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GEOSYNTHETIC EDUCATION LIMITATIONS WITHIN AN ENGINEERING COLLEGE CURRICULUM: WHAT ARE THE ISSUES?

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ABSTRACT

The geosynthetic community is searching for methods to educate engineering students about geosynthetic products, increasing their awareness of the usefulness of geosynthetic materials. This paper summarizes the engineering curriculum and explains the levels of engineering education. This paper further explains how engineering programs must meet specific curriculum requirements in order to be accredited by the Accreditation Board for Engineering and Technology (ABET), and identifies who determines the components of the engineering programs. This paper details how these engineering programs are evaluated by ABET, National Council of Examiners for Engineering and Surveying (NCEES), and by the public. Typical goals of the engineering program are denoted, as are how this relates to the ability of the graduating engineer to obtain a professional engineering license. This paper concludes with approaches that may increase geosynthetic education.

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1. INTRODUCTION

From the first day we are born, we are learning. We start by simply grasping a finger or rattle, to crawling, to walking, to riding a bike, etc. We start learning that crying will get our parents attention, that we should share our toys, that lying or cheating is wrong, and how to be a friend. We start by learning our ABC's, by reading and writing and applying arithmetic, to algebra, etc. Each area of learning is built upon what was previously learned. In 1956, Dr. Benjamin Bloom, et.al, published "Taxonomy of Educational Objectives", which is a way of distinguishing the fundamental questions of the education system. Within Bloom's Taxonomy, education is denoted within three specific domains. These are:

- Psychomotor Domain – the ability to physically manipulate a tool or instrument;
- Affective Domain – describes the way people react emotionally (e.g. attitudes); and
- Cognitive Domain – encompasses knowledge, comprehension, and critical thinking.

This paper describes the cognitive domain as it relates geosynthetic education. It also details the educational approach to a civil engineering education. Once this fundamental knowledge of the educational system is established, this paper will denote the issues and organizations that establish the goals of a civil engineering curriculum, and how these hinder the inclusion of geosynthetic technology within the curriculum. This paper will conclude with recommendations on how to improve the likelihood of including geosynthetic technology as a component of future engineering curricula.

2. ASSESSMENT OF COGNITIVE KNOWLEDGE

Bloom's Taxonomy uses action verbs to classify the different objectives of the education process. Each classification denotes a specific level of knowledge, skill and ability. The progression of these objectives is knowledge, comprehension, application, analysis, synthesis and evaluation. Table 1 lists various action verbs for the specific education objectives.

An individual goes through the above levels of education over and over again. Each area of new knowledge is built upon previous knowledge. For example, the knowledge learned in college is built upon coursework taken in high school. If we apply Bloom's Taxonomy to the knowledge of geosynthetics, Table 2 shows the general assessment of geosynthetic knowledge for different levels of achievement.

Please note, what constitutes each level of knowledge assessment is a subject of debate even among the experts in a field of study. For geogrid Level 1 knowledge, is it sufficient to simply know a geogrid is a plastic construction material, or does the individual also need know the type of polymer of which it is made? What is typically not subject to debate are the six levels of knowledge denoted in Tables 1 and 2.

Table 1 – Bloom's Taxonomy

Level	Definition	Illustrative Behavioral (Action) Verbs
1. Knowledge	Remembering previously learned material. It is the lowest level of the learning outcomes.	Define; describe; identify; name; recognize; state.
2. Comprehension	Ability to grasp the meaning of material. It is the lowest level of understanding.	Classify; describe; discuss; give examples; organize; summarize.
3. Application	Ability to use learned material in new and concrete situations. It requires a higher level of understanding.	Apply; calculate; chart; demonstrate; implement; show; solve; use.
4. Analysis	Ability to break down material into its component parts so that its organization structure is understood. It requires an understanding of both the content and structural form of the material.	Analyze; break down; differentiate; distinguish; separate; subdivide.
5. Synthesis	Ability to put parts together to form a new whole. It requires creative behaviors, with emphasis of formulation of new patterns or structures.	Adapt; collaborate; compose; design; devise; incorporate; modify; reorganize.
6. Evaluation	Ability to judge the value of material for a given purpose. This is the highest level because it requires value judgement based on clearly defined criteria.	Appraise; compare and contrast; conclude; critique; defend; judge; justify.

