Integrating Professional Software in Undergraduate Civil Engineering Education

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ABSTRACT

The effective use of computing in undergraduate civil engineering education is becoming an integral part of education in the US institutions. This paper presents the use of professional software in the following three areas of civil engineering: Hydraulics Engineering, Structural Analysis and Design, and Transportation Engineering. In addition, the paper will include an example on the use of AutoCAD in real life project during the freshmen year.

The paper will present a brief description of software, how it is utilized including examples from individual classes and capstone course. The following software will be presented:

a) CAD Software: AutoCAD 2010/2011.
b) Construction Management package: Microsoft Project.
c) Structural Analysis and Design packages: SAP2000 and ETABS
d) Transportation packages: The Synchro and SimTraffic,
e) Hydraulics package: KYPipe 2010.

In addition, the use of Excel in construction management and transportation classes will be introduced. A discussion on the pros and cons of using these packages as well as a summary of students' comments and evaluation of these packages will be presented.

Keywords: Professional Civil Engineering Software, freshmen and Capstone courses, Construction Management, Structural Analysis, Transportation, and Hydraulics.

1. INTRODUCTION

Using technology in education is becoming an integral part of civil engineering (CE) education in the US. Computer software packages can be used in many tasks including but not limited to collecting, storing, analyzing, and displaying data[1]. A study conducted by the American Society of Civil Engineers' Task Committee on Computing Education of the Technical Council on Computing and Information Technology found that the use of Computer-aided Design (CAD) and Spreadsheet software ranked the highest among educator and practitioners as shown in Table 1[2]. A list of all software packages are presented in the reference 2. In the same study, practitioners prefer to have graduates with solid theory and fundamentals, be able to do hand calculations, and to have real engineering experience before graduation. N.S. Grigg, et al. reported that the CE profession will be left behind if it ignore technologies and does not take advantage of it[3].

Table 1: Selected Skills from the "Survey of Importance Results"[2]

Computer Skill	Practitioners		Educators	
	Rank	Rating[(a)]	Rank	Rating[(a)]
Computer-aided Design	3	4.0	3	3.9
Construction Software	10	3.0	11	3.2
Spreadsheet	1	4.5	1	4.4
Structural software	6	3.3	6	3.6
Transportation software	12	2.9	7	3.5
Water Resources	8	3.1	9	3.4

[(a)] 5: most important, 1 = least important

One of the major challenges for engineering educators is that technology and practice of engineering increases in its complexity with time. Accordingly, there will never be enough time to cover all of the required topics in depth[4]. However, it is important for educators to remain current with ongoing trends in their field in order to present a general overview of technologies that are used in the workplace. Numerous studies have been conducted to develop new technologies and methods that can be introduced to students in order to allow them to become successful engineers upon exiting universities. In a study conducted by Romero and Museros suggested that computers could play an important in engineering education and in particular in structural engineering education in a variety of ways, one of which is using commercial design programs[5].

2. PROFESSIONAL SOFTWARE IN CIVIL ENGINEERING EDUCATION AT IPFW

The new civil engineering program at Indiana University-Purdue University Fort Wayne (IPFW) was established in 2006.

One way to provide all students with real life experience is by requiring a real life project in most of the engineering courses. In order to achieve this goal, students have to do the calculations for the project by hand and then use appropriate software in their project. The flowing is a summary of selected software used in several areas of civil engineering courses at IPFW including Graphic Communication, Construction Engineering and Management, Structural Engineering, Transportation Engineering, and Hydraulics courses.

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Computer Aided Design Software

Student at IPFW learn AutoCAD software in their freshmen year in Graphic Communication and Spatial Analysis course. It is a two-hour course that teaches student how to communicate engineering concepts effectively using AutoCAD, writing memos, and conducting presentation. Students are required, in addition to assignments and exercises, to do two projects. One the project is to a layout for a building and design a parking lot. The goal of this project is to expose students early to some aspects of professional life. The proposed lot and layout of the new building are shown in Figure 1.

Figure 1 (a): Proposed lot for new building
(Source: Google Maps accessed on January 21, 2009)

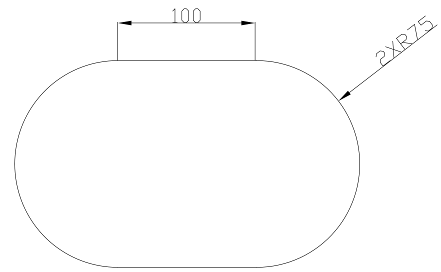


Figure 1 (b): New Building layout, dimensions are in feet.

