The Relevance of Geo-Engineering in Civil Engineering Education and Practice in Ghana

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ABSTRACT: The paper reviews undergraduate civil engineering education in Ghana and describes the content of geo-engineering courses that form part of the undergraduate civil engineering degree programme at the Kwame Nkrumah University of Science and Technology. The geo-engineering courses comprise soil and rock mechanics, engineering geology, foundation engineering and geotechnical engineering. The content of these courses as well as the credits relative to the total number of credits required for graduation are discussed and the challenges involved in teaching these courses are presented. Finally the paper reviews geotechnical engineering practice in Ghana looking at the registration of engineers and the geotechnical engineering market.

1 ENGINEERING EDUCATION IN GHANA

Ghana has five national universities and recently a number of private universities have also emerged. However, until recently[1] the private universities concentrated on business and management courses, religion, and computer sciences. Sub-degree Higher National Diploma (HND) engineering education occurs at the polytechnics (Afeti, 2002). However, the content of geo-engineering in the HND civil engineering programme is negligible. Until now, university engineering education has been carried out by the national universities. Among the national universities applied engineering education is currently available only at the Kwame Nkrumah University of Science and Technology (KNUST) in Kumasi and the University of Mines and Technology (UMaT) in Tarkwa. Civil engineering education, however, is offered only at the KNUST.

KNUST has a current student population of about 22,000. Initially the University ran joint BSc programs with the University of London until it attained University status in 1961. The Civil Engineering Department was one of the first Departments to be thus established. The civil engineering programme was modeled essentially on the London University pattern. Since January 2005 KNUST has been reorganised into 6 colleges made up of the College of Engineering, College of Health Sciences, College of Art and Social Sciences, College of Architecture and Planning, College of Science and College of Agriculture and Natural Resources.

[1] The Central University College in Ghana is one the few private universities that has recently received accreditation approval to commence civil engineering programme.

2 THE CIVIL ENGINEERING PROGRAMME AT KNUST

2.1 *The Programme Size*

The Civil Engineering Programme is one of ten engineering programmes offered in the College of Engineering. Table 1 shows the relative size of the civil engineering programme in the College. It can be seen that civil engineering alone accounts for an average of about 20% of all students admitted into the college of engineering.

Table 1 Enrolment in Civil Engineering relative to all Engineering programmes at KNUST

Academic Year	Enrolment in Civil Eng	Enrolment in College of Eng.	% Enrolment in Civil
2000/2001	320	1,444	22%
2001/2002	381	1,724	22%
2002/2003	440	2,063	21%
2003/2004	507	2,548	20%
2004/2005	616	3,155	20%
2005/2006	731	3770	19%
2006/2007	767	4,035	19%

2.2 *The Programme Structure*

The detailed structure of the civil engineering programme at KNUST is shown in Tables 2 to 5 for both semesters of each of the four years.

Table 2 B.Sc. Civil Engineering Course Structure for 1st Year

Course No	Course Title	T	P	C
MATH 151	Mathematics I	4	0	4
ENGL 157	Communication Skills I	2	0	2
ME 159	Technical Drawing	1	3	2
ME 161	Basic Mechanics	3	1	2
CE 151	Elementary Structures	2	1	2
CE 153	Engineering Technology	0	2	1
SE 151	Intro to Info Tech	1	2	2
ARC 155	Architectural Science I*	2	0	2
FREN 181	French for Com I*	2	0	2
ECON 151	Introductory Econs I*	2	0	2
Total		15	9	17
MATH 152	Mathematics II	4	0	4
ENGL 158	Comm. Skills II	2	0	2
CE 164	Civil Eng. Drawing	1	3	2
CE 156	Elem Fluid Mechanics	2	2	3
CE 154	Prop.of C. Eng. Materials	2	1	2
EE 152	Basic Electronics	2	1	2
MGT 252	Principles of Man. *	2	0	2
ARC 156	Architectural Science II*	2	0	2
FREN 182	French for Comm II*	2	0	2
ECON 152	Intro Economics II*	2	0	2
Total		15	7	17

*Open Elective. Students select only one course each semester.

