AC 2012-2963: COMPARISON OF DIFFERENT PEDAGOGICAL TECHNIQUES TO TEACH MECHANISTIC-EMPIRICAL PAVEMENT DESIGN GUIDE

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Comparison of Different Pedagogical Techniques to Teach Mechanistic-Empirical Pavement Design Guide

ABSTRACT

Mechanistic-Empirical Pavement Design Guide (MEPDG) is relatively new design methodology for conducting pavement structural and materials design. MEPDG is a significant departure from the current Association of American Society of Highway Transportation Officials (AASHTO) empirical design. The required inputs are not only ten times more numerous than that of the empirical design guide, but also much more complex. In addition, the MEPDG is still in its beta version which requires internet access to use the software. MEPDG is an AASHTO-approved design; therefore it is critical that the next generation of civil engineers have a conceptual and practical understanding of how the MEPDG works and some hands-on experience with the software. Faculty members from Rowan and Villanova University taught MEPDG in their respective courses. However, at Rowan University the Pavement Design course (of 20 students) was a senior elective and at Villanova University it was a senior design elective (of 45 students). The purpose of the paper is to compare the pedagogical techniques of teaching the MEDPG and presenting the challenges and successes of each of the techniques. The paper presents the course outline with a week-by-week breakdown of activities, typical handouts for each, and typical exam questions. In addition, the learning outcomes and student evaluations and feedback are also presented in the paper.

Introduction

The purpose of this paper is to explain the differences in pedagogical techniques of teaching Flexible pavement design, especially with the recently developed Mechanistic Empirical Design Guide, at Rowan and Villanova Universities.

Background

Mechanistic-Empirical Pavement Design Guide (MEPDG)
The beta-version of MEPDG was developed in 2006. The MEPDG was significantly different than the current American Association of State Highway Transportation Officials (AASHTO 1993) empirical design guide in its approach to predicting pavement performance. It includes inputting much more detailed material, structural, and traffic data than the empirical design guide. It predicts performance based on mechanistic-empirical equations rather than a thickness. Since the new design guide is in the process of being implemented in the near future, it is necessary for the students entering the workforce to have a basic understanding of the MEPDG and the software. Therefore, the instructors from Rowan and Villanova universities incorporated the MEPDG as part of their courses.

Structure of Pavement Design Course

Rowan University
The pavement design course is taught as a combined undergraduate and graduate course. It is a technical elective for the undergraduate students. The graduate students do an additional paper and a presentation. The class is taught once a week for 150 minutes. The class size is around 20 to 25 students, with approximately 3 to 4 graduate students. The instructor has been teaching the pavement and analysis course every alternate year since spring 2002. The instructor has developed innovative techniques in several courses (1, 2, and 3) including in this course (4). However, with the development of the Mechanistic Empirical Pavement Design Guide, the course outline was revised accordingly (the revised pavement course outline is shown in Table 1). The required textbook was Pavement Design and Analysis by Huang, Third Edition.

Villanova University
Pavement design is taught separately to undergraduates and graduate students at Villanova University. At the undergraduate level, the course is structured as a senior design elective focused on the design of transportation facilities. The class is taught thrice a week for 50 minutes. The class size has been ranged between 40 to 50 students. The instructor has been teaching the course in this format every year since fall 2009. More than fifty percent of the course is dedicated to pavement design concepts and application of the MEPDG software. The required textbook was Fundamentals of Transportation Engineering by Fricker and Whitford, First Edition. The course outline is shown in Table 2.

At the graduate level, the entire course is focused on pavement design and is offered every other year. It is held once per week for 120 minutes and the class size has ranged between 5 and 11 students. Typically the graduate level students who attend Villanova University are working professionals who are completing their master's degrees on a part-time basis. There are only one or two full-time masters students who attend the course each time it is taught. The required textbook for the graduate course was Pavement Design and Analysis by Huang, Third Edition. Table 3 presents the course outline for the graduate level pavement design course.

