

## **AC 2008-2324: A "GLOBAL" CURRICULUM TO SUPPORT CIVIL ENGINEERING IN DEVELOPING NATIONS**

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# A “Global” Curriculum to Support Civil Engineering in Developing Nations

## Abstract

The Civil Engineering (CE) program at the United States Military Academy (USMA) is a traditional program emphasizing the foundations of civil engineering with a focus on structural engineering. Typically, about 65 percent of the cadets majoring in CE select the United States Army Corps of Engineers as their branch of service following graduation. To ensure that programs maintain relevance, ABET requires that all programs identify their constituencies and demonstrate that the program meets the constituents’ needs. The United States Army, the Corps of Engineers and program graduates are the three principal constituents of the USMA CE program.

Over the last six years, the Army has been involved in ongoing conflict in Iraq and Afghanistan. As directed in Department of Defense Directive 3000.05,<sup>1</sup> the Army and the US Army Corps of Engineers (USACE) has become intensely involved with the development, management, and security of infrastructure as a means to shape success and bring future stability to both countries. Feedback from the field, personal experiences, and common sense have shown that current USMA CE program course requirements may not be optimal for preparing graduates to meet the needs of constituents. The ASCE Body of Knowledge (BOK) has suggested also new curricular requirements which must be considered as part of the program review process. *The Vision for Civil Engineering in 2025*,<sup>2</sup> an ASCE publication, articulates an “aspirational global vision” for the civil engineering profession and includes significant discussion about the need to focus on infrastructure and for civil engineers to find their role in a “radically transformed world.”

In response to these developments, a major curriculum review is underway to ensure the USMA CE program content will prepare graduates to be relevant as Army officers, meet the anticipated requirements of the BOK, and be prepared to function in a radically transformed world. This paper discusses collection and analysis of survey data from constituents, evaluation of the data, and initial development of a revised CE curriculum. The paper also provides a framework for further analysis and development efforts focused on developing a curriculum that will enable its graduates to be relevant, flexible, and ready to face future civil engineering challenges.

## Background

The United States Army has become increasingly involved with the development, management, and security of infrastructure in developing nations, especially in Afghanistan and Iraq. As the nation’s infrastructure manager, USACE is also extensively involved with activities related to infrastructure within the United States (US). Graduates of the USMA CE program who select the Army Corps of Engineers as their branch of service often find themselves involved in activities related to infrastructure during their first and subsequent tours of duty both overseas and in the US. Communications with Army officers serving in the US and deployed in the field and an evaluation of the missions typically faced by engineer units has shown that certain vital

topics may not be covered adequately, if at all, in our CE program. In addition, there has been an increased focus within the CE profession on sustainability and *The Vision for Civil Engineering in 2025* provides encouragement for civil engineers to find their role in a “radically transformed world.”<sup>1</sup>

To ensure that USMA CE graduates are prepared to face the challenges of their first and future assignments, and to ensure that our program maintains its relevance to the Army, the primary constituent of the USMA CE Program, a survey was recently conducted. The survey posed seven questions focused on identifying which CE topics are most useful to graduates. Those surveyed were Army officers, some of whom were recent graduates of the program, and civilians. Many of those surveyed had over 20 years experience working in or around the field of civil engineering. Survey results showed that many topics currently covered in the USMA CE program are highly relevant, while some new topics should be added to the current curriculum to improve its relevance. Graduates of the USMA admittedly serve a unique role upon graduation. However, it can be argued that the skill set they need to be successful as civil engineering leaders in Iraq and Afghanistan is much the same as civil engineers working in other developing nations having limited or inferior infrastructure.

### The Current CE Program

The current CE program at the USMA emphasizes fundamental civil engineering skills with a focus on structural engineering. Figure 1 depicts the last five of eight semesters for a typical program of study with a focus on structures.