Table 3 B.Sc. Civil Engineering Course Structure for Year 2

Course No	Course Title	T	P	C
MATH 253	Mathematics III	4	0	4
CE 255	Theory of Structures	2	2	3
CE 251	Strength of Materials	2	1	2
CE 259	Engineering Geology	2	1	2
CE 263	Computer Aided Design	1	2	2
CE257	Computer Program.	1	2	2
CE 261	Principles of Design	1	3	2
ENGL 263	Literature in English I	1	0	1
Total		14	11	18
MATH 254	Mathematics IV	4	0	4
CE 264	Intro Environ. Eng.	2	1	2
CE 260	Soil & Rock Mechanics	2	2	3
CE 256	Fluid Mechanics	2	2	3
GE 282	Large Scale Surveying	2	3	3
ENGL 264	Literature in English II	1	0	1
		13	8	16

Table4 B.Sc. Civil Engineering Course Structure for Year 3

Course No	Course Title	T	P	C
MATH 351	Numerical Methods	2	0	2
MATH 353	Statistics	2	0	2
CE 351	Structural Analysis	2	0	2
CE 359	Soil Mechanics	2	2	3
CE 367	Transportation Eng.	2	0	2
CE 355	Hydrology	2	0	2
CE 353	Reinf. Conc. Design	2	2	3
GE 381	Engineering Surveying	2	3	3
CE 371	Industrial Training	0	8	2
Total		16	7	21
CE 352	Steel & Timber Design	2	2	3
CE 360	Foundation Eng.	2	2	3
CE 364	Environ Quality Eng.	2	2	3
CE 356	Hydraulic Engineering	2	2	3
CE 368	Highway Engineering	2	2	3
CE 376	Civil Eng Quantities	2	0	2
CE 378	Integrated Design	0	4	1
Total		12	14	18

Table 5 B.Sc. Civil Engineering Course Structure for Year 4

Course No	Course Title	T	P	C
CE 497	Civil Eng. Design	0	6	3
CE 461	Eng. Economy & Entre-preneurship	3	0	3
CE 471	Irrig & Drainage Eng.	2	0	2
CE 477	Geotechnical Eng +	3	0	3
CE 457	Drainage Systems+	3	0	3
CE 463	Water & Waste Treat.+	3	0	3
CE 467	Highway Eng+	2	2	3
CE 475	Systems Eng+	3	0	3
CE 473	Development Eng+	3	0	3
CE 451	Structural Eng+	3	0	3
Total		14	8	17
CE 498	Project	0	8	4
CE 462	Construction Man	3	0	3
CE 468	Transportation Eng+	3	0	3
CE 452	Structural Dynamics+	3	0	3
CE 458	Water Resources Eng.+	3	0	3
CE 476	Systems Eng+	3	0	3
CE 464	Environ. Quality Eng.+	3	0	3
CE 478	Geotechnical Eng II+	3	0	3
Total				16

+Elective. Students select at least 3 courses each semester.

A categorization and analysis of the structure of the civil engineering programme in Table 6 shows that the mathematics and statistics courses account for 20 credits and are taken in the first three years, while the Engineering Science and Core engineering courses which comprise the courses in mechanics, properties of materials, spatial measurements and engineering drawing are mostly in the first and second years and account for 46 credits. The applied engineering courses are in the third and final years and account for 64 credits or 46% of the total credits required for graduation.

Table 6 Structure of BSc Civil Engineering Programme

	Year				Total
Course Category	1	2	3	4	
Mathematics and Statistics courses	8	8	4	-	20
Open Electives and communication Skills	8	2	-	-	10
Engineering science and core engineering courses	17	24	5	-	46
Applied Engineering Courses	-	-	30	33	64
Total	33	34	39	33	140

2.3 *Geo-Engineering Content*

The geo-engineering courses in the civil engineering programme are isolated in Table 7. It can be seen that the geo-engineering courses contribute 17 out of the total 110 credit hours or 15% of engineering science, core engineering and applied engineering input required for graduation. It may also be seen that CE 259, CE 260 and CE 359 are categorized as engineering mechanics and core engineering courses, while CE 360, CE 477 and CE 478 are applied engineering courses. The detailed contents of the geo-

engineering courses in the civil engineering programme are summarized in Table 8.