Students are required to draw the lot to scale with access points to avoid congestions on the street, to locate and draw the building on the lot considering maximizing the utilization of excess land of the lot for the parking spaces, and to design and draw the layout for the parking lot around the building. They shall comply with handicap acceptability act with sufficient parking stalls allocated for handicapped parking. Student needs to communicate the information requested in the project in a brief, 1-2 page memo.

Students have difficulty at the beginning in drawing the lot to scale. They frequently ask about the right number of the parking spaces or what is the best location for the building. Although the project statement provide them will specifics, it is difficult for them at the beginning to handle the new concept of multiple solutions. However, the students' response to this project is mostly positive. Figure 2 show sample of student work.

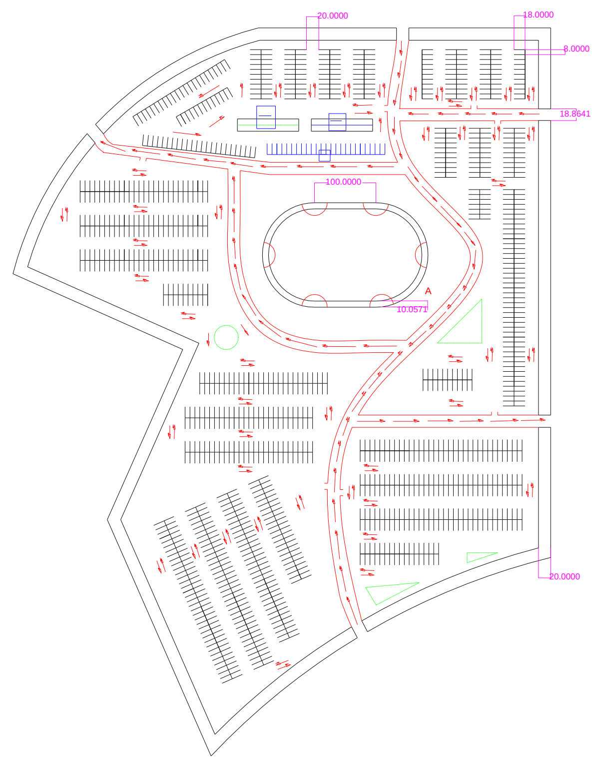


Figure 2: Sample Solution of the Parking Lot Project

Construction Management Software

Excel and Microsoft Project are used heavily in the construction management course. The project in this course requires students to work in a team in a virtual contracting company, and bid on a project. Students are provided with the bidding documents of the project including drawings, specifications, geotechnical report, etc. The goal of this project is to have students acquire a professional life experience by reading blue prints (drawings) and other contract documents. Acting as a contractor, students are required to prepare quantity takeoff, cost estimate for the project, and prepare a detailed schedule of the project activities using Microsoft Project software. Sample of student work in Excel and Project are shown in Figure 3 and 4. Students' feedback on the use of software and the project are positive. However, they would like to learn Excel early on in their life. Usually, students learn fundamentals of Excel in their freshmen year. This course requires high level of skills in Excel which introduced to them during the lab.

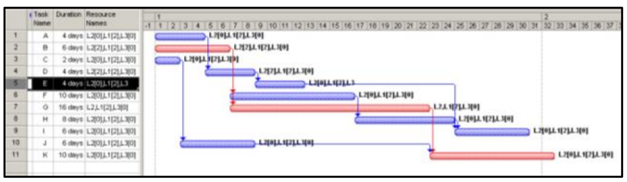


Figure 3: Resource Allocations using Microsoft Project.

Quantities Take off for Foundations

Structural Element (page)	Rebar # (H or V)	Rebar Length (ft)	λ	Rebars / ft	Length (ft)	Quantity	Total Length (ft)	Weight (lb/ft)	Total Weight (lb)	Nominal Diameter (in)
Foundation Wall 4 / S3.1	# 4 H	577.833	1.33	1.5	16.17	23	13434.6	0.668	8974.3	0.5
	# 8 V	17.167	1	1	577.83	579	9936.6	2.670	26530.8	1
	# 4 V	16.167	1	1	577.83	579	9357.8	0.668	6251.0	0.5
Foundation Wall Footings 4 / S3.1	# 5 H	577.833	1	2	1.00	2	1155.7	1.043	1205.4	0.625
	# 4 V	1.917	1	2	577.83	1157	2216.9	0.668	1480.9	0.5
Exterior Wall 15A / S3.2-3	# 4 H	69.290	1.33	1.5	4.00	7	485.0	0.668	324.0	0.5
	# 4 VR	5	2	0.5	69.29	35.645	178.2	0.668	119.1	0.5
	# 4 VL	4	2	0.5	69.29	35.645	142.6	0.668	95.2	0.5
Exterior Wall Footings 15A / S3.3-4	# 5 H	69.290	1	2	1.00	2	138.6	1.043	144.5	0.625
	# 4 V	1.750	2	1	69.29	69	121.3	0.668	81.0	0.5
Piers P1 / S2.1	# 8	13.667	-	-	-	8	109.3	2.670	291.9	1
Pier footer F8 / S2.1	#6	6	-	-	-	12	72.0	1.502	108.1	0.75