4 <sup>th</sup> Semester	5 <sup>th</sup> Semester	6 <sup>th</sup> Semester	7 <sup>th</sup> Semester	8 <sup>th</sup> Semester
<b>CE 300 (L)</b> Mechanics and Design	<b>CE 364 (L)</b> Mechanics of Materials	<b>CE 403</b> Structural Analysis	<b>CE 404 (L)</b> Design of Steel Structures	<b>ME 306 (L)</b> Dynamics
<b>MA 206</b> Probability and Statistics	<b>MA 364</b> Engineering Math	<b>CE 371 (R)</b> Soil Mechanics	<b>CE 483 (R)</b> Design of Concrete Structures	<b>CE 492</b> Design of Structural Systems
<b>PH 202</b> Physics II	<b>ME 311 (L)</b> Thermal Fluid Systems I	<b>CE 380 (R)</b> Hydrology and Hydraulic Design	<b>CE 491</b> Advanced Structural Analysis	<b>CE 489</b> Adv Individual Study in CE
<b>LX 20_</b> Foreign Language	<b>CE390 (R)</b> Site Civil	<b>SS 307 (R)</b> Intl. Relations	<b>CE 471 (L)</b> Adv Wood and Masonry Design	<b>CE 460</b> Construction Management
<b>SS 201</b> or <b>SS 202</b>	<b>PL 300 (L)</b> Military Leadership	<b>EN 302</b> Advanced Composition	<b>LW 403 (L)</b> Const. & Military Law	<b>EE 301 (R)</b> Fundamentals of Electrical Engineering
<b>EV 203</b> or <b>PY 201</b>	<b>HI 301</b> History of the Military Art I	<b>HI 302</b> History of the Military Art II		<b>CE 400</b> CE Seminar

Figure 1. Typical program of study for CE major selecting a structures focus.

The four major technical areas of study included in the program are structural engineering, construction management, geotechnical engineering, and hydrology & hydraulics. Students have several elective choices that allow them to develop breadth predominantly in the structures area. The shaded boxes show the CE specific courses taken by students typically beginning in their fourth semester at the USMA. Other courses shown (not shaded) are part of the USMA core curriculum that is taken by all students. An elective in geotechnical engineering is available within the CE program, and several electives in environmental engineering are also available from outside the program. There is currently not an additional course in construction management or hydrology & hydraulics available within the USMA CE program.

## The Need for Change

Reports from the field have indicated that CE graduates are adequately proficient in the traditional areas of engineering, but lack additional expertise in areas like project management, power generation, transmission and distribution, geomatics, and infrastructure assessment. The term “SWEAT” which is an acronym standing for Sewage, Water, Electricity, Academics and Trash is a term coined by the Army Corps of Engineers as a result of ongoing operations in Iraq and Afghanistan. It is thought that “SWEAT” provides focus for infrastructure engineering efforts in developing nations. Other renditions of “SWEAT” exist—most provide largely the same focus.

In order to accurately collect information on required subject areas, a survey was assembled and posted on-line using a commercial survey instrument. The survey was made intentionally short containing only seven questions such that those sent the survey would be more likely to respond. The survey was sent to approximately 100 people of whom about 60 responded in total. Two survey versions were used—one focused on respondents having served in the military and one focused on civilians not having served in uniform, but being familiar with circumstances surrounding the practice of civil engineering. The surveys were almost identical and differed only subtly in wording between the military and civilian versions. A sample of the “military” survey is shown as Enclosure 1. Several questions on the survey were focused specifically on the proficiency of Corps of Engineers officers; this paper does not include discussion of those areas. Instead, it focuses on responses related to questions 4 and 6 that attempt to identify which topics are most relevant for graduates’ preparation for service as Army engineers in the next 10-20 years.

In question 6 of the survey, participants were asked to rank-order areas of civil engineering into three categories— **essential topic**, must have in the curriculum, **important topic**, very useful to have in the curriculum, and **nice to have topic**, include in the curriculum if possible after all 1- and 2-rated topics are included. Results for the “essential” category are as listed below in Table 1. Fifty percent or more of the survey participants identified the topics in Table 1 as “essential.” The fact that construction and project management finished first on the list for essential topics was not a surprise based on the reported need for graduates to manage construction as part of ongoing CE projects in Iraq and Afghanistan. The third place finish for structural engineering was unexpected, but provided confirmation that the current curriculum is largely valid and may help explain why graduates of the current curriculum generally have been successful.

Table 1. Essential topics for CE in developing nations.