Table 2 – Levels of Knowledge of a Geogrid

Level	Illustrative Behavior
Knowledge	The ability to know a geogrid is an engineered material made of plastic produced in a grid structure and used in various earthen structures.
Comprehension	The ability to understand and state a geogrid is a polymeric construction material used for soil reinforcement. Typical uses for a geogrid include foundation strengthening for roadways and segmental retaining walls.
Application	The ability to calculate the pull-out resistance of geogrid under specific design conditions.
Analysis	The ability to assess how a geogrid is used in an engineered structure and the design conditions for which it must function.
Synthesis	The ability to design a structure using geogrids as one of its components and have it meet specific design requirements.
Evaluation	The ability to examine the geogrid design and its function within the structure to determine the quality and completeness of the structure.

3. CIVIL ENGINEERING CURRICULUM

The basic framework of civil engineering education starts with the base courses of calculus, physics, introduction to engineering, etc., along with a few general education courses (Figure 1). These courses are required, as prerequisites, for the next level of education, which is "engineering sciences." This includes courses such as statics, dynamics, material sciences, mechanics of material, etc. The engineering students are then introduced to various areas of civil engineering through the Principles of "…" coursework (i.e. transportation, hydrology, structures, etc.). Only after the student has gained the needed knowledge of fundamental math, sciences, engineering sciences, and Principles of "…" do they take the design courses that form the basic components of an "engineered" structure or system. The final component of the individual's civil engineering education is the Capstone Design Course(s). As the capstone to their engineering education, the student is required to take the knowledge collectively learned from all the previous courses and apply this knowledge to an engineering project within a selected area of study. This capstone course is done in association with an organization outside of the university, such as the State Department of Transportation, consulting engineering firm, industry, etc.

The student must complete the civil engineering program curriculum prior to graduating from the engineering college. The average number of credit hours required for graduation ranges from 126 to 128 credit hours. This graduation requirement is down substantially from approximately 148 credit hours that was common 25 years ago. However, the field of engineering and associated technologies is continuing to expand. Based on the restricted time allocated for teaching each course, civil engineering programs are forced to limit the magnitude of material included within their courses. Civil engineering programs also select specific areas of civil engineering upon which to focus their programs, while still meeting program certification requirements. What is program certification and how does it impact what is being taught with the civil engineering program? To understand this, one must first understand who the decision-makers are, and their roles in what is learned within the civil engineering curriculum.

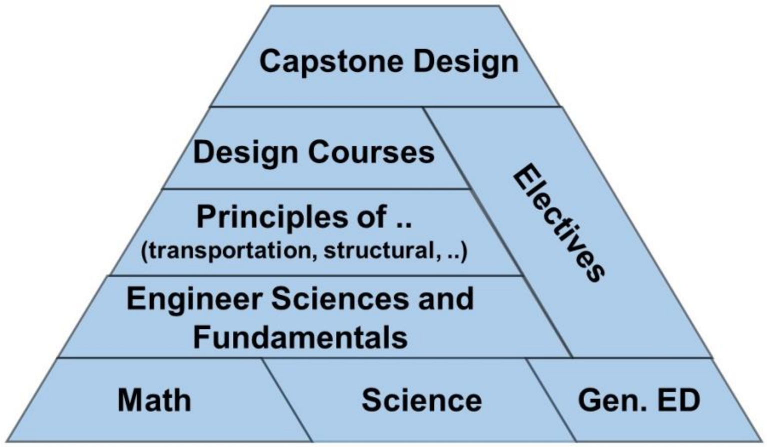

Figure 1 – Framework of Civil Engineering Curriculum

4. ORGANIZATIONS THAT IMPACT THE CIVIL ENGINEERING PROGRAM CURRICULUM

Each of the following organizations has a significant impact on the curriculum of a civil engineering program. However, none of the following organizations have what may be considered the "overall" responsibility for what is being taught within civil engineering colleges of the United States. A primary objective or goal of each organization is to have civil engineering graduates capable of entering into the professional practice of engineering.

4.1 Engineering College and Faculty

A civil engineering college is typically started to address a need by the state or specific region of a state/United States. For example, there may be a need in a state or region for water management or stormwater control. The program will then specialize in research and education to address that particular need. A program may also focus on a particular area of research and study due to the expertise of a certain faculty member or members.

