Bringing Graphics and Design to First Year Engineering Students  

C.E. Conron and J.A. Bergendahl  
Department of Civil and Environmental Engineering  
Worcester Polytechnic Institute, Worcester, MA 01609

ABSTRACT - Worcester Polytechnic Institute (WPI) has found success through the introduction of design software, on the freshmen level, which helps students to visualize their designs and start “designing” early.

The use of AutoCAD Civil 3D, allows the instructor to introduce basic Transportation engineering concepts and introduce a design/modeling tools which represents the state-of-the practice. The inclusion of AutoCAD Civil 3D acquaints students with key Civil Engineering concepts through an interesting methodology and excites Freshmen such that they pursue the use of this tool in subsequent courses. This paper presents an overview of the introductory module that utilizes AutoCAD Civil 3D.

I. Introduction

The design process has become an integral part of the Civil Engineering program in the United States. Many freshmen come to an engineering program expecting to learn how to design their first semester and want to start designing by the end of their first year. The process of design is complex and has many steps. These steps are graphically depicted in Figure 1.

Providing design opportunities to freshmen students can be a challenging undertaking. They lack the technical skills necessary to accomplish traditional design objectives, but they have the enthusiasm to explore prospects within their discipline. Worcester Polytechnic Institute (WPI) has experienced success with the introduction of a freshmen transportation design module through the use of AutoCAD Civil 3D and its interface with Google Earth.

AutoCAD Civil 3D (Civil 3D), one of the highway design parametric modeling tools currently available, is interoperable with Google Earth. Using Civil 3D to demonstrate the highway design workflow and Google Earth to engage the students, WPI has developed a Freshmen module which satisfies the ABET design criteria, excites students and teaches them the process of highway design.

II. Background

WPI’s Civil and Environmental Engineering (CEE) department offers an introductory-level “Civil Engineering and Computer Fundamentals” course (CE1030). This course presents freshmen with the basic computer fundamentals they may need throughout their college career and an introduction to the sub-disciplines within Civil Engineering to provide freshmen with an elementary understanding of each sub-discipline and grant freshmen access to essential information about each sub-discipline to facilitate informed decisions about their concentration.

The computer fundamentals aspect of this course usually includes basic concepts such as manipulating spreadsheet files to perform calculations and preparing charts or graphs as well as formulating word documents in a professional manner. These fundamentals are interwoven into assignments designed to introduce students to the sub-disciplines of Civil Engineering.
WPI’s curriculum is delivered in four seven week terms in an academic year, with students taking three classes per term. In CE1030, the first few weeks focus on basic Civil Engineering concepts, while the remaining weeks focus on each sub-discipline of Civil Engineering. This paper presents the transportation module, developed for one week of instruction and introduction to transportation engineering.

Transportation engineering, a sub-discipline of Civil Engineering, is a field which has been plagued by declining interest from new graduates (Mineta, 2006; Slater, 1999). There is a misconception among students that Transportation professionals are responsible for cleaning the roads or plowing the streets. Overcoming this misconception and exciting students about Transportation Engineering can be challenging.

III. AutoCAD Civil 3D & Google Earth

The transportation engineering industry is at the beginning of a monumental transformation in the way design documents are produced. For years, researchers have imagined possible contract document production workflows which have the possibility of reducing the creation of error on documents which reference the same item. (Eastman, 2007; Jaselskis, Walters, Andrle & Harrington 2004) The introduction of parametric modeling software which dynamically links the horizontal and vertical alignments with the cross-section of the roadway and earthwork quantities has become a reality. Departments of Transportations (DOTs) and transportation consulting firms alike have begun adopting these new tools.

Civil 3D, one such parametric modeling software, can be thought of as three software packages in one. The highway design tools are layered on top of Map3D, Autodesk’s geospatial software, and presented in a familiar AutoCAD user interface. The AutoCAD user interface allows students who are familiar with AutoCAD to begin working in Civil 3D immediately with training on the advanced tools only (i.e., highway design, pipe design, geospatial database, etc.). Allowing students to work in groups helps establish a level playing field for the students without AutoCAD training and allows the instructor to focus on the more advanced tools within the software.

Civil 3D is interoperable with Google Earth. This interoperability has proven remarkably usefully for instructive purposes. The user can import an aerial photograph and contour map from anywhere in the world (Google Earth’s coverage is the only limitation), as a starting point for an assignment or lecture. Rather than using an arbitrary field survey which possesses little interest to students, the instructor can import the college campus, a beach road in Hawaii, or a ski trail in Colorado for development. Upon completion of the development plans, the model can be exported back to Google Earth for review, or a *.kmz file (Google Earth extension) can be created and submitted for grading, sent to a friend, posted on a web page for viewing, etc.

At the time of this paper, Civil 3D 2009 and the most recent release of Google Earth, v4.3 are not interoperable. However, Civil 3D 2009 is completely interoperable with Google Earth 4.2, which can be installed for free from this link http://dl.google.com/earth/client/GE4/release_4_2/GoogleEarthWin.exe.

IV. Freshman Transportation Module

The freshmen transportation module and the accompanying assignment (see Figure 4) are designed to demonstrate the major steps of the highway design process, not the technical aspects of highway design.

The use of Civil 3D in CE1030’s Transportation module allows the instructor to discuss the different phases of the highway design process while graphically displaying these phases on an imported image and
surface from Google Earth. The intertwining of these two topics complements each other and improves material comprehension, as demonstrated in student papers.