Rank	Civil Engineering Topic	Percent Responding
1	Construction & Project Management	94%
2	Infrastructure Assessment	76%
3	Structural Engineering	60%
4	Infrastructure Maintenance and Management	50%

Results for the “important” category are listed in Table 2. Sixty six percent or more of the survey participants identified the topics below as “important.” In examining the data, there is only a 14 percent spread from the top-ranked to the bottom-ranked item, not a significant variation, indicating that all topics were considered similarly necessary in determining a graduate’s relevance. The placement of urban and regional planning above wastewater, transportation, and power generation and distribution showed the need for initial planning to enable efficient and correct placement and operation of other critical infrastructure items.

Table 2. Important topics for CE in developing nations.

Rank	Civil Engineering Topic	Percent Responding
1	Geotechnical Engineering	84%
2	Hydraulics and Hydrology	82%
3	Water Resources Engineering and Management	80%
4	Urban and Regional Planning	80%
5	Geomatics (Surveying, GPS and GIS)	78%
6	Wastewater (gray/black) and Solid Waste Management	76%
7	Transportation Engineering	74%
8	Power Generation and Distribution	74%
9	Information Technology	70%

### Guidance for Developing a Solution

Several requirements exist that must be met in developing a more relevant CE curriculum.

- It is necessary for the CE Program to maintain ABET accreditation. The proposed solution must continue to robustly satisfy the ABET Criterion 3a-k. It must also offer flexibility and be forward thinking enough to satisfy the requirements of the Body of Knowledge as spelled out in ASCE Policy 465.
- The curriculum must seek to satisfy needs identified in the survey. The acronym SWEAT was verified in the surveys, but a slightly modified acronym “**SWETT**” standing for **S**ewage, **W**ater, **E**lectrical, **T**rash and **T**ransportation was defined. The “A” in SWEAT represented “Academics;” the development of schools did not fit within the scope of the civil engineering program. The need for transportation expertise seemed necessary based both on the survey, and the common sense realization that a transportation network is vitally necessary to support commerce within a nation.
- The curriculum must offer students options in their programs of study other than just the structures area. Students want to take additional courses in hydrology, geotechnical engineering, and construction management as well as other areas. The students want to

be relevant to the Army and the program must take note of this desire and make it a reality for them.

- The curriculum must be efficient. With a relatively small faculty, the program cannot offer large numbers of electives, but must concentrate on fewer high quality electives in major areas of study. In addition, with only a finite amount of student time, the curriculum can ill-afford to be repetitive or cover material that is felt unnecessary.
- The CE curriculum, along with the core curriculum, must provide students fundamental CE skills that will enable them to take and pass the Fundamentals of Engineering (FE) exam.
- The combination of courses that have traditionally been stand-alone bellwether CE courses is acceptable. There is history of such course combinations at the USMA that have produced efficiencies and have freed space for other curricular material. With the onset of the ASCE BOK, the coverage of additional topics within current courses promotes further efficiency.
- Finally, there can be no increase in the number of credit hours required for a BSCE.

The intent is for curriculum development teams within the USMA CE faculty to focus their efforts using the above guidelines to develop a new or modified program of study that is highly relevant to the Army and enables graduates to “find their role in a radically transformed world.”

### **An Initial Solution**

Definitions of the current courses are as follows in Table 3. Working within the confines of the current USMA core curriculum, and following the guidance above, an initial CE curriculum was developed for use as a starting point for further development. The initial solution is by no means the final solution—it merely offers a “first try” at fitting the requirements into a viable option. Table 4 shows the initial solution and lists courses in the USMA CE program as they currently exist as well as newly proposed courses that seek to change and augment the current course structure to satisfy the requirements of “SWETT.” Some courses have the designation (L) following them indicating the course is double blocked to facilitate a specified number of two-hour periods. The traditional period is one-hour at the USMA. Courses designated with an (R) following them indicate a course that has eight two-hour lab periods that occur outside of the normally scheduled class hour.