Table 7 Geo-Engineering Courses in B.Sc. Civil Engineering Programme

Year	Course	T	P	C
2	CE 259 Engineering Geology	2	1	2
	CE 260 Soil and Rock Mechanics	2	2	3
3	CE 359 Soil Mechanics	2	2	3
	CE 360 Foundation Engineering	2	2	3
4	CE 477 Geotechnical Engineering I	3	0	3
	CE 478 Geotechnical Engineering II	3	0	3
Total		14	7	17

Table 8 Detailed contents of geo-engineering courses

Course	Content of course
CE 259 Engineering Geology	Structure and chemical composition of earth, Mineralogy, properties of common rock forming minerals, major rocks, formation and properties, Geological structures, geological mapping, sections, classification of rocks, engineering properties
CE 260 Soil and Rock Mechanics	Particle size distribution, Atterberg limits, classification systems, phase relations, compaction, moisture-water content relationships, stress analysis, Mohr's circle, Mohr Coulomb failure criterion, strength measurement in triaxial, direct shear. Stress analysis in rock, properties of rock, rock mass properties, joint analysis and classification, effects
CE 359 Soil Mechanics	1-dimensional flow, effective stress, 2-dimensional flow, basic equation of flow, flow nets, calculation of quantities of flow, uplift forces, permeability, laboratory determination, Physics of consolidation, oedometer test, stress distribution, calculation of settlement
CE 360 Foundation Engineering	Earth pressure theories, coefficients, distribution, Retaining walls, Slope stability, methods of analysis, remedial measures, Bearing capacity, shallow foundation design
CE 477 Geotechnical Engineering I	Site investigation, pile foundation, stability of excavations, braced excavations, Rock Slope Stability Analysis: Rock strength and yield, Discontinuities in Rocks, Behaviour of Rock Masses
CE 478 Geotechnical Engineering II	Expansive soils, earthquakes, Earth and Rock Fill Dams: site investigation and material survey, design criteria, foundation treatment. Geological aspects of groundwater recovery: Hydrologic cycle, measurement of groundwater levels and permeability during site investigations, ground water reservoirs, groundwater abstraction, subsidence and sea water intrusion,

2.4 *Challenges in Teaching*

Over the past decade or so as shown in Table 1, the average class size in the civil engineering programme at KNUST has more than doubled, increasing from 80 in 2000/2001 to almost 200 in 2007/2008 without a commensurate increase in resources. This development poses great challenges in teaching in general but in particular in teaching the heavy laboratory components of CE 260 and CE 359. The challenge has been to give all students a hands-on experience in the laboratory work instead of students observing the tests being done by a laboratory technician. To attempt to get around this the class is broken down into small groups and the laboratory work is scheduled for all available "free" periods throughout the week. Consequently, it takes a long time to complete a given laboratory work and the pacing for the laboratory work and that for the theory class are difficult to synchronize.

The second challenge concerns the fact that students see laboratory work as drudgery and would rather not take part. In order to eliminate this drudgery problem-oriented laboratory assignment has replaced the routine stand-alone laboratory work. In the problem-oriented laboratory work, a simple geotechnical problem is posed and the students have to conduct the laboratory work and use their results as an input for the solution.

2.5 *Specializing in Geotechnical Engineering*

Within the undergraduate civil engineering programme, in the final year, students have a chance to major (specialize) in specific areas in civil engineering by taking certain courses referred to as "electives". In the final year, out of the total of 33 credit hours, students choose up to 18 credit hours in elective courses. The average number of final year students offering CE 477 Geotechnical Engineering I and CE 478 Geotechnical Engineering II as elective courses and the percentage of the students in the final year over the past 9 years are shown in Table 9.

