement: Braja M. Das
▪ Fundamentals of Geotechnical Engineering: Braja M. Das
▪ Foundation Design: Principles and Practices (3rd Edition) 3rd Edition by Donald P. Coduto (Author) & William A. Kitch</td></tr>
</table>

Course topics (Theory)	Weeks	Learning Outcome
Subsoil Explorations		
1. Introduction	1st	Under this subject the student shall be introduced to the importance of the explorations to identify the soil characteristics which shall be used as the based for the bearing capacity of the subsoil and evaluate the capacity of deep pile
2. Soil Explorations Scenario	1st	
3. Number of boreholes and test pits	1st	
4. Depth of boreholes and type of drillings	1st	
5. Sampling and types of samples	2nd	
6. Laboratory tests over soil samples	2nd	
7. Field tests	2nd	
8. Outcome of tests	2nd	
9. Reporting	2nd	
Bearing Capacity of Shallow Foundations		
1. Introduction	3rd	Student shall learn the evaluation of the bearing capacity for shallow foundations from shear strength parameters and field tests for all types of shallow foundations (Spread, Strip & Raft)
2. Bearing Capacity equations for Shallow Foundations	3rd	
3. Effect of water table over the bearing capacity	3rd	
4. Factor influencing Bearing Capacity	3rd	
5. Bearing capacity for eccentrically loaded foundations	4th	
6. Layered soil bearing capacity	4th	
7. Bearing capacity form field tests – SPT	4th	
8. Bearing Capacity from field test - PLT	4th	
Settlements of Foundations		
1. Introduction	5th	Students shall learn under the chapter's syllabus the difference between immediate and consolidation settlement and how to calculate each with time – consolidation scenario
2. Types of Settlements	5th	
3. Short Term Settlements (Immediate Settlements)	5th	
4. Consolidation Settlements	6th	
5. Time – Consolidation scenario	6th	
6. Solved examples	6th	
Deep (Pile) Foundations		
1. Introduction	7th	Student shall learn by end of this chapter when he should decide to go for deep foundation and the analysis of the pile's capacity and ultimately the design of the number
2. Types of Piles	7th	
3. Analysis of Piles Capacity	7th	
4. Pile End Bearing Evaluation	7th	
5. Pile Skin Friction Evaluation	8th	
6. Calculate Pile Capacity	8th	

7. Group of Piles	8th	of piles required under load column with its pile cap. The student shall also learn the testing methods for piles to ensure their carrying capacity.
8. Block Shear of Piles	8th	
9. Piles under eccentric load	8th	
10. Settlement of piles	9th	
11. Case of broken piles	9th	
12. Estimate pile length of designated load	9th	
13. Design of piles with pile caps	9th	
14. Testing of Piles	9th	
Reinforced Concrete Shallow Foundation Design		
1. Introduction	10th	Student shall learn in this chapter to differentiate between the different types of the shall ow foundations. The reinforced concrete design shall be taught for spread, strip, combined and raft foundation after ACI – 19 Code of Practice
2. Types of shallow foundations	10th	
3. Analysis and design of spread foundations	10th	
4. Analysis and design of strip foundations	11th	
5. Analysis and design of combined footing	11th	
6. Analysis and design of trapezoidal combined footing	11th	
7. Analysis and design of raft foundations	12th & 13th	

Questions Example Design

Attached copy for the academic year 2021 – 2022, final, first Attempt exam with solution

Extra notes:

None so far

External Evaluator

Ministry of Higher Education & Scientific Research		**Class: 4th year**
Erbil Polytechnic University		**Subject: Foundations Design**
Erbil Technical Engineering College		**Time: 3Hrs.**
		Date: May 19th, 2022
Highway Engineering Techniques Department	**2021 – 2022 Final Examination – 1st Attempt**	**Code: HE406**
Exam is Open Notes Only		

Answer all Questions – All questions hold same marks (25 Marks)

Q.1) The results of two plate load tests are tabulated below:

Plate Size (Circular 0.3m)		Plate Size (Circular 0.6m)	
Pressures (KPa)	**Settlement (mm)**	**Pressures (KPa)**	**Settlement (mm)**
150	8	50	3
300	14	100	9
450	23	150	17
600	30	200	21
750	40	250	24
900	52	300	30

A square column foundation has to be constructed to carry a total load of 850KN with tolerable settlement of 30mm. Determine the size of the foundation using **Housel Method**.