Civil 3D parametric modeling properties allow the instructor to further demonstrate the implications of changes to any design element (object). As changes are made to any object, these changes are propagated instantaneously through the design and a graphical representation appears for classroom discussion. Students show in their papers that these demonstrations resonated, as the papers recognize complicated three-dimensional relationships. Figures 2 and 3 provide the typical phases of highway design and the workflow steps necessary within Civil 3D to create a corridor model respectively.

While examining these figures, it can be noted that the highway design process is slightly different from the creation of a corridor model, but does include the same general phases or steps. The requirements for the horizontal alignment, the vertical alignment and the cross-section would be determined with either scenario. When designing a highway, the process of design is very fluid, and designers should be taught to revisit each phase as they progresses through design. The students experience this using Civil 3D. When developing a corridor model, the modelers must proceed through the steps in order, but they can edit each object as the design progresses.

Assignment Steps 1-3: The assignment shown in Figure 4 first asks the student group to import an image and existing ground surface from anywhere the group chooses, which draws them into the assignment, helps them begin to focus on general design process (Figure 1) and provides some flexibility, allowing the students to choose an area which hopefully interests them. An imported image and surface in shown in Figure 5.

Assignment Step 4: Next students create a horizontal alignment which has horizontal curves with a minimum radius of 500’. After the instruction from the preceding classes, the students should recognize that the horizontal alignment will dictate the length of their road, which the assignment specifies as a minimum of two miles. At this point, students who are cognoscente of this can capitalize on the parametric nature of Civil 3D to verify their proposed alignment meets the assignment criteria. In the event it does not, students can exploit the dynamic properties of Civil 3D to edit their horizontal alignment through charts. A proposed horizontal alignment in shown in Figure 5.

Assignment Step 5: At this point, students must recognize that they have a proposed alignment and an existing surface. In order to move to the next step of creating a profile, the students must first sample the existing ground surface along the proposed alignment. Students generally have a difficult time understanding why this intermediate step must take place. Essentially, it is the only way to link the proposed alignment with existing surface. A profile of existing ground along the proposed alignment is shown in red in Figure 6. Creating a proposed profile to the assignment standards (minimum length of vertical curve is 200”) requires the students to change some default settings in Civil 3D, and possibly alter their project’s existing ground conditions. This generates a more interesting graphical representation of the project in Google Earth at the conclusion of the assignment. A proposed profile is shown in Figure 6.

Assignment Step 6: Keeping in mind the level of technical instruction on highway design at the Freshmen level for a one week module is minimum, creating an assembly allows the students a good deal of flexibility in choosing the cross-section which they would like to build their road with. Some groups choose a simple two lane road, while others choose a
four lane highway with a median, as shown in Figure 7. The assembly represents the final “building block” of the design.

Assignment Step 7: The students then combine their horizontal alignment, vertical alignment, and cross-section to build a corridor, show in Figure 8. During this step, students gain an appreciation for the three-dimensional implications of each of their design decisions.

Assignment Step 8: Finally, students are asked to export their designs to Google Earth, as show in Figure 9. When viewing this particular design in Google Earth, the student might realize that a four-lane road with a median may not be the best choice for this residential area. Certainly, the student will question why some areas of the road are not showing, determining that those areas are not showing because that is where the student proposes to “cut” land.

V. Results and Conclusion

Student papers indicate their understanding of the highway design process. The papers summarize the design decisions they have made and the “re-designs” they have undertaken as a result of trying to meet the assignment requirements. Student papers also show whether students considered the cost implications of their designs. For example, some students discuss the potential for large land removal costs associated with the combination of lowering a vertical curve and widening of the road’s cross-section.

In one week, the students develop a corridor model, gain an understanding of the highway design process, and learn new software that is applicable across the Civil Engineering discipline. Additionally, students gain knowledge of an engaging tool that stimulates their interest in their field. One student indicated that “it’s cool to see the whole road built.”

In future years, students can build upon their highway design process knowledge and software knowledge in a sophomore level “Software Applications” course which examines the abilities of the software more closely and focuses on applying the software as a tool or in Transportation classes where they learn about the elements which comprise the design.

VI. Future Work

Future work should include more detailed tracking of freshman students at the start of CE1030 and at the close of CE1030 to determine how widespread the excitement generated is among the student body. Future work should also include a survey of entering freshman to determine when they believe they will begin designing.

IX. References


Figure 1. The Design Process.
Design a road that is a minimum of 2 miles in length. This road should have horizontal curves and vertical curves. The horizontal curves should have a minimum radius of 500' and the vertical curves should have minimum length of 200'. Please provide complete labels for your horizontal and vertical alignments.

When designing your road, please follow these steps:
1. Create a new project in AutoCAD Civil 3D using the (Imperial) NCS Extended.dwt template file. Assign a coordinate zone in Civil 3D (Massachusetts Mainland Foot or whatever is appropriate for your site).
2. Open Google earth and zoom to your location.
3. In Civil 3D, import your surface and image.
4. Create an alignment.
5. Create a profile.
6. Create an assembly.
7. Build your corridor.
8. Export to Google earth relative to sea level.
9. Save the Google earth file and submit it with your report.

Your final report should include:
- A summary of your design, the steps you took to design your road and your final design.
- A discussion of coordinates and why they are important to this project.
- A summary of Civil3D's features from the AutoDesk website.

Figure 4. Example assignment.
Figure 5. Imported Google Earth image and surface with proposed horizontal alignment.

Figure 6. Existing vertical profile along proposed alignment and proposed vertical alignment.
Figure 7. Proposed assembly (cross-section).

Figure 8. Built corridor in Civil 3D.
Figure 9 (a-b). Various Orientations of a built corridor published in Google Earth.