Table 9 Numbers and Percentages of students offering Geotechnical Engineering in Final Year

Year	No. in 4th Year	Average No Registering CE 477 & CE 478	% Registering CE 477 & CE 478
1999/2000	54	14	26%
2000/2001	82	24	29%
2001/2002	67	15	22%
2002/2003	80	21	26%
2003/2004	82	37	45%
2004/2005	132	74	56%
2005/2006	120	46	38%
2006/2007	125	50	40%
2007/2008	186	66	35%

The results show that the number of students taking these courses vary from year to year with the percentage varying from a low 22% in 2001/2002 academic year to a high 56% in 2004/2005. Further analysis shows that on the average 35% of final year students offer geotechnical engineering as an elective and the number has been increasing at an average of about 2% per year since 1999/2000 academic year. This appears to suggest that there is an increasing interest in geotechnical engineering as a specialization in civil engineering education. However,

how this translates into geotechnical engineering practice in Ghana is not clear.

3 GEOTECHNICAL ENGINEERING PRACTICE IN GHANA

3.1 *Registration of Engineers*

In Ghana, the law that regulates the practice of Engineering is the Ghana Institution of Engineers (GhIE) Decree which was passed in 1969. There is a new attempt at better organizing engineering practice in Ghana[2](GhIE, 2003) The GhIE exists to advance the science and profession of engineering to the benefit of society and to establish and manage a register of engineers qualified to practice in Ghana. The membership is categorized into various divisions reflecting the broad types of engineering. The GhIE membership breakdown by divisions for 2005 and for 2006 is shown in Table 10 (GhIE 2006) which clearly shows that civil engineering is the largest single division and accounts for about 50% of all registered engineers.

Table 10 Membership breakdown of GhIE by Division

Division	2005		2006	
	No	Percent	No	Percent
Civil	726	47	887	51
Electrical/Electronic	402	26	434	25
Mechanical/Agric/Marine	319	21	337	19
Chemical/Mining	87	6	89	5
Total	1534	100	1747	100

No systematic estimate of geotechnical engineers in practice in Ghana is available. Over the past few years a new subdivision of the civil division for geological engineers has emerged and according to the GhIE database, this currently has 25 registered members. This number of geological engineers combined with Civil Engineers with geotechnical engineering specialization constitutes the corps of Geo-engineers in the country.

3.2 *The Geotechnical Engineering Market*

Routine geotechnical engineering practice involves the collection and analysis of geotechnical data to guide the planning, design, construction and operation of civil engineering structures. In Ghana geotechnical engineers are routinely consulted on large commercial buildings, roads and bridges. For these structures, geotechnical engineers in Ghana are mainly called upon to do site investigation, construction material prospecting and evaluation and earthworks monitoring. Increasingly, there is the demand that the geotechnical engineer also doubles as a materials engineer. This new demand expands the expectation to include knowledge in concrete and in asphalt technology. The overall civil engineering programme contains sufficient content that adequately prepares students for routine geotechnical engineering practice. However, advanced degree may be required for advanced geotechnical analysis.

The practice of geotechnical engineering is not effectively regulated in Ghana. Private developers rarely do and appear not bound to request for geotechnical investigation. Geotechnical engineering Clients therefore consist mainly of large corporate Clients and the public sector. Relatively larger consulting firms usually consult in other areas of engineering in addition to geotechnical engineering. Firms that specialize in geotechnical consulting are usually very small in size. Most geotechnical firms hire the field equipment and subcontract the testing to one of the few national laboratories available. Consulting for the mining sector in Ghana is dominated by large foreign firms and is outside the scope of this study.

4 CONCLUSIONS

1 The civil engineering programme at KNUST is the only undergraduate civil engineering programme in Ghana and graduates an average of about 134 engineers annually.
2 There has been a large increase in enrolment in civil engineering recently and this poses challenges in the teaching of geo-engineering courses.
3 There appears to be increasing interest in geotechnical engineering as a specialization in civil engineering education.
4 In the civil engineering programme, geo-engineering courses contribute 15% of credits in engineering science, core engineering and applied engineering required for graduation.
5 The civil engineering division of the Ghana Institution of Engineers is the largest division and accounts for about 50% of all categories of registered engineers in the country.
6 The practice of geotechnical engineering in Ghana not effectively regulated and only large corporate firms and government agencies request for geotechnical input for development.

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[2] An Engineers Bill to replace this Decree is pending in parliament