where,

- Rebar # (H or V) = Reinforcing Steel Bar Number (Horizontal or Vertical and Left or Right if applicable)
- λ = Frequency of Steel Rebars (1 rebar every *x* feet)
- Rebars / ft = Number of Rebars per Linear Foot
- Length (ft) = Length of the Structural Element
- Weight (lb/ft) = Weight values for each rebar. Source: en.Wikipedia.org/wiki/rebar

Figure 4 Sample of Part of Steel Calculations Using Excel.

Structural Analysis Software

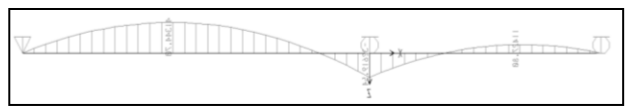
SAP2000 and ETABS are used at IPFW to help the civil engineering students gain real world experience with some of the most powerful software packages available to professionals. Students are exposed to the software step by step of modeling, analysis, and design in a sequential approach through successive core and elective courses including Structural Analysis, Reinforced Concrete Design, and Steel Design. SAP2000 is intended for use on structures such as bridges, dams, stadiums, industrial structures, and buildings. ETABS is a special version of SAP2000 that is used mainly for buildings[6].

Figures 5 show the results of SAP2000 for the shear and moment diagrams as well as the deflection curve for the two-span continuous beam. Figure shows the work of students in a senior design project to design, model and analyze a pedestrian bridge. The deformed view of bridge with wind load applied is shown in Figure 7.

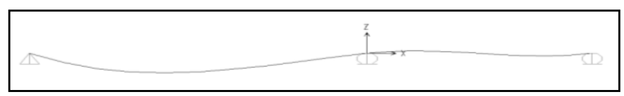
Transportation software

Excel, Highway Capacity Software, Synchro, and TrafficSim are used in the Transportation courses including Transportation Engineering, Traffic Engineering, Transportation Planning and Senior Design. In the Transportation Engineering course, one of the project statements required the use of Excel in developing a program for highway geometric design; from simple curves to compound curves; both vertical and horizontal. This project was linked to ABET outcomes that address the ability of students to design a system, component, or process to meet desired needs within realistic constraints and, measure student's ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. Figure 8 present the input screen for the design of simple and/or compound curve.

(a) Shear diagram for continuous beam



(b) Moment diagram for continuous beam.



(c) Deflection curve for continuous beam.

Figure 5: Structural Analysis of continuous beam using SAP2000.

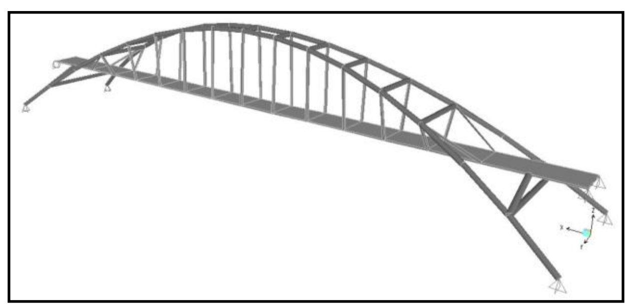


Figure 6: Extruded view of pedestrian bridge.

Synchro plus and SimTraffic are one of the most commonly used software packages in traffic engineering. Some of the important features of Synchro are the analysis tool for traffic engineers include the use of methodologies developed in the Highway Capacity Manual, the effectiveness in evaluating signals and signal systems in arterial networks, the ability to evaluate multiple intersections with a single controller such as Michigan Lefts, diamond interchanges and closely spaces intersections. Synchro's limitations include its limited analytical capabilities of roundabouts and some problems with extremely skewed intersections.

