120th ASEE Annual Conference & Exposition
FRANKLY, WE DO GIVE A D*MN
June 23-26, 2013

Paper ID #7045

Using DARWin 3.1 in Undergraduate Pavement Design Courses

Dr. Mohammad Ali Khasawneh P.E., Jordan University of Science and Technology

Dr. Mohammad Khasawneh earned his Ph.D. in Civil Engineering in August 2008 from the University of Akron at Akron, Ohio. His dissertation was titled "The Development and Verification of a New HMA Accelerated Polishing Machine." Dr. Khasawneh earned his M.Sc. in Civil Engineering in September 2005 also from the University of Akron and his B.Sc. in Civil Engineering in February 2003 from Jordan University of Science and Technology at Irbid, Jordan. Since Sept. 2008 he has worked as an assistant professor in the Civil Engineering Department at Ohio Northern University in Ada, Ohio. Here he develops and teaches general engineering and civil engineering courses, works on transportation engineering projects, and holds membership with a number of organizations and committees. From September 2003 to August 2008 he was a research assistant in the Civil Engineering Department at the University of Akron. He worked on a number of Transportation/Pavement Engineering research projects, and Geotechnical Engineering research projects. Then from September 2003 to August 2008, he was a teaching assistant with the Civil Engineering Department at the University of Akron. His work has been published in the International Journal of Pavements, Jordan Journal of Civil Engineering, and ASCE's Journal of Transportation Engineering among other publications. Dr. Khasawneh holds a number of professional affiliations. He is an associate member of the American Society of Civil Engineers, a member of the American Society for Engineering Education a member of the Institute of Transportation Engineers, and a member of the Jordan Engineers Association.

Dr. Mohammad Obadat, The University of Tennessee at Martin

Using DARWin 3.1 in Undergraduate Pavement Design Courses

Abstract

The objective of this study was to investigate the use of Windows-based software as a cognitive computer tool in undergraduate pavement engineering design courses. Engineering students worked cooperatively on design and analysis tasks. DARWin 3.1 stands for: Design, Analysis and Rehabilitation for windows. Authors felt that using the software may be extremely beneficial to the students' ability to grasp the concepts of pavement design through the software's integration of visual cross-sections and ability to directly compare various mix designs. As students completed in-class labs and take-home projects with the assistance of DARWin 3.1, specific attention was given to real-life problems that students may encounter in their senior design projects and/or later in their future jobs. Students were assigned to work in groups of two members each. Collected Data included student questionnaires and assignments. Students that participated in this study believed that the use of DARWin 3.1 provided them an opportunity to spend more time on interpreting results and focus on understanding by significantly reducing problem solving time as opposed to hand calculations. Also, the cognitive computer tool enhanced students' learning experience as long as they know how it works and the rationale behind it, which in turn stimulated students' thinking.

Introduction

Ohio Northern University was founded in 1871 as a selective, private, comprehensive university with five colleges (namely; Arts and Sciences, Business Administration, Engineering, Pharmacy and Law) with nationally ranked arts, sciences and professional programs.

The College of Engineering has approximately 450 students which includes 180 in the Mechanical Engineering Department, 120 in the Electrical and Computer Engineering and Computer Science Department, 130 in the Civil Engineering Department, 10 in the Engineering Education Department and the remaining undeclared. Quarter system had been used for a long period of time with three quarters; Fall, Winter and Spring in addition to the optional summer sessions. This past fall (Fall semester of 2011), the university converted to semesters to be consistent with other schools throughout the state of Ohio. The core Civil Engineering curriculum consists mainly of Transportation, Structures, Environmental, Geotechnical, and water resources courses. The Transportation sequence covers a comprehensive spectrum of knowledge; from geometric design of highways to traffic engineering to pavement analysis and design and highway materials. This study aims at studying Transportation III (Pavement Analysis and Design) course, which is an undergraduate course within the transportation sequence where the Design, Analysis, and Rehabilitation modules in DARWin 3.1 can be implemented.