4.2 Local Industry and Industry Advisory Board

Engineering programs can be established to furnish engineers for local industry. For example, engineering colleges near Detroit developed automotive engineering programs to support the automotive industry. Each civil engineering program has an Industry Advisory Board (IAB) primarily composed of local engineers. The purpose of the IAB is to keep the faculty of the engineering program informed regarding possible areas of future courses, weaknesses within the program, or in what direction the program should grow. The IAB represents the industry, consulting firms, and state agencies that hire their graduating students. It has significant influence in what the college should be teaching. Establishment of the IAB and obtaining their input regarding the program is a significant component of the program's accreditation process.

4.3 Abet-Engineering Accreditation Commission

In order to obtain a Professional Engineering (PE) license, all states require the individual to be a graduate of an undergraduate engineering program accredited by ABET, or its equivalent. ABET (formerly known as Accreditation Board for Engineering and Technologies, Inc.) is an organization hired by engineering colleges to review and accredit its engineering programs. Formerly established to review only engineering programs, the organization has grown to accredit disciplines of applied science, computing, engineering and engineering technology. Each discipline has its own commission, which establishes the general criteria for accreditation. The Engineering Accreditation Commission (EAC) establishes the general criteria, policies and procedures for review of all engineering programs. Individual engineering programs may have additional requirements established by the associated society (e.g. American Society of Civil Engineering (ASCE) for civil engineering programs), which must be approved by the EAC Board. A list of the EAC requirements for civil engineering programs is denoted in Table 3.

Table 3 – Curriculum Requirements for a Civil Engineering Program

ABET-EAC	Math and science – 1 year (32 credit hours) Engineering topics – 1 ½ years (48 credit hours) General education component – Open to college. (Range 18 to 26 credit hours)
ABET-EAC – Civil Engineering	Four technical areas of study (e.g. structural, geotechnical, transportation, etc.) Design a system, component, or process in more than one civil engineering context (i.e. design course).

Please note that the total credit hours for the EAC curriculum requirements are, on average, 102 credit hours. As stated earlier, a typical credit hour requirement to graduate from a civil engineering program is approximately 126 to 128 credit hours. The difference in credit hour requirements is where a civil program has the flexibility to make its program unique and still meet the requirements established by ASCE.

4.4 NATIONAL COUNCIL OF EXAMINERS FOR ENGINEERING AND SURVEYING

Another requirement for an individual to obtain a PE license is passing the Fundamentals of Engineering (FE) Exam, administered by the NCEES. The FE Exam is usually taken by the undergraduate students during their senior year. The test is broken into two components. All engineering test participants must take the first component, which covers courses all engineers must take, such as math, science and areas of fundamental engineering science (e.g. statics). The test participant can select a specific area of engineering for the second component of the exam (i.e. civil, environmental, mechanical, etc.) This second component of the exam will test the participant on a higher level of knowledge of engineering sciences (e.g. slope stability calculation) and design of components (e.g. circular pipe head loss). The FE Exam does not test the participant's knowledge of multi-component designs or systems. The student participant's knowledge obtained from the higher level design courses and capstone course(s) (Figure 1) is tested within the PE

Exam, which is taken after the individual completes four years of progressive experience in a specific area of engineering practice.

Engineering colleges use a review of the students FE Exam results of as one of the methods to self-assess the quality of their program(s). The FE Reference Handbook denotes areas of knowledge required to pass the FE Exam. This results in the engineering faculty developing the content of each course to make sure they cover the subject areas of the FE Exam.

NCEES performs a review of the subject areas of the FE Exam approximately every six years. Engineering areas of current significance tend to be included in the upcoming revision FE Exam. The new areas of significance are eventually incorporated into the engineering curriculum.

5. LACK OF GEOSYNTHETIC TECHNOLOGY IN THE ENGINEERING CURRICULUM

As stated above, the curriculum of a civil engineering program is developed by the state or local region's need to address a particular issue or issues, area(s) of expertise of the faculty, and/or requests of the industries that hire the program graduates. Since geosynthetic materials can be used in numerous study areas of civil engineering, it is unlikely that geosynthetics cannot be used to address state and/or regional issues. The same can be said about the expertise of the faculty. Civil engineering faculties are aware of geosynthetic materials and their use within engineered structures. ABET accredits over 600 civil engineering programs, mostly in the United States. However, only a small percentage of these programs are noted for teaching and doing research in geosynthetic technology. As engineering students progress through their degrees (i.e. Bachelors, Masters and Doctorate) to become college professors, unless the student is exposed to geosynthetics within the undergraduate curriculum, it is unlikely the college professor will develop the confidence to teach students about geosynthetic materials within their courses. This will be explained further in the text below. A civil engineering program will hire an instructor with geosynthetic knowledge or ask a current professor to attain the necessary geosynthetic knowledge to incorporate it into the course "if the IAB or significant number of members from local industry" requests graduates with such knowledge.