Q.2) The Administrative building for a Highway's Toll Plaza has a raft foundation with the dimensions of (15 X 25m) subjected to a net load of (93750kN) is to be constructed over a soil consists of three basic layers. The top (first) layer is Clay and the second layer is Sand resting over the third layer which is Clay again. Both clay layers are over consolidated with ($\sigma'_o + \Delta\sigma'_{ave.} < \sigma'_c$). The foundation is at depth of 1.5m below NGL which is the same depth of the ground water table. As it is required to calculate the Primary Consolidation settlement only, make use of the following data and estimate the total settlement **using Stress Influence Tables**:

a) Thickness of top first Clay Layer = 4.5m, **b)** Thickness of the second Sand Layer is 3m **c)** Thickness of the third clay layer is 9m **d)** Sand & Clays total density = 18kN/m^3 & saturated density = 20kN/m^3 **e)** C_s = 0.040, e_o = 0.72 for both encountered Clay layers. (Sketch the layers for easy understanding)

Q.3) Design a pile foundation (Number of piles and the dimension of the pile cap) to support a working load of 21000KN. The pile shall pass through the following layers:

Layer No.	Thickness of Layer, (m)	Type of Soil	C (kPa)	Ø (°)	$\gamma_{tot.}$ (kN/m^3)
1	5m	Soft Clay	30	0	18
2	8m	Medium Sand	0	20	18
3	7m	Dense Sand	0	30	18
4	10m	Stiff Clay	100	0	18

Consider the following:

1. Piles are Precast Driven Square 400mm X 400mm in size
2. No ground water table were encountered at site in question
3. FOS = 3.0
4. Divide & arrange the piles required in three (3) rows equally

Q.4) Design a strip footing to support a brick wall having a thickness of 300mm resisting a working dead load of (DL = 170KN) and working live load of (LL = 135KN). The allowable bearing capacity = 220KPa, $f_{c'}$ = 25MPa & f_y = 420MPa for both the footing and the wall's concrete. FOS for dead load = 1.4 and 1.7 for the live load. Sketch the footing at the end of the design process. Use Ø16 for main bars and Ø12 for distribution bars

Best of Luck

Assist. Lecturer
Ali J. Nouri

Ministry of Higher Education
& Scientific Research
Erbil Polytechnic University
Erbil Technical Engineering College
Highway Engineering Techniques Department
Exam is Open Notes Only

2021 – 2022
Final Examination – 1st Attempt

Class: 4th year
Subject: Foundations Design
Time: 3Hrs.
Date: May 19th, 2022
Code: HE406

Solution:

Q.1:

Corresponding pressure to 30mm of first Plate = 600KPa

Load = A X Pr. = $\pi \times 0.3^2 \times 0.25 \times 600 = 42.41$KN

Corresponding pressure to 30mm of second Plate = 300KPa

Load = A X Pr. = $\pi \times 0.6^2 \times 0.25 \times 300 = 84.82$KN

Q = Am + Pn

$42.41\text{kN} = (\pi/4) \times (0.3)^2 \times m + (\pi) \times (0.3) \times n$ -------------- (1)

$84.82\text{kN} = (\pi/4) \times (0.6)^2 \times m + (\pi) \times (0.6) \times n$ -------------- (2)

Solving (1) & (2) yields:

$m = -0.320073 \text{ kN/m}^2$

$n = 45.0453 \text{ kN/m}$

Q = Am + Pn

$850 = B^2 \times -0.320073 + 4B \times 45.0453$

$-0.320073B^2 + 180.1812B – 850 = 0$

Solving for B yields, B = 4.75m, Say **B = 5.0m**

Q.2:

At first layer:

σ'_o = 1.5 X 18 + 1.5 X (20 – 9.81) = 42.285kPa

q_{net} = (93750/15 X 25) = 250 KPa

Z	M	N	I_σ X 4	$\Delta\sigma' = I_\sigma \times q_{net}$
0	∞	∞	1	1 X 250 = 250
1.5	5	8.333	0.996	0.996 X 250 = 249
3	2.5	4.1666	0.974	0.974 X 250 = 243.5