Table 1 Course Outline at Rowan University

Week	Chapter Reading	Topic
Flexible Pavement Design		
1	1 and 9	Syllabus/Introduction/ Types of pavements distresses
2	1 and 9	Mechanical responses and material properties
3	2 and 7	Mechanical responses and material properties
4	6 and 8	Traffic
5	9, 10 and11	Design – AASHTO-Empirical Approach
6	9, 10 and11	Design AI Mechanistic-Empirical Approach
7	9, 10 and11	MEPDG software
8	Exam 1 (In-class conceptual/Assign Take home design)	
	Rigid Pavement Design	
9	9, 3 and 4	Types of pavements distresses
10	3 and 4	Mechanical responses and material properties
111	9, 10 and 11	Design – AASHTO-Empirical
12	9, 10 and 11	Design AI Mechanistic-Empirical
13	9, 10 and 11	MEPDG software
14		Graduate Presentations

Table 2 Undergraduate Course Outline at Villanova University

Topic	Design Theories	Tools & Software	Supporting Reading
Intro to Course and Land Use Planning	Land use, topography, roadway classifications	GoogleEarth; Census ACS	Chapter 4 pp. 183-189, 198-206
Travel Demand Planning	Trip generation; planning models	Websites; Census ACS	Chapter 4 pp. 206-214
Traffic Characterization	ADT, DHV/30 HV, DD, design speed	DVRPC Traffic Interactive; Green book	AASHTO Green book handout
Highway Capacity – freeway	FFS, LOS, design # of lanes, V	Highway capacity software	Chapter 3, HCM handouts
Highway Capacity – two-lane roads	PTSF, FFS, LOS	Highway capacity software	Chapter 3, HCM handouts
Highway Alignment	Geometric curves, superelevation	AASHTO Green book	Ch. 6 p 339-347; Ch. 7 p 370-400
Highway Cross-Sectional Design	Drainage, medians, safety elements	AASHTO Roadside Design Guide	Ch. 7 p 400-410; RDG handouts
Roadway Materials	Stress/strain/deflection; resilient mod.	Superpave bituminous mix design	Chapter 9; handouts
Traffic for Pavement Design	ESALs,	NC DOT ESAL Calculator	Chapter 9; handouts
Flexible Pavement Design	Layer thickness for asphalt	AASHTO nomographs	Chapter 9; handouts
Flexible Pavement Analysis	Prediction of pavement performance	AASHTO MEPDG	Handouts from MEPDG Manual
Rigid Pavement Design	Layer thickness for concrete	AASHTO nomographs	Chapter 9; handouts
Rigid Pavement Analysis	Prediction of pavement performance	AASHTO MEPDG	Handouts from MEPDG Manual

Table 3 Graduate Course Outline at Villanova University

Topic	Content	Reference
Introduction	• Course Description, Fundamental Design Principles • Pavement Types, Wheel Loads	Chapter 1 Chapter 1
Flexible Pavement Distress	• Flexible Pavement Distress and its Causes – Design Factors	Chapter 9
Flexible Pavement Stresses	• Load-Induced Stresses in Flexible Pavements	Chapter 2 & 3
Bituminous Mixtures	• Properties of Bituminous Mixtures • HMA Mix Design	Other material
Traffic	• Vehicle and Traffic Characterization for Design	Chapter 6
Material Characterization	• Strength and Deformation Tests, CBR, Resilient Modulus, Classification • Drainage	Chapter 7 & other material Chapter 8
Flexible Pavement Design	• AASHTO Design Procedure • AASHTO MEPDG Software	Chapter 11 & other materials
	EXAM 1	
Rigid Pavement Stresses	• Load-Induced Stresses in Rigid Pavements • Thermal Stresses and Combined Effects of Temperature and Load	Chapter 4 & 5
Rigid Pavement Distress	• Rigid Pavement Distress and its Causes – Design Factors	Chapter 9
Rigid Pavement Design	• AASHTO Design Procedure • AASHTO MEPDG Software	Chapter 12 & other materials
Pavement Rehabilitation	• Pavement Rehabilitation Design • AASHTO MEPDG Software	Other materials
Pavement Preservation	• Pavement Preservation Techniques • AASHTO MEPDG Software	Other materials
	FINAL EXAM	