An engineer must have knowledge of geosynthetics and confidence in its use in order to use geosynthetic materials in their design. If so, what needs to happen first? Does the college need to teach geosynthetic technology in order for the industry to begin using geosynthetic materials, or does the industry need to see the significance of using geosynthetic materials and ask the local civil engineering program to teach geosynthetics. This is a typical chicken or egg scenario. Both the instructor and the user must reach a particular level of geosynthetic knowledge. Both the instructor and the user typically need to start gaining this knowledge within the undergraduate program.

6. HOW FUNDING HAS IMPACTED THE ENGINEERING CURRICULUM

Starting in the early 1980's, the average annual inflation in the cost of college tuition has increased at a rate approximately twice the average annual general inflation rate. Depending on the data source, this rate of tuition increase has resulted in current tuition costs 2.5 to 5 times greater than the cost of tuition 30 years ago. The higher cost of tuition has brought about pressure to reduce the number of credits hours required to obtain a Bachelor's degree in civil engineering. This pressure to reduce credit hours is coming from two sources. First, the parents of the engineering students started to review the cost per credit hour versus the number credits hours required to obtain an engineering degree. To these parents, the difference of a few additional credits hour requirements to obtain a degree made selecting an engineering college more of a financial consideration. Engineering colleges started reducing engineering credit hour requirements in order to be more financially competitive with other institutions. Second, state universities are financially supported by their state government at a ratio of $2 to $3 for every $1 collected from tuition. Due to the dramatic increase in annual yearly college tuition, state governments have been experiencing a dramatic increase in costs for funding higher education. State legislatures have noticed that almost all non-engineering colleges require only 120 credit hours to obtain a degree. Thirty years ago, engineering degrees typically required 148 to 150 credit hours to obtain a degree. In order to plan future funding for higher education, state legislatures have resisted funding programs that require more than 120 credit hours to obtain a degree. Engineering colleges have slowly relented to this funding pressure from their state legislature by reducing the number of credit hours necessary to obtain a bachelor's degree.

Civil engineering colleges have to continually re-assess what is being taught in their curriculum, as the reduction of graduation credit hour requirements is expected to continue to 120 credit hours. Engineering colleges tend to emphasize traditional technologies within various civil engineering study areas, finding it extremely difficult to include additional study material within their coursework and/or modify a course to include new technologies.

7. WHAT ARE THE PRE-REQUISITE COURSES OF THE ENGINEERING CURRICULUM?

As seen in Table 3, ABET-EAC does not denote the courses or the specific topics within the course for an accredited civil engineering program. However, the type of courses required for an engineering education and their content have remained standardized for decades. These fundamental math, science, engineering science and engineering fundamental courses are denoted in Table 4. The content of these courses are based on the prerequisite knowledge required for higher level courses. The content can be adjusted slightly at the request of the IAB. However, the content of each course should never exclude the topics noted within the FE Exam. Since the terminology or names of the engineering courses differ slightly from one university to another, this paper will either use generic names (e.g., calculus) or those course names from the University of Iowa, Civil Engineering College curriculum as standard terms for this discussion.

Table 4 – Pre-requisite Engineering Curriculum Courses

Subject Area	Courses
Math	Calculus Differential equations Probability and statistics
Science	Chemistry Physics
Engineering science	Soil mechanics Fluid mechanics Material science Mechanics of materials, etc.
Engineering fundamentals	Statics Dynamics Thermodynamics Earth sciences

8. WHERE TO INSERT GEOSYNTHETIC TECHNOLOGY WITHIN THE CURRICULUM

As stated previously is this paper, it is important to realize the levels of knowledge development. If all knowledge is built upon what was previously learned, to fully understand geosynthetic technology, it is important realize the significance of previously learned knowledge. This paper will use the analogy of a "steel beam" as an example of an engineered material for the development of knowledge, and show the comparison to a geosynthetic material, such as a geogrid. Using Bloom's Levels of Knowledge, Table 5 is an extension of Table 2 to denote where geosynthetic knowledge is gained. For ease of review, Figure 1 is repeated after this table.