Pavement Analysis and Design (CE 456) is a core course in the civil engineering curriculum at Ohio Northern University. The course used to be offered only once a year during the Winter Quarter and now during the Spring Semester after the conversion to semesters. This course is taught by the principal author of this study and is offered to the senior class. The course is divided into three major components; namely: design inputs (50%), pavement analysis (25%) and pavement design (25%). Currently, this course has the following outcomes:

1. Determine Equivalent Single Axle Load repetitions for a given project.
2. Describe pavement distress and incorporate that into pavement management.
3. Characterize paving materials and describe some of the laboratory tests conducted on them.
4. Determine stresses and strains in flexible and rigid pavements using different methods.
5. Design a flexible pavement using different design procedures.
6. Design a rigid pavement using different design procedures.
7. Use DARWin 3.1 AASHTO software to design flexible and rigid pavements.

Once DARWin software had been implemented, the previously mentioned classical topics remained the same. The inclusion of this software into the syllabus was for many reasons: building knowledge of using viable programs in the pavement engineering field to strengthen the comprehension of the subject. Furthermore, it saves considerable amount of time after ensuring that students have a good understanding of the material and theory and then the mathematical formulation used in building the computer program. This is more of an issue for complex and iterative processes. In addition, the implementation of such software allows conducting parametric and comparison studies to further understand the main controlling factors of a specific phenomenon. Also, knowledge of this kind comes in handy when students are working on their senior design projects besides enhancing their resumes when it is time to look for future jobs. Moreover, implementing this course improvement enabled the fulfillment of ABET outcome-K[1]. This ABET outcome focuses on the ability to use techniques, skills and modern engineering tools necessary for engineering practice. These benefits could not be attained without implementing and using softwares with modeling and simulation capabilities as is discussed later based on the instructor's observations before implementing DARWin 3.1. Fortunately, introducing students to such software is not time consuming and could be presented in few lectures, in addition to extra tutorial as needed, without the need to remove any class content.

In general, students had a good understanding of how to design flexible and rigid pavements according to AAHSTO 1993 Design Guide. The design process is lengthy and of course time consuming with large room for mistakes. Additionally, it is always helpful to provide students with ways to double check their designs, which is one significant advantage of using a computerized method for this purpose. Finally, it was obvious that students, in general, lack the ability to identify the most controlling factors or parameters while following ready mathematical formulas or standardized procedures. This weakness could be eliminated, or at least alleviated, by teaching them a computer program that can run the analysis and/or design in a matter of seconds. The aforementioned benefits of using DARWin 3.1 software in Pavement Engineering worth to be investigated more in the following sections.

Several studies were carried out to evaluate the need for using simulation packages or modeling softwares in undergraduate teaching in many different majors. These studies were effective in supporting implementation of various softwares into undergraduate programs. Abdel-Mohti and Khasawneh1 studied the benefits of teaching finite element analysis in undergraduate courses. It was found that students found it rewarding and it is well-received by employers. They also found that this addition resulted in better learning experience as was validated through students' feedback. Another study by Shaalan[2] concluded that using the Distribution Engineering Workstation as engineering software to teach Electric Power Distribution can be considered as an effective educational tool as was illustrated by positive feedback from participants in his study. A study by Blake and Cornett[3] on Teaching an Object-Oriented Software in Undergraduate Engineering Education resulted in nourishing students' learning experience as this tool helped them in their job interviews and to understand the big picture of their internships as well. Borchelt studied the use of computer tools in the teaching and learning of undergraduate calculus[4]. Based on his study computer tools proved to be valuable in allowing students to explore more, reflect on results and focus on understanding. The computer tools also allowed for critical thinking and creativity in problem solving permitting students to move toward more sophisticated type of thinking. In 1997, Kinsner considered the value of using computer programs for undergraduate teaching to help solve field problems[5]. It was concluded that the use of such computer packages in class settings improves students' comprehension and skills in solving field problems. There is a need to conduct a parallel study to investigate the potential benefits of using engineering software(s) in pavement engineering courses at the undergraduate level.