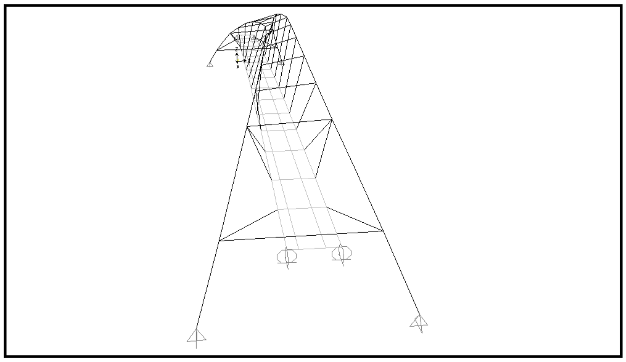


Figure 7: Deformed view of bridge with wind load applied.

Figure 9 shows part of a senior design project entitled "Transportation Network for IPFW." The main objectives of the project is to design a transportation network for the IPFW campus that adequately handles the 60% projected growth of the campus population and facilitates the growth objectives of the Master Plan, while promoting safety. The figure presents the existing design and the proposed design.

INPUT			
Simple Curve enter **1**, Compund Curve enter **2**	CT=	1	
Simple Curve Data			
Multiple of the Stationing (ex. 25, 50, 100)	n =	100	ft
u = Speed [mph]	u =	-	mph
PC = Point of Curvature	PC =	4+65	
Length of Curve 1 (max 68 STA)	L_1 =	183	ft
Radius of First Curve	R_1 =	500	ft
User Deflection Angle	D_1 =	-	degrees
Degree Angle of Simple Curve 1	θ_1 =	34	degrees
Second Curve Data, For Compund Curve			
PCC = Point of Compound Curve	PCC =	6+00	
Length of Curve 2 (max 68 STA)	L_2 =	-	ft
Radius of Second Curve	R_2 =	350	ft
Degree Angle of Simple Curve 2	θ_2 =	26	degrees
User Deflection Angle	D_2 =	-	degrees
Simple Curve Output Data			
Point of Curvature	PC =	4+65	
Radius	R_1 =	500.00	ft
Length (max 68 STA)	L_1 =	183.00	ft
Tangent Length	t_1 =	152.87	ft
External Distance	E_1 =	22.85	ft
Middle Ordinate	M_1 =	21.85	ft
Degree of Curvature	θ_1 =	34.00	degrees
Deflection Angle	D_1 =	11.459	degrees
Angle to determine first full STA	δ_{11} =	6.503	degrees
Angle to determine last STA	δ_{12} =	0.000	degrees

Figure 8: Input and Output Table for Simple Horizontal Curve

Hydraulics Engineering Software

In the Hydraulics Engineering course, students learn sources and distribution of water in urban environment, including surface reservoir requirements, utilization of groundwater, and distribution systems; analysis of sewer systems and drainage courses for the disposal of both wastewater and storm water;

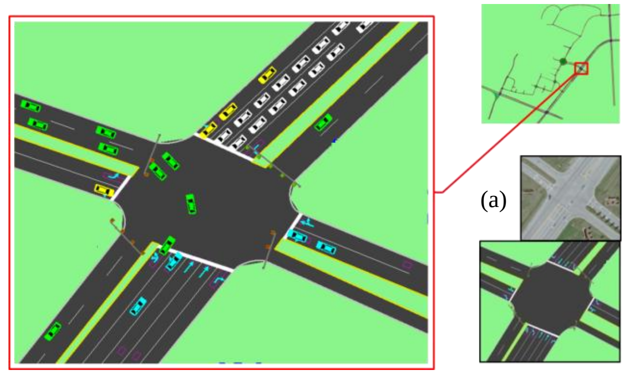


Figure 9: Input and Output Table for Simple Horizontal Curve
([a]) Source: Google Maps accessed on February 21, 2008

pumps and lift stations; and urban planning and storm drainage practice. All these contents are based on the scientific and engineering principles of conservation of mass, energy, momentum, and force balances. The specific laws and equations include Manning's law, Darcy's law, Bernoulli equation, Hazen-Williams equation, and Darcy–Weisbach equation. The students are required to understand and be familiar with all these fundamental principles, which are incorporated in all of the exams, exercises, homework, and projects.

One of the course learning outcome is "to identify and use modern computer software to analyze and design different water and wastewater systems" to the course. This outcome was added because software modeling is a common tool and important platform for current engineers to design and simulate different hydraulic applications.