Table 3. Definitions of courses in the current USMA CE program

<b>CE300:</b> Fundamentals of Engineering Mechanics and Design	<b>CE471:</b> Timber and Masonry (elective)
<b>CE364:</b> Mechanics of Materials	<b>CE472:</b> Foundation Design (elective)
<b>CE371:</b> Soil Mechanics	<b>CE483:</b> Reinforced Concrete
<b>CE380:</b> Hydrology and Hydraulics	<b>CE492:</b> CE Capstone Concrete
<b>CE390:</b> Site Civil Engineering	<b>MA364:</b> Engineering Math
<b>CE400:</b> CE Professional Practice Seminar	<b>ME306:</b> Dynamics
<b>CE403:</b> Structural Analysis	<b>ME311:</b> Thermal Fluid Sciences I
<b>CE404:</b> Structural Steel Design	<b>EE301:</b> Electrical Engineering I
<b>CE460:</b> Construction Management	

Table 4. An initial solution for the revised USMA CE curriculum

Current Course	Credit Hours	Proposed Course	Credit Hours	Comments
CE300	3.0 (L)	CE300	3.0 (L)	CE300 remains the same
CE364	3.5 (L)	CE364	3.5 (L)	CE364 remains the same
CE390	3.5 (R)	CE350	3.0	CE390 is revised to become a 3.0 CH civil site engineering course (CE350) with the remaining 0.5 CH (lab portion of course) transferred to CE360, a new course in Geomatics. Basic transportation fundamentals are covered in CE350.
		CE360	3.5 (R)	<b>New</b> required course entitled <b>Geomatics</b> that captures the 0.5 CH lab components from CE390 and features survey techniques, the use of GPS and the use of GIS systems. 3.0 CH for this course is provided by the combination and removal of CE404 and CE483.
MA364	3.0	CE340	3.0	<b>New</b> required course entitled <b>Engineering Fundamentals</b> that includes 1.5 CH of dynamics from the former ME306 and 1.5 CH of electrical engineering from the former EE301. The math requirement is sufficiently covered in the core math curriculum and in applications in CE Courses. 3.0 CH for this course is provided by the removal of MA364.
ME311	3.5 (L)	ME311	3.5 (L)	ME311 remains the same
CE403	3.0	CE403	3.0	CE403 remains the same
CE371	3.5 (R)	CE371	3.5 (R)	CE371 remains the same
CE380	3.5 (R)	CE380	3.5 (R)	CE380 remains the same
CE404	3.0 (L)	CE470	3.5 (R)	<b>New</b> required course entitled <b>Structures I</b> that includes parts of CE404 (Steel) and CE483 (Concrete). CE404 and CE483 would be removed from the curriculum. The lab component of this course would be made-up primarily with concrete topics. The 3 CH made available by combining these courses provides 3.0 CH for CE360.
CE483	3.5 (R)			
CE400	1.0	CE400	1.0	CE400 remains the same
CE460	3.0	CE460	3.0	CE460 remains the same
CE492	3.0	CE492	3.0	CE492 remains the same
ME306	3.0			1.5 CH from ME306 goes to the new course entitled Engineering Fundamentals, CE340. 3.0 CH is available from the removal of this course.
EE301	3.5 (R)	CE490	3.5	<b>New</b> required course entitled <b>Infrastructure I</b> . The 3.5 CH for this course came from ME306 (3.0 CH) and EE301 (0.5 CH). The anticipated topics include water supply, treatment, and distribution; wastewater collection and treatment; solid waste management; and basic transportation systems.
46.5 Total Req'd CH 9.0 Total Elective CH		43.5 Total Req'd CH 12.0 Total Elective CH		
Elective	3.0	Elective	3.0	
Elective	3.0	Elective	3.0	
Elective	3.0	Elective	3.0	
These electives are currently chosen from a list of "field" and "engineering" electives.		Elective	3.0	
Total CH = 55.5		Total CH = 55.5		

Table 5 depicts the current and newly proposed CE electives to accompany the required course in Table 4. The addition of CE451 (Urban Planning) and CE491 (Infrastructure II), along with the current CE electives, now provides students the option of gaining additional experience in each of the four main technical areas of study.

Table 5. New and existing CE elective choices

CE451	3.0	<b>New</b> elective course entitled <b>Urban and Regional Planning</b>
CE471	3.0	Elective course entitled <b>Structures II</b> that includes timber and masonry.
CE472	3.0	Elective course entitled <b>Foundation Design</b>
CE491	3.0	<b>New</b> elective course entitled <b>Infrastructure II</b> . The anticipated topics include the development, assessment, maintenance and security of integrated infrastructure systems.
EE377	3.0	Elective course in <b>Power Generation and Distribution</b> . Prerequisite electrical engineering content (normally taken in EE301) for EE377 can be taken from the new course in Engineering Fundamentals, CE340. It is possible that this may become a required course in place of a planned elective.