Description of DARWin Software

In simple terms, Design, Analysis, and Rehabilitation for Windows (DARWin) is a computerized pavement design tool based on the AASHTO Guide for the Design of Pavement Structures. However, DARWin is much more than an online presentation of the design methodology in the AASHTO Design Guide. In addition to providing an accurate and comprehensive means of performing pavement designs, DARWin performs a wide range of analyses and calculations not available in other pavement design software. DARWin is also fast, easy to use, and can streamline many repetitive tasks. With its many customizable features, DARWin simplifies the pavement design process which results in improved designs[6].

Because it operates in the Windows environment, multiple designs can be carried out or viewed at the same time and compared. You can also use other software, such as spreadsheets and word processors, while working with DARWin. In fact, almost any Windows-compatible software can be used along with DARWin. DARWin project helps keep you organized by incorporating your pavement designs and supporting documents from other Windows programs into a single DARWin file[6].

The following section provides an overview of each of the three DARWin design modules along with the life cycle cost analysis module. Design modules are: Flexible Pavement Structural Design Module, Rigid Pavement Structural Design Module and Overlay Design Module. Tutorial and specific examples were presented to students to cover these topics in an effort to achieve the previously mentioned objectives.

The Flexible Pavement Structural Design Module[7] can be used to design and analyze Asphalt Concrete (AC) pavements using different methods; they are analysis, specified and optimized design. Based on the design inputs, DARWin calculates the required structural number (SN). Instead and for a given SN the process can be reversed to calculate the load-carrying capacity of a pavement. Options are also available to calculate the required inputs. Parametric studies showing the effect of varying primary inputs can be completed and graphically presented using sensitivity plots. The main window, with all input requirements of this module, is shown in Figure 1 below.

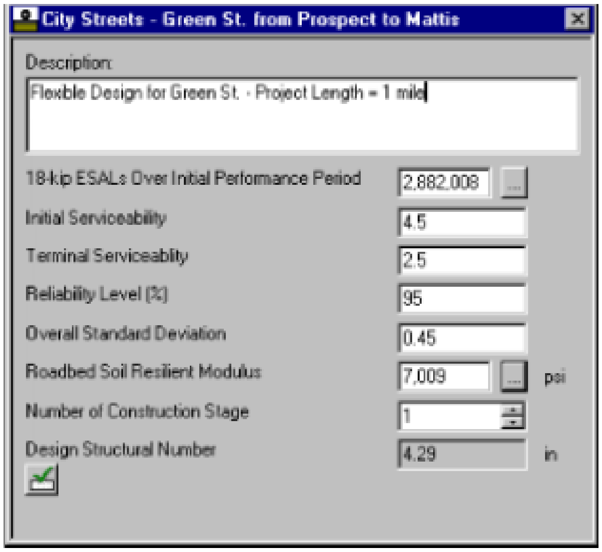


Figure 1: Flexible Structural Design Module

The Rigid Pavement Structural Design Module is used to design and analyze Portland Cement Concrete (PCC) pavements (see Figure 2). The required slab thickness (D) is directly calculated based on the given design inputs. Sensitivity plots and other features found in the flexible pavement module are also available here. Other rigid pavement features, including steel reinforcement, tie bars and joint reservoirs can be designed using this module[7]. Figure 2 shows all required inputs for this module.

Figure 2: Rigid Structural Design Module

The Overlay Design Module can be used to design seven different overlay types as seen in Figure 3. These types are: (1) AC overlay of AC pavement, (2) AC overlay of fractured PCC pavement, (3) AC overlay of PCC pavement, (4) AC overlay of AC/PCC pavement, (5) bonded PCC overlay, (6) unbonded PCC overlay, and (7) PCC overlay of AC pavement. Three different methods can be used to design each overlay as applicable; these are component analysis, nondestructive testing and remaining life. Back-calculation technique is also an option in the Overlay Design Module using specific analytical routines to calculate deflection load transfer using Falling Weight Deflectometer (FWD) data.