Quizzes, Homework, and Exams

At Rowan University, quizzes were assigned every week at the end of every class in a closed book, closed notes format that included conceptual questions. Quizzes were attempted by each student individually. The content covered in the quiz was from the class the week before. The homework was done by a group of two students. The homework was extensive; as it required students to do literature review on selected topics, and included design and analysis problems. There were two exams in the course. Each exam involved two parts: a) the in-class conceptual portion, and b) take-home open-book portion. The take home open-book exam was a group effort (same group assignment as that of the homework). In the Villanova University undergraduate course, homework was assigned to align with each major concept area. Homework was structured in a small group (two to three people) format. For the majority of the pavement design assignments, some portion of the homework required the use of the MEPDG or related supporting software. The idea was to first test students on their comprehension of the design concepts, but also to introduce them to the tools they will be expected to use upon entering the transportation work force. There were two exams in the course which were open-note, open-book format and 25 percent of the exam problems required the MEPDG software to generate solutions. The exams were an individual effort; thus, giving the Instructor an opportunity to gauge each individual student's level of understanding and competency with the pavement design concepts and MEPDG software.

Because of the smaller class size, the graduate course was structured more of a project-centric course and included very few traditional problem-based homework assignments. A majority of the homework assignments required the MEPDG software for generating solutions and were to be completed individually. There were two exams which were take-home, open-note format and individually completed. Because the graduate students are challenged to a more rigorous level, the MEPDG software was required to solve 50 percent of the problems in the exams.

Projects Using MEPDG Software

The class projects developed by the Instructors at Rowan and Villanova Universities were very similar in format and in the way the MEPDG software was incorporated. In fact, there were a few assignments developed jointly by the instructors at both universities that were used as part of the learning process in their respective courses. One example of this is the New Jersey Department of Transportation Long-Term Pavement Performance (LTPP) section evaluated by students at both universities as part of a project using the MEPDG software. In both universities, projects were done in groups of two students. They required an extensive write-up, the format of which was provided at the beginning of class. The typical topics for the projects included:

1) Conduct sensitivity analyses of mechanical responses for various pavement types, layer thicknesses, loading scenarios, and material properties from a variety of resources.
2) Use the results of the analyses to recommend the most cost-effective pavement design using empirically-based AASHTO design approach.
3) Compare designs that result from the empirically-based AASHTO design approach to the mechanistic-empirical MEPDG software.

Figure 1 presents an example of the project format from Rowan University and Figure 2 presents the grading rubric for the flexible pavement design project from Villanova University.

I. Organization and presentation **40 %**

Suggested order of organization and presentation is shown below:

a. A cover page (very briefly summarizing the final results).
b. Table of contents (including list of tables and figures).
c. Include data and analysis in the order used in the design.
d. Final results (with necessary eligible graphs and sketches).
e. Summary and conclusions (if any).

II. Technical content **60 %**

a. Clearly mention and justify all assumptions made, including inputs in HCS.
b. If using any graphs or data for the design, provide complete and accurate reference.
c. If someone intends to execute the project, they should be able to understand the process and duplicate the results after going through the data, the assumptions, and the analysis.

Figure 1 Example Format Required for a Rowan University Project

Design Submittal score	Objective 1: Design pavement structure using AASHTO nomograph	Objective 2: Design pavement structure using MEPDG software	Objective 3: Design checks with AASHTO Greenbook section on pavements
1	Incomplete, technique or math incorrect, steps/calcs not shown, no written explanation/references	Software not used, inputs to software incorrect, no written discussion of results from software runs, design incorrect	No references, not tied to codes, no written explanation
2	Between 1 and 3	Between 1 and 3	Between 1 and 3
3	Complete, calcs shown, steps not shown, some written explanation, references not shown	Software runs completed, most inputs to software correct, design somewhat correct, some analysis of results with written discussion	Some references, mostly tied to codes, some written explanation
4	Between 3 and 5	Between 3 and 5	Between 3 and 5
5	Complete with traffic, all steps/calcs shown, math & tech correct, supporting written explanation, references shown	Software runs complete, all inputs to software correct, design correct, detailed analysis of results with written discussion	Correct references shown, properly tied to codes, supporting written explanation

Figure 2 Example Grading Rubric for a Villanova University Project

Introducing the Mechanistic-Empirical Pavement Design Guide (MEPDG)