8.1 Knowledge of Geosynthetics

The first awareness of a geosynthetic materials used in engineering design should typically occur in the Principles of "…" courses or the soil mechanics course, as shown in Table 5. Each of these courses has the same prerequisites. For example, although many people have the basic knowledge of a steel beam and its use, the steel beam is first recognized within a specific course(s) of the engineering education program, such as the "Principles of Structures" course.

8.2 Comprehension

Table 5 shows that the comprehension of a geogrid starts within the chemistry course and is greatly influenced by the various engineering sciences. Although the Principles of "…" course(s) can show the function or use of a geogrid, this would be considered a "macro" view of a geogrid. The basic sciences and engineering science address more of the "micro" view of the composition of the geogrid material. For example, we know that a steel beam is an alloy of iron (Fe), carbon (C) and other elements. We know that the iron within the engineered material can oxidize or rust. We know steel has a crystalline microstructure. Its microstructure relates to its strength and brittleness. We also know steel can crack due to fatigue. Knowledge of chemistry and engineering sciences allows the engineer to understand the strength and limitations of an engineered material. The engineer knows not to place a steel beam in an environment where it will tend to deteriorate over time. The engineer should also know that the polymer of the geogrid will "creep" over time and is subject to damage during installation due to its soft nature.

Can an engineer design a structure using a geogrid without full comprehension gained through the science and engineering sciences courses? The answer is "Yes." However, the ability to use geosynthetic materials successfully is greatly improved if the engineer has the micro knowledge of geosynthetic.

Table 5 – Geosynthetic Knowledge within the Civil Engineering Curriculum

Level	Illustrative Behavior	Engineering Courses
1. Knowledge	The ability to know a geogrid is an engineered material made of plastic produced in a grid structure and used in various earthen structures.	Soil Mechanics, Principles of "…" (e.g. Transportation Engineering, Structural Engineering, Hydraulics and Hydrology, etc.
2. Comprehension	The ability to understand and state a geogrid is a polymeric construction material used for soil reinforcement. Typical uses for a geogrid include foundation strengthening for roadways and segmental retaining walls.	Chemistry, Material Science, Soil Mechanics, Mechanics of Materials, Principles of "…", Civil Engineering Materials.
3. Application	The ability to calculate the pull-out resistance of geogrid under specific design conditions.	Statics, Soil Mechanics, Mechanics of Materials, Principles of "…", Civil Engineering Material, Foundation of Structures, etc.
4. Analysis	The ability to assess how a geogrid is used in an engineered structure and the design conditions for which it must function.	Principle of "…" and Design courses.
5. Synthesis	The ability to design a structure using geogrids as one of its components and have it meet specific design requirements.	Design and Capstone Courses.
6. Evaluation	The ability to exam the geogrid design and its function with the structure to determine quality and completeness this structure.	Capstone course(s).

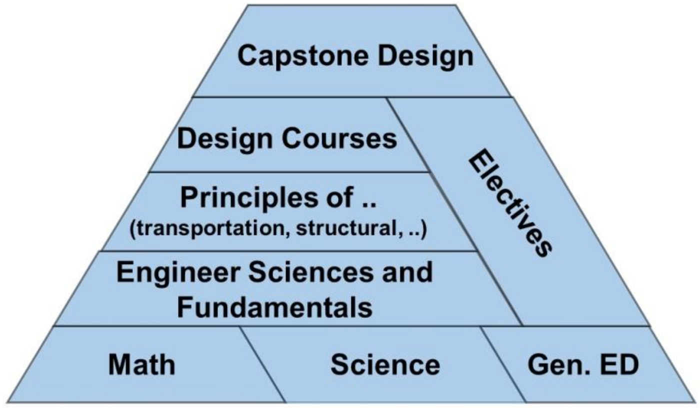

Figure 1(Repeat) – Framework of Civil Engineering Curriculum

8.3 Application

The ability to design a structure with an engineered material starts with calculating the forces acting upon a single element of this material. For example, steel beams are designed based on the forces of loads acting upon it. Once students learn how to design a steel beam, they can start to design a system of beams or structure in the more advanced design courses. If the same learning sequence is used for a geogrid, the student must first learn to calculate the necessary length of a geogrid element placed within a known soil matrix to resist a stated force. The student can then proceed to design a segmental retaining wall of known dimensions in the more advanced design courses.