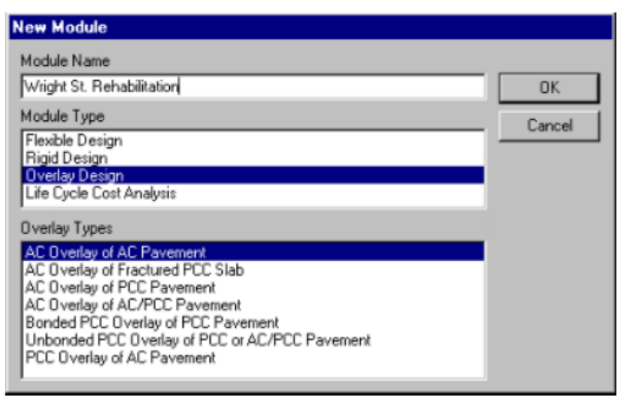


Figure 3: Overlay Design Module

Considering all costs in the analysis, including initial construction costs, maintenance costs, rehabilitation costs and salvage costs, the Life Cycle Cost Analysis Module can be used to financially compare different alternative designs[7]. The most economically advantageous alternative is ultimately identified using different evaluation methods such as net present value or equivalent uniform annual cost method. Cash flow diagrams are generated automatically for each project and presented graphically. Figure 4 shows the main window for this module that illustrates main coast analysis inputs.

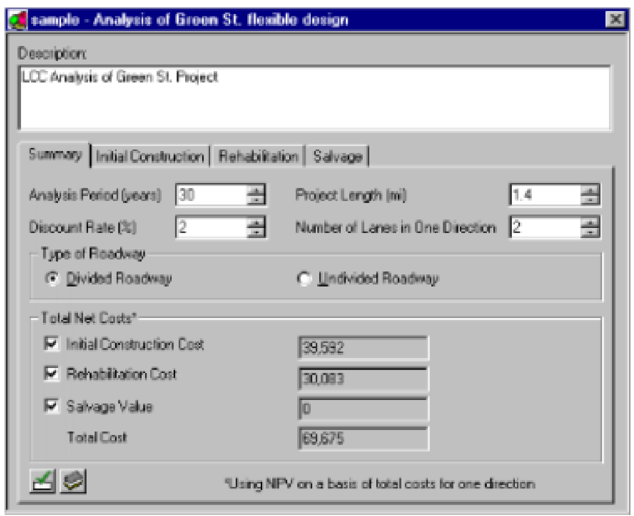


Figure 4: Life Cycle Cost Module

Survey Structure

In order to assess the usefulness of incorporating DARWin 3.1 in the Pavement Engineering course, a survey was designed carefully to cover important aspects of such course development. This survey was completed by students toward the end of the semester. The purpose of this survey was to provide numerical values indicative of the rate of success attained from this course improvement. Ten questions were used in the survey that can be divided into four main categories. Questions 1, 4 and 5 are all under one category that compares students' learning experience in a classroom setting as opposed to a computer lab using computer software. These questions are of great importance since they show whether or not a class instruction is adequate by itself and vice versa. Question 2 and question 3 are under the second category that measures the advantages obtained from adding DARWin 3.1 to the course syllabus. Questions 6, 7 and 9 represent the third category, they evaluate the software as an engineering tool in terms of ease of operation, extent of tutorial required to get students started and its rank amongst other softwares they used in their undergraduate study thus far. The last category includes question 8 and question 10. These two questions are used to assess students' satisfaction concerning the number of assignments they had to work on using the software and the quality of assistance they received from the instructor to help understand the software and its capabilities. Each question was rated on a 5-point scale; 1 denotes "strongly disagree or 20% student satisfaction", 2 denotes "disagree or 40% student satisfaction", 3 denotes "partially agree or 60% student satisfaction", 4 denotes "agree or 80% student satisfaction" and 5 denotes "strongly agree or 100% student satisfaction". A copy of this survey similar to those used by students is shown in Figure 5.

DARWin AASHTOWare Software

For the statements below, please circle one number.

1 = "strongly disagree"	2 = "disagree"	3 = "partially agree"	4 = "agree"	5 = "strongly agree"

1. I learn material just as well from a normal lecture/homework/exam class format as I do working in a team using software in a computer lab.