$\Delta\sigma'_{ave.} = \frac{1}{6}(\Delta\sigma'_t + 4\Delta\sigma'_m + \Delta\sigma'_b) = \frac{1}{6}$(250 + 4 X 249 + 243.5) = 248.25 kPa

$$S_c = \frac{C_S H_C}{1+e_o} log \frac{\sigma'_o+\Delta\sigma'_{ave.}}{\sigma'_o}$$

$$S_c = (\frac{0.04 \times 3}{1+0.72} log \frac{42.285+248.25}{42.285}) \times 1000$$

Total Settlement = 58.4mm

At third layer:

σ'_o = 1.5 X 18 + 3 X (20 – 9.81) + 3 X (20 – 9.81) + 4.5 X (20 – 9.81) = 133.995kPa

q_{net} = (93750/15 X 25) = 250 KPa

Z	M	N	I_σ X 4	$\Delta\sigma' = I_\sigma \times q_{net}$
6	1.25	2.083	0.861	0.861 X 250 = 215.25
10.5	0.714	1.190	0.634	0.634 X 250 = 158.5
15	0.5	0.833	0.449	0.449 X 250 = 112.25

$\Delta\sigma'_{ave.} = \frac{1}{6}(\Delta\sigma'_t + 4\Delta\sigma'_m + \Delta\sigma'_b)$ $= \frac{1}{6}$(215.25 + 4 X 158.5 + 112.25) = 160.25 kPa

$$S_c = \frac{C_S H_C}{1+e_o} log \frac{\sigma'_o + \Delta\sigma'_{ave.}}{\sigma'_o}$$

$$S_c = (\frac{0.04 \times 9}{1+0.72} log \frac{133.995+160.25}{133.995}) \times 1000$$

Total Settlement = 71.50mm

Total Primary Consolidation Settlement = 58.4 + 71.5 = 129.9mm

Q.3:

400 X 400mm Precast Concrete Driven Pile

- $\mathbf{Q_{b.ult.}}$ = (CNc') X Ab = 100 X 9 X (0.40 X 0.40) = 144Kn

- $\mathbf{Q_{f1}} = \alpha C A_f$ = 1 X 30 X 0.40 X 4 X 5.0 = 240kN

- $\mathbf{Q_{f2}} = \sigma_{ave.} \times K \times \tan(S) \times A_f$

$\sigma_{ave.}$ = 5 X 18 + 4 X 18 = 162kN

Q_{f2} = 162 X 1.5 X tan (0.75 X 20) X (0.4 X 4 X 8) = 833.4kN

- $\mathbf{Q_{f3}} = \sigma_{ave.} \times K \times \tan(S) \times A_f$

$\sigma_{ave.}$ = 5 X 18 + 8 X 18 + 3.5 X 18 = 297kN

Q_{f3} = 297 X 2 X tan (0.75 X 30) X (0.4 X 4 X 7) = 2755.68KN

- $\mathbf{Q_{f4}} = \alpha C A_f$

L/B = 10/0.4 = 25,

Case (1),

$\mathbf{Q_{f4}} = \alpha C A_f$ = 1.1 X 100 X (0.4 X 4 X 10) = 1760kN

ΣQf = 240 + 833.4 + 2755.68 + 1760 = 5589.08kN

$Q_{ult.}$ = 144 + 5589.08 = 5733.08kN

$\mathbf{Q_{all.-comp.}}$ **= 5733.08/3 = 1911.03kN**

No. of piles required = 21000/1911.03 = 11, use 18 Piles

No. of piles in a row = 18/3 = 6

Spacing between Piles = 3d = 3 X 400mm = 1200mm

$$E_g = 1 - \emptyset\left[\frac{(n'-1)m+(m-1)n'}{90mn'}\right] = 1 - 18.417\left[\frac{(6-1)\times 3+(3-1)\times 6}{90\times 3\times 6}\right] = 0.69305$$

Pile Group Capacity = 18 X 1911 X 0.69305 = 23840KN > 21000 KN, Ok

Pile Cap Length = 5 X 1.2 + 0.4 + 0.3 = 6.7m
Width of Pile Cap = 2 X 1.2 + 0.4 + 0.3 = 3.1m

Check for Block Shear:

$\sigma_{ave.}$ = 30 X 18 = 540kN

$\mathbf{Q_{b.ult.}}$ = (CNc' + $qN_{q'}$) X Ab = (100 X 9 + 540 X 1) (6.4 + 2.8) X 2 = 26496Kn