8.4 Analysis

Example designs form the basis of learning for this level of knowledge. The student sees typical designs using a particular construction material. However, the students must not only understand how the material is being used within the design, they must also understand the forces reacting on that material and associated component(s) within the structure that allows it to function. For a steel beam structure, students must not only understand the framework of the structure, they must also be able to determine which cross beams resist lateral forces, observe beam connections, type of foundation supports, and loads it must support. For a structure using a geogrid, students must not only see where the geogrid is placed, they must also note the spacing of the geogrids, type of drainage along the segmental retaining wall, and wall geometry.

8.5 Synthesis

The next higher level of knowledge is to design a structure based on specific design conditions and utilizing the knowledge gained from previous courses. For a steel beam structure, students are not only required to design the beams for the structure based on the loads applied to the structure, they must understand the environment for which it must function, quality of the soil foundation, and design the connections. For a geogrid in a retaining wall, students not only calculate the strength and length of the geogrid, they must also design the drainage along the wall and method to discharge the collected water, the spacing of the geogrid and type of retaining wall.

8.6 Evaluation

The evaluation level of knowledge requires the student to perform critical thinking on the review of a design. This critical thinking process usually includes a close examination of the design and a series of questions. These questions could be as follows:

- Are all components in place as necessary to constitute a successful design?
- What are the areas within the design for which there is some uncertainty in the design parameters?
- Could the objectives be accomplished within an alternate design?
- What are the strengths and weaknesses of the design?

The student may obtain some measure of accomplishment for this final level of knowledge within the Capstone course. However, the accomplishment of this sixth level is usually obtained after the student has graduated and gained years of design experience.

9. WHAT CAN BE DONE TO CHANGE THE PARADIGM OF GEOSYNTHETIC EDUCATION?

9.1 Past Approaches to Geosynthetic Education

Most civil engineers graduate from civil engineering programs that do not include geosynthetic materials within their fundamental engineering sciences course. Within the Principles of "…" course, geosynthetic materials may be denoted within specific applications of a study area. However, these materials are usually not included in design courses. If an engineer needs to learn about a geosynthetic material, publications and continuing education courses (i.e. webinars, seminars and workshops) represent typical pathways to obtain geosynthetic knowledge after graduation. Continuing education courses on geosynthetics almost always start at Level 3 of Knowledge development (i.e. Application). The course will briefly address the fundamental engineering sciences in which the parameters of design for the application are determined.

This approach to geosynthetic knowledge is understandable. Limited time is available to cover all the information required to design a structure using geosynthetic materials. Continuing geosynthetic education promotes the understanding of using geosynthetic materials in a "macro" application without significant "micro" knowledge of the geosynthetic material. Although continuing education courses can be of substantial quality, these courses rarely require the same rigor (i.e. homework and testing) as is the norm in college. This rigor has a benefit of improving the quality of the education and gauging the student's knowledge of the subject of study. It also improves the confidence of the engineer in the future use of the construction material.

9.2 Current Approaches to Geosynthetic Education

The International Geosynthetic Society, North American (IGS-NA) Chapter has re-established the "Educate the Educators" (EtE) Program. With the support of the Geosynthetic Manufacturers Association (GMA) and various sponsors (e.g. Geosynthetic Institute), IGS-NA has developed a two (2) day event where experts in the geosynthetic field introduced approximately 40 college professors to various geosynthetic materials and their applications. These experts also show where and how geosynthetic technology can be included within the college curriculum. In July 2015, an EtE Program was convened in Austin, Texas. Once the college professors arrived in Austin, all of their other expenses were covered by the sponsors. Each professor was given sufficient educational materials and product samples to develop geosynthetic teaching materials for various civil engineering courses. The only request made of the professors by the IGS-NA was to teach one (1) 50-minute class on a geosynthetic or geosynthetics.