   1 2 3 4 5

2. I enjoyed the Pavement Analysis and Design class more because of the DARWin software.

   1 2 3 4 5

3. The DARWin software enhanced my understanding of the pavement design principles it employed.

   1 2 3 4 5

4. I remember how to use the pavement design principles used in the software better than I remember other principles from this class.

   1 2 3 4 5

5. The design project using DARWin software was related to the material taught in class.

   1 2 3 4 5

6. The DARWin software was user-friendly.

   1 2 3 4 5

7. The DARWin software tutorial provided in class was enough to complete the assigned project.

   1 2 3 4 5

8. If I were to retake the Pavement Analysis and Design class, I would recommend having more computer assignments using DARWin software.

   1 2 3 4 5

9. If I were to rank this software among others that I have completed, I would rank it among the best.

   1 2 3 4 5

10. The instructor had enough experience to teach this software.

   1 2 3 4 5

Any additional comments on the usefulness of the DARWin design software or any suggestions for improvement?

Figure 5: Survey Structure

Discussion of Results

Total number of seniors participated in this survey was 16. All answers are summarized in a tabular format as shown in Table 1. The average value for each question and each participating student along with the standard deviation, maximum and minimum is listed in the same table (Table 1). A detailed discussion of results for each question is presented herein. Each question was looked at in terms of the number of students with rating greater than or equal to 3 out of 5 (≥ 60% satisfaction); this rating (≥ 3) is within the agree range as was discussed earlier in the survey structure section.

Question 1 "I learn material just as well from a normal lecture/homework/exam class format as I do working in a team using software in a computer lab" 81% of students rated this question 3 and above, this indicates that there is a high consensus among students of the benefit of using this software as a supplementary tool to class instruction. Questions 4 and 5 in the same category further support this finding with 31% and 100%, respectively. Question 4 is "I remember how to use the pavement design principles used in the software better than I remember other principles from this class". The low percentage for this question can be attributed to the way question 4 is stated; it examines if computer assignments in a computer-lab setting can replace the classroom teaching. It is neither correct nor the intention of this course enhancement to eliminate the class teaching element, which can be thought of as another evidence that the software used is a supplementary tool and not the only that can be relied on. To allow comparisons between normal teaching methods and computer-based assignments, question 5 "The design project using

DARWin software was related to the material taught in class" was utilized. Based on this question, it is evidenced that assignments from these two teaching techniques were comparable.

Questions 2 and 3, or questions from the second category, gave the same rating of 88%. It is clearly shown that incorporating DARWin 3.1 into the course syllabus had a significant influence on students' satisfaction. It makes the class more enjoyable and enhanced the students' learning experience. Question 2 is "I enjoyed the Pavement Analysis and Design class more because of the DARWin software" and question 3 is "The DARWin software enhanced my understanding of the pavement design principles it employed".

The third category, questions 6, 7 and 9, showed substantial agreement (100%, 100% and 94%, respectively) among students that DARWin is user-friendly software, the amount of tutorial provided in class was sufficient and DARWin is highly ranked software among others they studied over the past three years. These questions are: question 6 "The DARWin software was user-friendly", question 7 "The DARWin software tutorial provided in class was enough to complete the assigned project" and question 9 "If I were to rank this software among others that I have completed, I would rank it among the best".

The fourth category includes question 8 "If I were to retake the Pavement Analysis and Design class, I would recommend having more computer assignments using DARWin software" and question 10 "The instructor had enough experience to teach this software". 81% of students recommended with variable levels of agreement that more computer assignments should be accessible to students next time this course is offered. It is well demonstrated that students highly prefer more practice with higher level of complexity to deepen their understating and better equip themselves with this engineering tool (question 8). This finding was further demonstrated from students' comments presented next. Question 10 shows that 100% of students agreed that the class instruction provided to them was sufficient to help them excel in using DARWin 3.1 software. All of these results are graphically shown in Figure 6.

Students provided few comments and suggestions that are listed below:

1. The assignment just seemed like busywork. I was not challenged.
2. More assignment over different problems; make each assignment less time consuming.
3. Software is useful as long as the students understand how it works instead of memorizing the steps from a tutorial.