Both universities followed the same general approach to introducing students to the AASHTO mechanistic-empirical pavement design guide (MEPDG). The MEPDG design approach was taught sequentially after the Asphalt Institute (AI) method, in order to introduce the basic concepts of the mechanistic design process.. Then, the concepts and the computational engine behind the MEPDG software were explained. For example, the focus for flexible pavements can be summarized as follows:

1) Elastic mechanical responses were calculated for each time slot, accounting for traffic loads, material properties, and climate.
2) The mechanical responses are superimposed over the design life, and
3) The mechanical responses are then empirically-correlated with pavement distress to develop mechanistic-empirical models

After the pavement design and other supporting concepts were explained in detail, the MEPDG software was run based on real highway sections. For example, at Rowan University, one of the Long Term Pavement Performance (LTPP) sections in the state of NJ. The LTPP section was selected because of its history of field monitoring and the detailed material, structural and traffic data that is available for students to use as inputs. In addition, the pavement performance data is also available. The students were provided structural, material and traffic data (from a nearby truck weigh-in-motion station) for the LTPP sections. In addition, performance data is also provided. The goals of the project were:

1) To predict performance of the NJ LTPP section and compare with measured performance.
2) To provide a detailed explanation about the differences between measured and predicted performance. These include commenting on the accuracy of measured performance data, the performance model, and the input data.

The rigid pavement design is the focus of the second half of the semester, and follows the same format as the flexible pavement section. Since many of the concepts from flexible carry over to rigid, it is easier for the students to grasp the underlying concepts of rigid pavements based on what they have already learned. The failure modes, failure mechanisms, and material properties that impact rigid pavement performance are different. The overarching learning objective is to teach students to recognize these differences.

In the undergraduate course at Villanova University, the students designed pavements for a low-volume two-lane rural highway in Rhode Island and a section of highly urbanized interstate (I-95) near Philadelphia, PA. The graduate course at Villanova required students to evaluate a longer stretch of the I-95 section, including pavement variations based on traffic or right-of-way restrictions (e.g., near the Port of Philadelphia; near the central business district; and near the interchange for one of the area's bridges), and a separate section of rural interstate near Johnstown, PA. In addition, the graduate level course required students to conduct a pavement type selection which meant they needed to review analyses of both flexible and rigid pavements, consider current costs of the materials, and use MEPDG software service life predictions to estimate a cost-benefit ratio of each pavement design. An example of the format for the graduate level project follows:

Topic: *AASHTO Mechanistic Empirical Pavement Design (MEPDG software)*

Goal of MEPDG Project: To become proficient in the use of the MEPDG software, through familiarization with the AASHTO guidance manual and demonstrated capability of inputting data. The measure of proficiency is based on the interpretation of analytical solutions, leading to rational decisions regarding appropriate pavement designs.

Project Deliverable: Final report, no more than 15 written pages, which presents the background of the case study, brief summary of data inputs (could be incorporated in tables in appendix), presentation of analyses, interpretation of results (what you might or might not try differently in further design iterations), and general perception of the effectiveness of the design approach. Include tables, figures, and data appendices as appropriate.

Materials Provided: Weekly reading plan; exercise schedule; case study parameters (including some data inputs); web link to download software; outcome for the course; expectations for course deliverable.

Web Link to MEPDG Software: The software can be downloaded for free from the Transportation Research Board website - http://www.trb.org/mepdg/software.htm. Additionally, you must also download the "Climatic Database" for Pennsylvania (see link on the webpage listed above) to your hard-drive. These files are very large, so it is important that you only download data for Pennsylvania alone.

SUGGESTED READING PLAN and MILESTONE SCHEDULE

Week 1: Introduction – Introduction/background on MEPDG models and calibration factors for both flexible and rigid pavement systems. *Manual 1, Chapter 1.*

Week 2: Traffic Inputs - Traffic inputs used in the MEPDG including the concept of load spectra. *Manual 2, Chapter 4; Manual AA.*

Week 3: Environmental (Climatic) Inputs - Climate considerations and models used in the MEPDG including the concept of integrated climatic model (ICM). *Manual 2, Chapter 3.*

Week 4: Base/Subgrade Inputs - Subgrade (e.g., soil) and base (e.g., granular, HMA) materials used in flexible pavement design. *Manual 2, Chapter 1 (for asphalt pavements only)*

Week 5: Asphalt Inputs - Asphalt materials (multiple HMA layers) used in flexible pavement design. *Manual 2, Chapter 2 (asphalt only); Manual 3, Chapter 3 (new flexible pavements only).*
Exercise

Week 6: Flexible Pavement Design & Analysis - Use the information given in the case study and any relevant inputs given to perform a flexible pavement design.