As previously noted, the engineering field is experiencing an ever increasing growth rate of new materials and technologies, while the number of credit hours required for graduation with a Bachelor's degree is being reduced. This reduction in the curriculum is one of the primary reasons it is difficult to include new technologies within civil engineering courses. The ASCE is attempting to address this issue with their "Raise the Bar" initiative. This initiative seeks to revise the undergraduate curriculum to allow the inclusion of more technologies in the civil engineering coursework. In order to accomplish this objective within a 120 credit hour graduation requirement, the upper level design courses and Capstone course(s) would be part of a 30 credit hour Master's degree program or additional 30 hours of post-graduation coursework, mostly consisting of graduate level courses. Numerous foreign countries have taken notice of the ASCE initiative and investigating the possibility of revising their countries engineering colleges based on the "Raise the Bar" model for civil engineering education.

Finding various methods to include geosynthetic education within the civil engineering coursework is a major objective of the GMA and IGS-NA. The current approach to geosynthetic education includes the continuing education areas. However, the geosynthetic field is promoting new means of including geosynthetic education within the civil engineering curriculum. These efforts include the EtE Program and ASCE's "Raise the Bar" initiative. To promote this objective, the GMA and IGS-NA have mailed letters to ASCE in support of their "Raise the Bar" initiative.

9.3 Future Approaches for Geosynthetic Education

The content within civil engineering courses is directly related to the focus of the program (e.g. transportation), requirements of local industry and the contents of the FE Exam. Since the focus of the program will vary according to state and regional needs, a larger approach to include geosynthetic technology is via the FE Exam. NCEES will revise the topic areas of the exam based on the current needs of the engineering field. For example, in the past NCEES realized the need to include remediation technology in the undergraduate courses and included exam questions to address this current concern. Geosynthetic organizations (e.g. GMA and IGS-NA) need to express their concerns regarding the lack of geosynthetic education within engineering programs. If NCEES agreed with the inclusion of geosynthetic technology-related test questions, these organizations must prepare to help develop these questions for the FE Exam. This approach will not advance geosynthetic construction materials introduction in the engineering course, but it will promote the inclusion of geosynthetic technology into the fundamental engineering sciences. This will allow students to gain a greater comprehension of geosynthetic materials, and generate increased confidence in their future designs.

Success of these organizations in convincing NCEES to include geosynthetic technology questions within the FE Exam does not mean their work effort is complete. Design problems using geosynthetic materials will need to be developed for future PE Exams, taken by those individuals seeking a PE license and authenticating their capability to design structures with geosynthetic materials.

The future approach to geosynthetic education must include the formation of a committee of geosynthetic experts to generate FE Exam test questions and PE Exam problems for the "micro" and "macro" knowledge required to successfully incorporate geosynthetics materials into future design projects.

10. SUMMARY

Engineers will design structures with construction materials for which they have knowledge and confidence in their use. Although an engineering student may first learn about these materials in courses that show their application within a design, the student's ability to fully comprehend these materials starts within the courses on sciences, engineering sciences and engineering fundamentals. The current civil engineering education paradigm includes mostly traditional technologies. The limited credit hour requirements for graduation and limited time for the instructors to teach each course inhibits the academic institution's ability to include new technologies in various courses. The study topics within these courses are influenced by the focus of the engineering program on regional issues, requests by the IAB and topics included within the FE Exam.

Only a small percentage of civil engineering programs include geosynthetic technology within their courses. An engineer seeking to obtain knowledge in geosynthetics usually accomplishes this task through the review of publications and participation within continuing education courses, such as webinars, seminars and workshops. These courses typically give students a "macro" view of geosynthetics and their application. This is understandable. There is limited time to teach geosynthetic knowledge through these courses and build adequate confidence to include geosynthetic materials within future designs. A greater comprehension of geosynthetics requires the "micro" knowledge of these materials. Although the EtE program may assist in the education of a greater number of students about geosynthetic materials, there needs to be a change in the civil engineering curriculum to allow inclusion of geosynthetic technology within science, engineering science and engineering fundamental courses. ASCE's "Raise the Bar" initiative can assist the geosynthetic community in achieving the objective of including geosynthetic technology in the civil engineering coursework.

Another method to get geosynthetic technology incorporated into the civil engineering coursework is the FE Exam. Since engineering programs strive to cover the topics of the FE Exam within their courses, the ability to include geosynthetic related questions within the exam would almost assure the addition of geosynthetic technology within future civil engineering programs. If this occurs, the geosynthetic community should cultivate a committee of geosynthetic experts to develop test questions and exam problems for future FE and PE exams.

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