## Results of Initial Curriculum Development

The initial revised curriculum shows that it is no longer possible, in many cases, to maintain courses that are single-topic specific. It is necessary to merge course content and creatively package course material to create adequate free-space in the program of study such that students have options and are able to select electives in areas that interest them. With the onset of more powerful technology, there are hardware and software that were not available 20 years ago. This has changed the face of civil engineering and must be discussed if the curriculum is to maintain its relevance. Review for the purpose of continuous improvement is absolutely required.

## The Road Ahead

With an initial revised curriculum established, further iterations are now possible to refine and improve the plan. Development of course objectives for new courses can take place as well as crosswalks between the courses to ensure topics are well nested and supported between courses. Survey of the constituencies must also proceed to ensure continuous improvement and to maintain relevance of the curriculum with the practice of CE. With the increasing pace of change, the only constant will be change itself.

## Bibliography

1. Department of Defense Directive 3000.05, *Military Support for Stability, Security, Transition, and Reconstruction (SSTR) Operations*, November 28, 2005, 11 pp.
2. *The Vision for Civil Engineering in 2025*, prepared by the ASCE Steering Committee to Plan a Summit on the Future of the Civil Engineering Profession in 2025, American Society of Civil Engineers, 2007, 103 pp.

**Enclosure 1 - USMA Civil Engineering Curriculum Survey (Fall, 2007)**

*As part of the USMA Civil Engineering Program curriculum revision and update process, we are soliciting input to the following questions to better shape our undergraduate program. Please answer the following questions as completely and candidly as possible based on your experiences and your beliefs about the skills our civil engineering graduates should have to be successful in the future.*

1. What is your current position, grade, and branch? What undergraduate degree do you hold? What advanced degrees do you hold?

2. What single engineering topic or course, in an undergraduate curriculum, would have benefited you the most in your current or a recently held position?

3. **To be answered by active duty engineer officers above the rank of Captain:** Do you feel that new engineer lieutenants are adequately prepared to contribute to the fight? Do they have the civil engineering fundamentals required to complete their missions? If not, what skills need the most improvement?

4. Using the scale below, please rate the importance of the following curricular topics with respect to their relevance to USMA graduates' preparation for service as Army engineers in the next 10-20 years.

**1 - Essential topic**, must have in the curriculum

**2 - Important topic**, very useful to have in the curriculum

**3 - Nice to have topic**, include in the curriculum if possible after all 1- and 2-rated topics are included

- \_\_\_\_\_ Construction/project management
- \_\_\_\_\_ Computer aided design and drafting (CADD)
- \_\_\_\_\_ Computer simulation and visualization
- \_\_\_\_\_ Geomatics (surveying, GPS and GIS)
- \_\_\_\_\_ Geotechnical engineering
- \_\_\_\_\_ Hydraulics and hydrology
- \_\_\_\_\_ Information technology
- \_\_\_\_\_ Infrastructure assessment
- \_\_\_\_\_ Infrastructure maintenance and management
- \_\_\_\_\_ Power generation and distribution
- \_\_\_\_\_ Structural engineering
- \_\_\_\_\_ Transportation engineering
- \_\_\_\_\_ Urban and regional planning
- \_\_\_\_\_ Wastewater (gray/black) and solid waste (solid/industrial/hazardous waste/trash) management
- \_\_\_\_\_ Water resources engineering and management (for agricultural, industrial and human consumption)
- \_\_\_\_\_ Other (please specify)\_\_\_\_\_

5. What is your experience with the following teams/systems? What rank did you hold and what position did you serve on the team? Is the team/system effective in theater? What function do civil engineers serve in each?

Provincial Reconstruction Team (PRT):

Field Engineering Support (FES) Team:

Reach-back Technology: (VTC, TEOC, EI2RC)

6. As we assemble our new undergraduate civil engineering program, what skills do you believe our graduates will need in 2012 (5 years from now)?

7. If you could teach one thing about civil engineering to every officer (not just Engineer officers) in the Army, what would it be?