KYPipe is professional software for hydraulic analyses. The newest version Pipe2010 has a common user interface linked all of the calculation models including hydraulic, water hammer, steady state, and transient systems. However, all kinds of hydraulic software, including KYPipe are just tools. They cannot replace scientific and engineering principles. Students must understand the theories and mechanisms of hydraulics behind the software. As a result, students can be trained as masters with a strong scientific and engineering background, instead of software operators merely. Accordingly, the fundamental principles and hand calculations are arranged to be taught ahead of the software modeling. Afterwards, software is taught using simple examples followed by a couple of design projects to reinforce the skills of computer modeling learnt by the students.

The interface of KYPipe is pretty user-friendly. Generally, left-click of mouse makes nodes and right-click of mouse connects nodes by pipes or conduits. The properties of each node or conduit can be entered or modified in the pull-down window by selecting it. Figure 10 shows an example of a layout pipe network in Pipe2010. In this example, the node of *R-1*, *R-2*, and *R-3* is reservoir, which has a constant water surface elevation and zero velocity. The working curve was given for *Pump-1*. With the assigned pipe materials and diameters, the water surface elevation of each reservoir, and the elevation of each node, the flow rate in every individual pipe was calculated in seconds as shown in Figure 11.

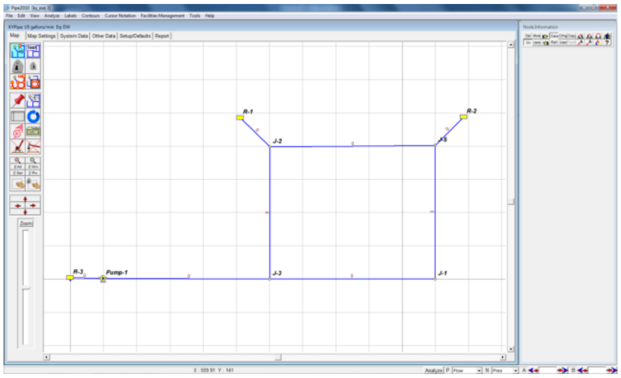


Figure 10: Layout network of a piping system in Pipe2010.

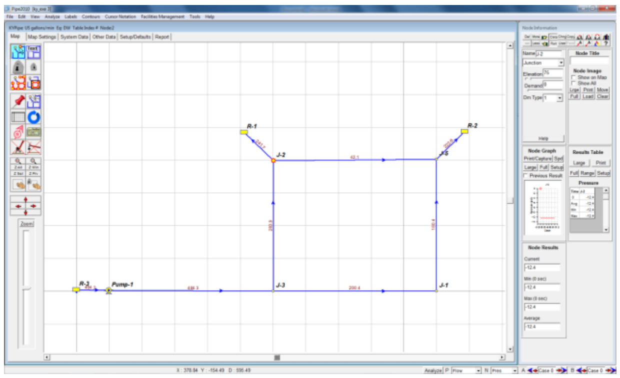


Figure 11: Simulation results showing the flow rate for the piping system by Pipe2010.

3) STUDENT FEEDBACK

The overall students' feedback on using the software is positive. The following is a selected sample of their input:

- Structural Software: the sample of students surveyed used SAP2000/ETABS throughout various stages of their design projects. When students asked on using the software packages in their structural design of their projects, 63% found it very helpful and 37% helpful (37%). In addition, 100% of the students either recommend or strongly recommend using SAP2000 and ETABS in structural engineering courses.

- Excel in Transportation: the results of the assessment indicate that student students have a major improvement of their skills in Excel and in their ability to model and develop engineering design.

- Water Resources: upon completion of the course, a survey was conducted at the end of 2010 to collect comments and suggestions from the students regarding the course and KYPipe software. 60% of the students listed KYPipe as the most favorite part of the course. They were happy to see the software gave them the correct answers within seconds, compared to otherwise difficult, complicated and time-consuming hand calculations. However, although KYPipe has a pretty strong function in simulating pressurized piping system; in storm sewer area, the students found its function and interface could not compete with EPA's Storm Water Management Model.

4) CONCLUSIONS

It is critical for any civil engineering program to focus on the fundamentals of engineering principles, to provide solid theoretical background of the concepts, and expose students to real world projects. Using the software in civil engineering education should be as a tool and in way replace learning sound scientific and engineering principles. However, software can have the advantage of supplementing this knowledge with tool to analyze complicated real world projects. In addition, using these software packages in the Capstone Senior Design project supplies the students with very powerful tools needed not only to complete the project successfully, but also to provide them with a skill that may be attractive to potential employer.

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