Table 1: Survey Data

Question #	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	Average	Standard Deviation	Maximum	Minimum
1	4	5	2	3	3	3	2	3	5	4	5	4	4	2	3	3	**3.4**	**1.0**	**5.0**	**2.0**
2	3	4	3	3	3	5	2	2	5	3	4	4	3	3	4	4	**3.4**	**0.9**	**5.0**	**2.0**
3	4	4	4	4	4	5	2	2	4	4	4	4	5	3	4	4	**3.8**	**0.8**	**5.0**	**2.0**
4	3	2	2	4	3	2	2	2	4	3	2	2	2	2	2	2	**2.4**	**0.7**	**4.0**	**2.0**
5	5	5	4	4	5	5	3	4	5	5	4	5	5	4	4	5	**4.5**	**0.6**	**5.0**	**3.0**
6	5	4	4	4	4	4	3	4	5	4	4	5	5	4	4	5	**4.3**	**0.6**	**5.0**	**3.0**
7	3	5	4	4	4	5	4	3	5	5	5	4	5	4	4	5	**4.3**	**0.7**	**5.0**	**3.0**
8	4	3	4	3	4	3	2	2	5	4	2	3	4	3	4	4	**3.4**	**0.9**	**5.0**	**2.0**
9	3	3	3	4	2	4	3	3	4	3	3	3	4	4	4	5	**3.4**	**0.7**	**5.0**	**2.0**
10	5	5	5	4	4	5	3	4	5	5	4	5	5	4	4	5	**4.5**	**0.6**	**5.0**	**3.0**
Average	**3.9**	**4.0**	**3.5**	**3.7**	**3.6**	**4.1**	**2.6**	**2.9**	**4.7**	**4.0**	**3.7**	**3.9**	**4.2**	**3.3**	**3.7**	**4.2**				
Standard Deviation	**0.9**	**1.1**	**1.0**	**0.5**	**0.8**	**1.1**	**0.7**	**0.9**	**0.5**	**0.8**	**1.1**	**1.0**	**1.0**	**0.8**	**0.7**	**1.0**	Sample Size = 16			
Maximum	**5.0**	**5.0**	**5.0**	**4.0**	**5.0**	**5.0**	**4.0**	**4.0**	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**	**4.0**	**4.0**	**5.0**				
Minimum	**3.0**	**2.0**	**2.0**	**3.0**	**2.0**	**2.0**	**2.0**	**2.0**	**4.0**	**3.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**				