Week 7: Subgrade Inputs - Subgrade (e.g., granular, soil) materials used in rigid pavement design. *Manual 2, Chapter 1 (concrete pavements only).*

Week 8: PCC Inputs - Concrete materials (one PCC layer) used in rigid pavement design. *Manual 2, Chapter 2 (concrete only); Manual 3, Chapter 4 (new rigid pavements only).*
Exercise

Week 9: Rigid Pavement Design & Analysis - Use the information given in the case study and any relevant inputs given to perform a rigid pavement design.

Week 10: Prepare Final Report - This week can be used to prepare your final pavement design deliverable for the course.

CASE STUDY PARAMETERS

The project requires that you conduct one flexible and one rigid pavement design for given parameters and inputs. These will be only for new pavement designs, and you are not required to *perform any rehabilitative pavement designs for this particular project. Assumptions should be made for any inputs that are not given (e.g., using "defaults" in the software) and document these assumptions. For the purposes of this investigation, use Level 3 inputs.*

In 2005, a new 10-mile alignment was planned in order to connect the newly expanded Johnstown-PA airport (proposed by a local Congressman) to the Johnstown industrial district, west of the city and directly en route to Pittsburgh. Information on Johnstown's industry, etc., can be found on http://en.wikipedia.org/wiki/Johnstown%2C_Pennsylvania and you should look up the average groundwater table depth (feet) for Johnstown. Highway capacity analyses indicated that a 6-lane rural freeway facility with standard lane widths would be needed. In 2002, the AADT for nearby interstate facilities was approximately 15,000 with a heavy-truck percentage of 52%. For this area of PA, a traffic growth rate as high as 6% per year was estimated. The majority of the truck traffic growth is expected to be concentrated for Class 9 and higher, operating mostly between the early morning and early evening hours. The rolling terrain of the greater Johnstown area has been found to induce additional lateral wander in the wheel paths for many trucks.

In order to appease both the concrete and asphalt industries active in the state, Pennsylvania DOT has committed to evaluate both the flexible and rigid pavement system options. They have selected the interim AASHTO MEPDG software to perform their analysis of what pavement type will provide the longest-lasting life, prior to any major repair or rehabilitation being required. For this initial stage, PennDOT is not considering cost of materials or the pavement design as a factor and their only criteria is long-term performance of each system.

A reasonable design life for flexible pavements is considered to be 15 years and so both designs will be evaluated for that amount of time. Assume that the base/subgrade construction will take place 3 months prior to final surface placement (in 2007) and that it will be opened to traffic the same month as surface is placed.

Features of Flexible Pavement:

Given the climatic conditions of western PA, the most important performance targets are thermal cracking, rideability, and alligator cracking. For example, the initial smoothness of the HMA pavement is targeted to be 60 and no greater than 150 at the end of 15 years. The trial flexible pavement structure is: asphalt concrete (4 inches), asphalt permeable base (4 inches), crushed stone granular base (10 inches), semi-infinite A-4 subgrade. Other properties of the flexible pavement layers include:

- Default HMA E* predictive models, but with FEL of 75 microstrains
- Surface: PG 64-28 Binder with 375 psi tensile strength at 14°F. HMA aggregate fine gradation.
  ¾" sieve: 100% passing, 3/8" sieve: 90% passing, #4 sieve: 58% passing, #200 sieve: 7% passing
- Volumetric as-built properties: 12% V_{be}, 93% compaction, 150 pcf unit weight
- Permeable base: PG 64-28 Binder. HMA aggregate coarse gradation.
  ¾" sieve: 100% passing, 3/8" sieve: 86% passing, #4 sieve: 47% passing, #200 sieve: 5% passing
- Volumetric as-built properties: 11.4% V_{be}, 91.5% compaction, 143 pcf unit weight
- Crushed stone: M_R = 28,500 psi
- Subgrade A-4: M_R = 15,500 psi