- $\mathbf{Q_{f1}}$ = $\alpha C A_f$ = 1 X 30 X (6.4 + 2.8) X 2 X 5.0 = 2760kN

- $\mathbf{Q_{f2}}$ = $\sigma_{ave.} \times K \times \tan(S) \times A_f$

$\sigma_{ave.}$ = 5 X 18 + 4 X 18 = 162kN

Q_{f2} = 162 X 1.5 X tan (20) X (2 X (6.4 +2.8)) X 8 = 13019kN

- $\mathbf{Q_{f3}}$ = $\sigma_{ave.} \times K \times \tan(S) \times A_f$

$\sigma_{ave.}$ = 5 X 18 + 8 X 18 + 3.5 X 18 = 297kN

Q_{f3} = 297 X 2 X tan (30) X (6.4 + 2.8) X 2 X 7 = 44171KN

- $\mathbf{Q_{f4}}$ = $\alpha C A_f$ = 1.0 X 100 X (6.4 + 2.8) X 2 X 10 = 18400kN

ΣQf = 2760 + 13019 + 44171 + 18400 = 78350kN

$Q_{ult.}$ = 26496 + 78350 = 104846kN

$\mathbf{Q_{all.-comp.}}$ = 104846/3 = 34948kN > 21000KN, OK

Q.4:

A_f = (DL + LL)/$Q_{all.}$ = (170 + 135)/220 = 1.386m^2

B = 1.5m

P_u = 1.4DL + 1.7LL = 1.4 X 170 + 1.7 X 135 = 467.5KN/m

Q_u = P_u/A_f = 467.5/1.5 = 311.67KPa/m

Vc = $\frac{\emptyset}{6}\sqrt{f_c'}$ = (0.75/6) X ($25^{0.5}$) X 1000 = 625KN/m^2

$(\frac{B-a}{2} - d) \times L \times q_u$ = L X d X V_c

(((1.5-0.3)/2) – d) X 1 X 311.67 = 1 X d X 625

187.002 – 311.67d = 625d

d = 187.002/ (311.67+625), d = 0.199m = 199mm

M_u = (q_u X l^2)/2, l = (B/2 – b/4) = (1.5/2) – (0.3/4) = 0.675m

M_u = (311.67 X 0.675^2/2) = 71kN.m

R_u = M_u X 10^6/ (ØBd^2) = 71 X 1 000 000/(0.9 X 1000 X 199^2) = 1.992

m = f_y/0.85$f_{c'}$ = 420/ (0.85 X 25) = 19.76

$\rho = \frac{1}{m}(1 - \sqrt{1 - \frac{2mR_u}{f_y}}) = \frac{1}{19.76}(1 - \sqrt{1 - \frac{2\times19.76\times1.992}{420}})$ = 0.0049887> $\rho_{min.}$ = 0.002

$$\rho_{max.} = 0.75 \times \left(\frac{0.85 \times \beta_1 \times f_c'}{f_y} \times \frac{600}{600 + f_y}\right) = 0.75 \times \left(\frac{0.85 \times 0.85 \times 25}{420} \times \frac{600}{600 + 420}\right) = 0.0253$$

$\rho_{max.} > \rho > \rho_{min.}$

$A_{s-tension}$ = 0.0049887 X 1000 X 199 = 992mm^2/m

Area of steel bar Ø16 = 201mm^2

No. of bars/m = 992/201 = 4.93 bras, spacing = 1000/5 =200mm
Use Ø16@200mmC/C

$\rho_{sec.} = 0.3\,\rho$ = 0.3 X 0.0049887 = 0.0015< $\rho_{min.}$, then use $\rho_{min.}$ = 0.002

$A_{s-secondary}$ = 0.002 X 1500 X 199 = 597mm^2/m

Area of steel bar Ø12 = 113mm^2

No. of bars within the width of the strip = 597/113 = 6bras, spacing = 1500/6 =250mm

Use Ø12@250mmC/C

Total Thickness of the strip footing = 199 + (12+16)/2 + 75 = 288mm, say 300mm

To calculate the development length:

1. $L_d = 0.02 \times A_b \times (f_y/(f_{c'})^{0.5})$ = 0.02 X 201 X (420/5) = 337.7mm, or
2. $L_d = 0.058 \times d_b \times f_y$ = 0.058 X 16 X 420 = 390mm, or
3. L_d = 300mm

Then L_d = 390mm

Available L_d = ((1500 - 300)/2) – 75 = 525mm > 390mm, OK