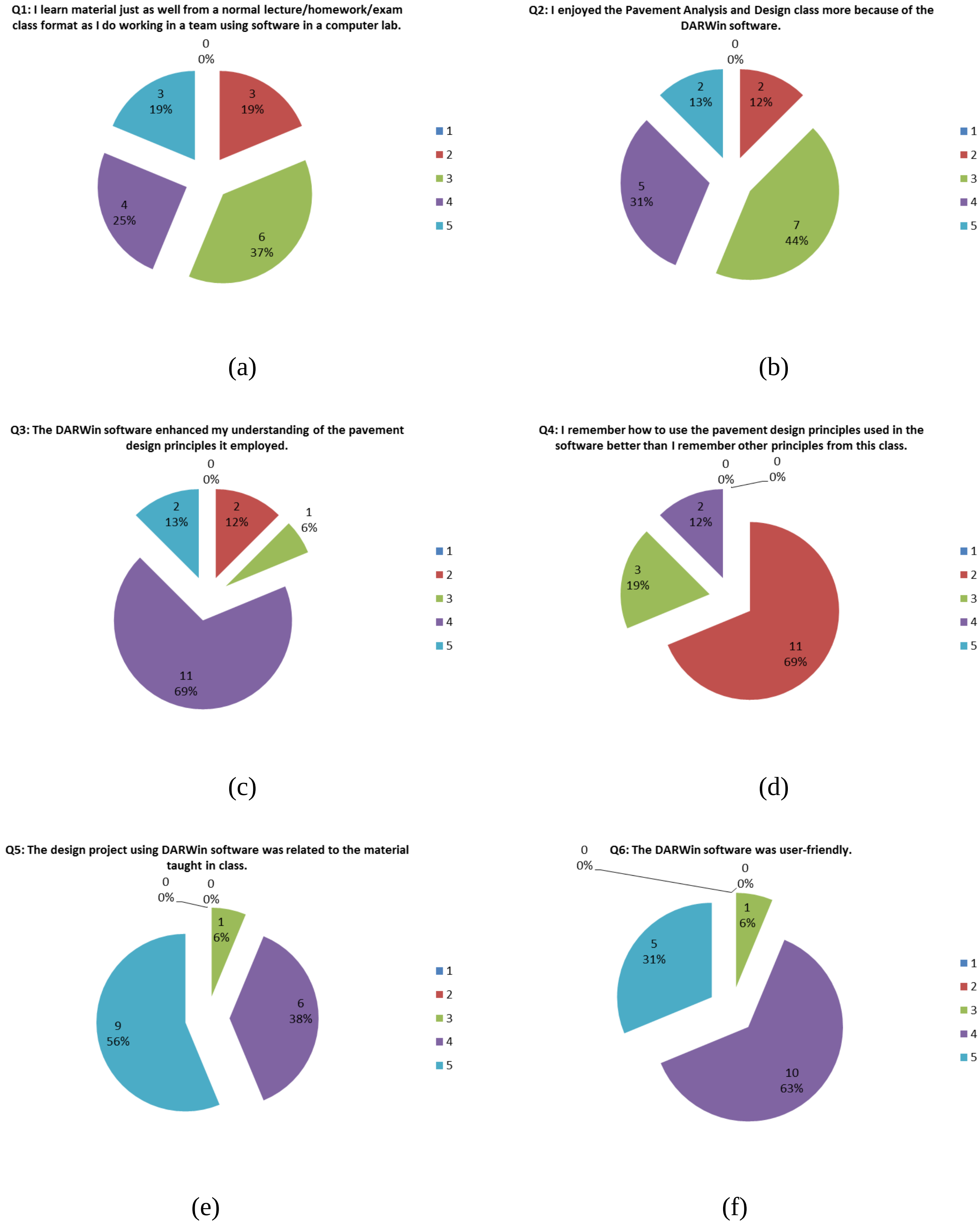
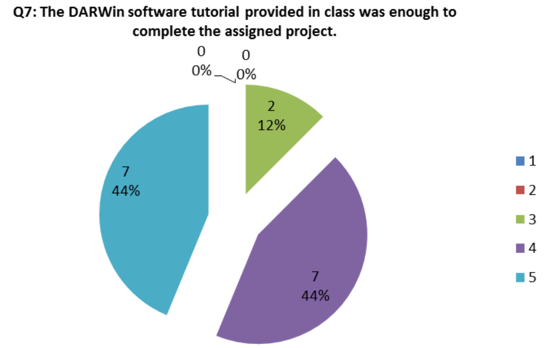
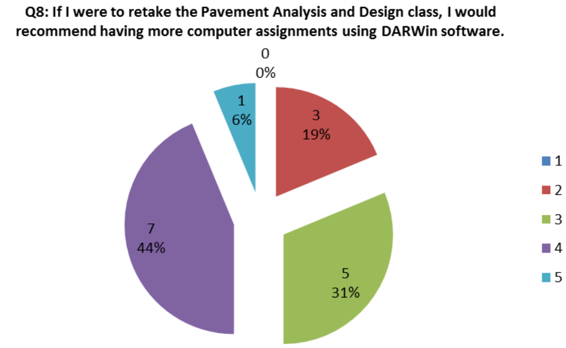