Features of Rigid Pavement:
Given that the economy is still in decline, PennDOT elected to construct the cheapest option (jointed plain concrete pavement) for rigid pavements. The most important performance targets are transverse cracking, rideability, and joint faulting. The smoothness targets of the PCC pavement should be the same as the HMA pavement. Cold temperatures make it almost impossible to guarantee a cracking limit less than 20% but PennDOT expects contractors to place a rigid pavement that doesn't exceed one-tenth inch of faulting. Default PCC design features include: jointed plain concrete pavement (8 inches), chemically stabilized soil cement subbase (6 inches), and semi-infinite A-4 subgrade. Properties of the various layers include:

- Coefficient of thermal expansion 5.3 x 10^{-6}, Dolomite aggregate, 0.4 w/c ratio
- Type I cement of 560 pcf, 50% ultimate shrinkage at 28 days
- Wet cure used
- 28-day compressive strength of 5600 psi
- Soil-cement stabilized layer stiffness M_R = 1,828,500 psi
- Subgrade A-4 stiffness M_R = 15,500 psi

Graduate Student Paper and Presentation

In both university pavement course curricula, the graduate students are required to do a graduate paper and presentation in order to instill more rigor in the respective courses. At Rowan University, the graduate students select a topic approximately eight weeks before the end-of the semester. The graduate student paper and presentation is focused on the depth of the topic rather than the breadth, and must be subject to instructor approval. The topic must be pavements-related and it must also add value to the course content. For example, if a graduate student selects "Selection of filter criteria for Pavement Drainage," they must conduct a detailed literature search leading up to the study that led to the development of the criteria. Then, they must study the reports that explain the experimental design, limitations, and assumptions of the models. Then, students prepare slides and do several practice presentations before the instructor. The Instructor reviews the presentations as if he is a student and the graduate student is a teacher. In effect, the instructor is teaching the topic to the entire class through this process. Students learn the concepts of experimental design, the complexities involved in developing models, and why certain assumptions are made. It provides them with a better understanding of how the models were developed. The handout regarding the presentations and summary of the paper are distributed to all students, and questions from the presentations are included in the final exam. Tables 4 through 6 show the relative weightings of the different deliverables in the two universities.

Table 4 Relative Weightings of the Grade at Rowan University

Deliverables	Weightings	Remarks
Homework	20%	Groups of two
Projects	30%	Groups of two/ Graduate students will do an additional paper and presentation
Quizzes	20 %	Individual effort
Midterm and Final Exam	30 %	In-class is an individual effort Take-home is a group effort. (group of two

Table 5 Relative Weightings of the Grade in Villanova University Undergraduate Course

Deliverables	Weightings	Remarks
Homework	20%	Groups of two
Projects	20%	Groups of two to three
Class Participation	10%	Actively engaged in software sessions
Midterm and Final Exam	25% each	In-class individual effort

Table 6 Relative Weightings of the Grade in Villanova University Graduate Course

Deliverables	Weightings	Remarks
Homework	0%	Limited use; thus, not graded and solutions provided
Projects	15%	Individual effort
Paper	15%	Groups of two with presentation
Midterm and Final Exam	35% each	Take-home , individual effort

Guest Speakers

Both universities incorporated invited guest speakers as an effective part of the active learning techniques related to teaching MEPDG. Professionals from New Jersey Department of Transportation (NJDOT), the Federal Highway Administration (FHWA), and the pavement industry were invited during the latter part of the semester to discuss the state-of-practice with the MEPDG software, real-life case studies, or relevant projects. The guest speakers provided a practical perspective and presented the students with a better appreciation of the subject matter.

Capturing Outcomes for Undergraduate Level Courses

The civil engineering (CE) department at Rowan University developed a new rubric in summer 2004 to assess each course according to the ABET outcomes to facilitate assessment continuously throughout the four-year curriculum. As an example, the outcome rubric for the Pavement Design course at Rowan University is shown in Tables 7a and 7b. If the particular outcomes were assessed, a response of Yes or No was added, and explanation was provided in the case of Yes. The rating was based on a five point scale, 5 indicating100% of the students achieved that outcome and 0 meaning none of the students achieved the outcome. The numbers were quantified based on the deliverables submitted by the student. The "Outcome" column is the interpretation of the ABET goals. The interpretation was developed by the faculty members in the CEE program.

After all the scores from all the courses taught in the semester were averaged, the outcomes where the average was less than 3 were flagged and discussed on how to improve a particular outcome. For example, for ABET Goal 4 (Objective 1) *The Civil Engineering Program at Rowan University will produce graduates who demonstrate an ability to communicate effectively (ABET G)*, one of the outcomes was *Graduates will demonstrate oral presentation skills*. If, the average for all courses taught in a given semester was less than 3, ways of introducing presentations into the courses would be discussed. In addition to the rubric, the following tools were also used in assessment.

1. Capstone senior design reports and presentations,
2. Engineer-in-training exam, and
3. Senior exit interviews

An almost identical approach is used by the civil and environmental engineering (CEE) department at Villanova University. The same three tools are tracked by the department to assess the long-term value of the course. However, the outcomes applied to the Villanova undergraduate course were ABET K (*an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice*), ABET E (*an ability to identify, formulate, and solve engineering problems*), and ASCE 4 (*can design a system, component, or process in more than one civil engineering context*).

Course Evaluations

The numerical course evaluations for the three courses taught at the two universities are shown below in Table 8. Each evaluation item was rated out of a maximum score of 5. As the table illustrates, the majority of scores were rated above 4 by the students taking the courses. The Rowan university undergraduate and graduate course and the Villanova graduate course is a technical elective. On the other hand, the Villanova undergraduate course is a required course. The evaluation instrument is the same for a required and a technical elective in both schools.

To further assess the value of teaching the pavement design concepts and MEPDG software, the students in the Villanova University 2010 undergraduate course were asked to complete supplemental evaluation questions related directly to the software. The evaluation questions and response statistics are shown in Table 9. The majority of students responded positively to the use of MEPDG as a teaching tool and the hardest concepts listed by students were consistent with those reported by practitioners (5) in the field.

Comparison of Courses between Rowan and Villanova

The paper compares two pavement design courses that include Mechanistic Empirical Design Guide (MEPDG), which were taught at two universities using different pedagogical techniques. The comparison shows that the MEPDG was seamlessly integrated as projects at one university and as case studies in another. In both cases, MEPDG was introduced in a similar fashion, explaining the concepts behind the software before introducing MEPDG software in the form of a project or case study. There were a few assignments developed jointly by the instructors at both universities that were used as part of the learning process in their respective courses. The course evaluations demonstrated that the courses were well received, and the assessment shows that the ABET outcomes were met.

Table 7a. Course Outcomes for Rowan University

		Addressed	Describe	Rating
Goal 1 - Objective 1: The Civil Engineering Program at Rowan University will produce graduates who demonstrate an ability to apply knowledge of mathematics, science, and engineering (ABET A) and, specifically, demonstrate a proficiency in mathematics thro	**Outcome 1:** Students and alumni will demonstrate the ability to apply mathematics, science, and engineering principles to solve engineering problems.	Y	Homework and assigned reading covered transportation engineering principles and work related applications.	5
Goal 1 - Objective 2: The Civil Engineering Program at Rowan University will produce graduates who recognize the need for and the ability to engage in lifelong learning. (ABET I).	**Outcome 1:** Students and graduates will participate in activities that enhance their ability to remain current in their field.	Y	Discussed the need to continue learning throughout career	5
Goal 1 - Objective 3: The Civil Engineering Program at Rowan University will produce graduates who have the ability to use the techniques, skills, and modern engineering tools necessary for engineering practice (ABET K).	**Outcome 1:** Students will use techniques, skills, and modern engineering tools to facilitate the problem solving process.	Y	Conducte design using MEPDG/Kenlayer software	5
Goal 1 - Objective 4: The Civil Engineering Program at Rowan University will produce graduates proficient in a minimum of four (4) recognized major civil engineering areas (ABET M).	**Outcome 1:** Students and alumni will demonstrate the ability to perform analysis and design tasks in at least four (4) recognized major areas of civil engineering.	Y	Transportation	5
Goal 2 - Objective 2: The Civil Engineering Program at Rowan University will produce graduates who demonstrate an ability to design a system, component, or process to meet desired needs (ABET C) and are able to perform civil engineering design by means of	**Outcome 1:** Students will design a system, component, or process to meet desired needs.	Y	Students solved practical examples and assignments for pavement designs.	5
Goal 2 - Objective 3: The Civil Engineering Program at Rowan University will produce graduates who demonstrate the ability to identify, formulate, and solve engineering problems (ABET E).	**Outcome 1:** In classroom, design and laboratory activities, students will identify known variables, formulate key relationships between them and solve engineering problems.	N		
	Outcome 2: Students will identify, formulate, and solve problems in technical areas in which they have not received formal training	y	students learned the new pavement design software	5