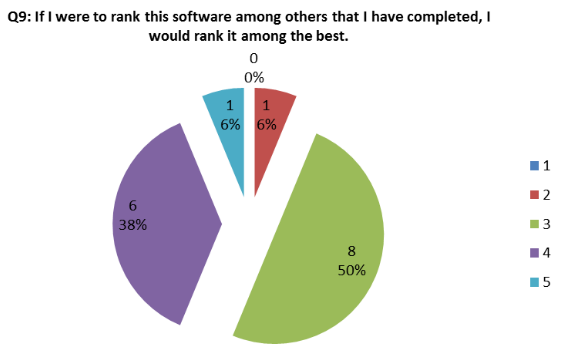
Figure 6 (a-j): Survey Results



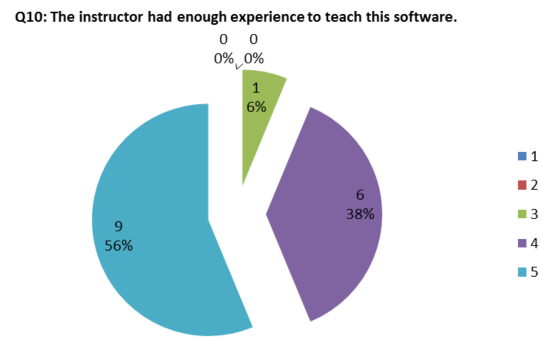
(g)



(h)



(i)



(j)

Figure 6 (a-j): Survey Results, continued

Conclusions and Recommendations for Future Work

The specific remarks and statements from the study can be mentioned succinctly as follows:

1. As a supplementary tool following students' proficiency in the course material, the use of DARWin 3.1 software was found to enhance students' learning experience, solidifies methods presented in class and better clarifies the details taught in class.
2. Students thought that DARWin 3.1 is an easy to operate engineering tool with user-friendly interface. This software can be used in checking the adequacy of manual designs.

3. The assignment of more challenging problems and/or projects covering different scenarios was recommended. It was also recommended to implement the software for years to come.
4. The provision of tutorials in a classroom using snapshots from the software was shown to be adequate.

I feel that the future studies that may stem from this study may be extremely beneficial to the industry and civil/construction engineering (technology) programs in the U.S. and on the international level. One point worthy to be mentioned here is the fact that larger sample sizes of future studies are needed or, at least, additional statistics, such as a margin of error be provided. Also, a multi-semester data set with a control group who does not use the software is suggested for comparison purposes. It could also be argued in future studies that having the students build Excel models rather than using AASHTO software may actually increase their knowledge of pavement design processes.

It is recommended that the long-term benefits of this implementation be measured. This could be done by changing the sample selected to make it cover students who have just finished their senior design capstones and pavement engineers after one, three and five years of college graduation. This might help further understand the benefits of teaching DARWin software, or any other computer program with analysis and design capabilities, in undergraduate courses.

References

[1] Abdel-Mohti A. and Khasawneh M. (2012) "Teaching Finite Element Analysis in Undergraduate Courses" American Society for Engineering Education (ASEE), ASEE North-Central Section Conference (8 pages).

[2] Shaalan H. (1999) “Using Engineering Software to Teach Electric Power Distribution” The Electronic Journal for Engineering technology, Volume 3 No. 2, ISSN# 1523-9926.

[3] Blake M. B. and Cornett T. (2002) “Teaching an Object-Oriented Software Development Lifecycle in Undergraduate Software Engineering Education” Institute of Electrical and Electronics Engineers (IEEE), CSEET '02 Proceedings of the 15th Conference on Software Engineering Education and Training, pp. 234-240.

[4] Borchelt N. (2007) “Cognitive Computer Tools in the Teaching and Learning of Undergraduate Calculus”, International Journal for the Scholarship of Teaching and Learning, Volume 1, Number 2, 2007.

[5] Kinsner W. (1977) “Computer Programs for Undergraduate Teaching of Field Problems”, Institute of Electrical and Electronics Engineers (IEEE) Education Society, ISSN: 0018-9359, Volume: 20, Issue 1, pp. 54 – 60.

[6] Design, Analysis, and Rehabilitation for Windows software (DARWin 3.1) User’s guide, darwin.aashtoware.org, Applied Research Associates, Inc., www.ARA.com/transportation.

[7] AASHTOWare webpage: http://darwin.aashtoware.org/modules.htm