Table 7b: Course Outcomes for Rowan University

Goal 3 - Objective 1: The Civil Engineering Program at Rowan University will produce graduates who have an ability to function on multidisciplinary and diverse teams (ABET D).	**Outcome 1:** Students will learn to function effectively on multidisciplinary and/or diverse teams.	Y	Students completed assignements in groups	5
Goal 3 - Objective 2: The Civil Engineering Program at Rowan University will produce graduates who have an understanding of professional and ethical responsibilities (ABET F).	**Outcome 1:** Students will take pride in the profession of civil engineering and recognize their professional and ethical responsibilities.	Y	Discuss ethical land professional responsibilities in class	5
Goal 3 - Objective 4: The Civil Engineering Program at Rowan University will produce graduates who understand professional practice issues such as: procurement of work; bidding versus quality based selection processes; how the design professions and the c	**Outcome 1:** Graduates will enter the workplace cognizant of professional practice issues.	Y	The practical examples and discussions will aid the students with respect to the non-engineering related issues as they affect the design process.	5
	Outcome 2: Graduates will have an awareness of the licensure process and the impact of professional licensure on their career.	Y	We discussed the licensure and responsibility associated with the design process.	5
Goal 4 - Objective 1: The Civil Engineering Program at Rowan University will produce graduates who demonstrate an ability to communicate effectively (ABET G).	**Outcome 1:** Graduates will write effectively.	Y	students wrote 4 extensive reports	5
	Outcome 2 Graduates will demonstrate oral presentation skills.	Y	graduate students gave an oral presentation	5

Table 8 Course Evaluations by Students at Rowan and Villanova University

Evaluation Criterion	Rowan University combined undergraduate and graduate		Villanova University undergraduate		Villanova University graduate
	Spring 2008	**Spring 2010**	**Fall 2009**	**Fall 2010**	**Fall 2009**
Number of students	20	21	39	45	11
Were your class sessions characterized by clearly presented lectures and/or learning activities?	4.80	3.86	4.60	4.50	4.00
Was your understanding of course concepts enhanced by your professor's presentation of the material?	4.85	3.91	5.00	4.90	4.40
Did your professor encourage questions & comments during the class?	4.85	4.77	4.70	4.80	4.60
Was your professor responsive to students' questions & ideas?	4.07	3.97	4.60	4.60	4.10
Was your professor's evaluation of students' work impartial & unbiased?	4.75	4.64	5.00	4.80	4.10
Did your professor stimulate thinking in this course?	4.85	4.73	4.50	4.50	4.0
Did your professor require a high level of student performance in this course?	4.85	4.82	4.90	4.80	4.60
Overall, how would you rate your professor in this course?	4.85	4.18	4.80	4.70	4.10
Total	**4.84**	**4.45**	**4.60**	**4.50**	**4.40**

Table 9 Evaluation of Use of MEPDG Software by Students at Villanova University

Evaluation Question	Response Evaluation Statistics	
Do you feel like you have learned more design-oriented skills than traditional lecture?	Yes No	85% 15%
Did you find it interesting and worthwhile to learn the AASHTO MEPDG design software, despite that it is not a streamlined product at this time?	Yes No	85% 15%
Would you recommend more emphasis on the AASHTO MEPDG design software (more homeworks, exam questions, in-class exercises) in future, realizing that there might not be time for some of the other topics planned for the course?	Yes No	50% 50%
Do you intend to list the AASHTO MEPDG software on your resume as a computer program skill?	Yes No	75% 25%
What did you find the hardest concept or functionality of the AASHTO MEPDG design software to be?	Open-ended Output clarity; traffic/climate input clarity; reliability concept; soil selection	

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