

INTEGRATING CIVIL 3D IN HIGHWAY ENGINEERING COURSE

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ABSTRACT

Highway engineering is one of the core courses in Civil Engineering for undergraduate students. This course covers topics such as geometric design of highways, pavement design, traffic flow theory etc. This course usually has a lecture and a lab component. Most of the campuses across the nation use the lab to teach highway engineering software. At Penn State Harrisburg, during the labs, highway design software such as Highway Capacity Software and drafting software such as AutoCAD were taught for the past few years. In practice though, Civil 3D or MicroStation have gained popularity and are being used for highway design. Civil 3D is an advanced version of AutoCAD and specifically designed for viewing objects in three dimensions. With recommendations from Alumni who are employed in Highway Engineering field and from the Academic Board members, Civil 3D was introduced in the lab for Highway Engineering course from Fall 2022. This paper describes how Civil 3D was integrated with the highway engineering course and the benefits of this software for this course. Also included in this paper are the feedback received from the students and the improvements that are proposed to be made for the lab.

INTRODUCTION

Instructors throughout the world have always shown great interest in integrating course specific software. It helps the student better understand the course and equip them with much needed tools for their careers after graduation. Diegert et al [1] showed how to integrate Bluebeam into an Architectural Engineering Design course. Goncalves and Santos [2] implemented teaching methodologies aiming to facilitate the acquisition of three-dimensional project visualization skills using Computer Aided Drafting. A study to investigate the perception of mining engineering students on AutoCAD in their courses regarding its value as a computational tool and its intense use of digital resources was done by Arriagada and Zavala [3]. They showed that the acceptance given by students to the use of AutoCAD as a design and three-dimensional modeling tool was very favorable. Osakue [4] explored the teaching of solid modeling using AutoCAD. Zhang and Probst [5] found that CAD software packages can get students more interested in the subject, as well as help students to visualize physics concepts and also better understand the theories. Gaikawad and Ghodmare [6] showed a typical design of roadway with the support of AutoCAD Civil 3D.

This paper specifically focusses on how Civil 3D is integrated in highway engineering course offered to undergraduate students in Civil Engineering at Penn State Harrisburg. The paper includes the various topics covered in the lab relating to Civil 3D and also includes the student feedback received for the lab component of the course for Spring 2022.

HIGHWAY ENGINEERING LAB

Highway engineering deals with such topics including design of highways, pavement design, traffic models etc. A full list of topics covered in highway engineering is provided in Table 1.

Table 1. Topics Covered in Highway Engineering

INTENDED TOPICS	TEXT	LAB
Introduction to Transportation Systems	Chapter 1	AutoCAD
Vehicle Performance and Resistance	Chapter 2	Introduction to Civil 3D
Tractive Effort, Acceleration and Stopping Distance	Chapter 2	
Horizontal Alignment	Chapter 3	Horizontal Alignment using Civil 3D
Vertical Alignment	Chapter 3	
Flexible Pavement Design	Chapter 4	Vertical Alignment using Civil 3D
Rigid Pavement Design	Chapter 4	
Traffic Stream Parameters and Models	Chapter 5	Cross Sections using Civil 3D
Queuing Theory	Chapter 5	
Capacity and LOS: Freeways and 2-lane Highways	Chapter 6	Highway Capacity Software
Intersection Operation/Control	Chapter 7	
Signalized Intersections – Saturation Flow	Chapter 7	

The same table (third column) also lists the various labs associated with this course. Among all the topics listed in Table 1, highway design is the most important and Civil 3D helps to better understand and visualize the design. The lab portion of the course starts with an introduction to AutoCAD because Civil 3D uses the same commands when it comes to basic drawing of objects. The next lab session focusses on introducing Civil 3D commands that are relevant highway design. The following lab sessions on Civil 3D focus on horizontal alignment, vertical alignment, and cross section that are integral part of highway design.

HORIZONTAL ALIGNMENT

Horizontal alignment of a roadway includes the straight line path and curves as seen from a plan view. Figure 1 below shows a neighborhood with new horizontal alignments (red lines). This drawing and other associated exercise files were taken from linkedin resource [7] available for penn state students. In the lab session(s) associated with horizontal alignment, students are taught the following in Civil 3D,

- Creating alignment using objects and alignment creating tools.
- Edit an alignment with grips and alignment editing tools.
- Create criteria based design and use design check set.

The criteria based design and design check set are very useful tools that directly relate to what is being taught in the lecture portion. Sight distance, design speed, radius of curve, and length of straight line segment are checked against established standards. If these checks were to be done manually, it would take a considerable amount of time based upon the total length of the alignment. But, using Civil 3D these checks are done instantly with the available tools.

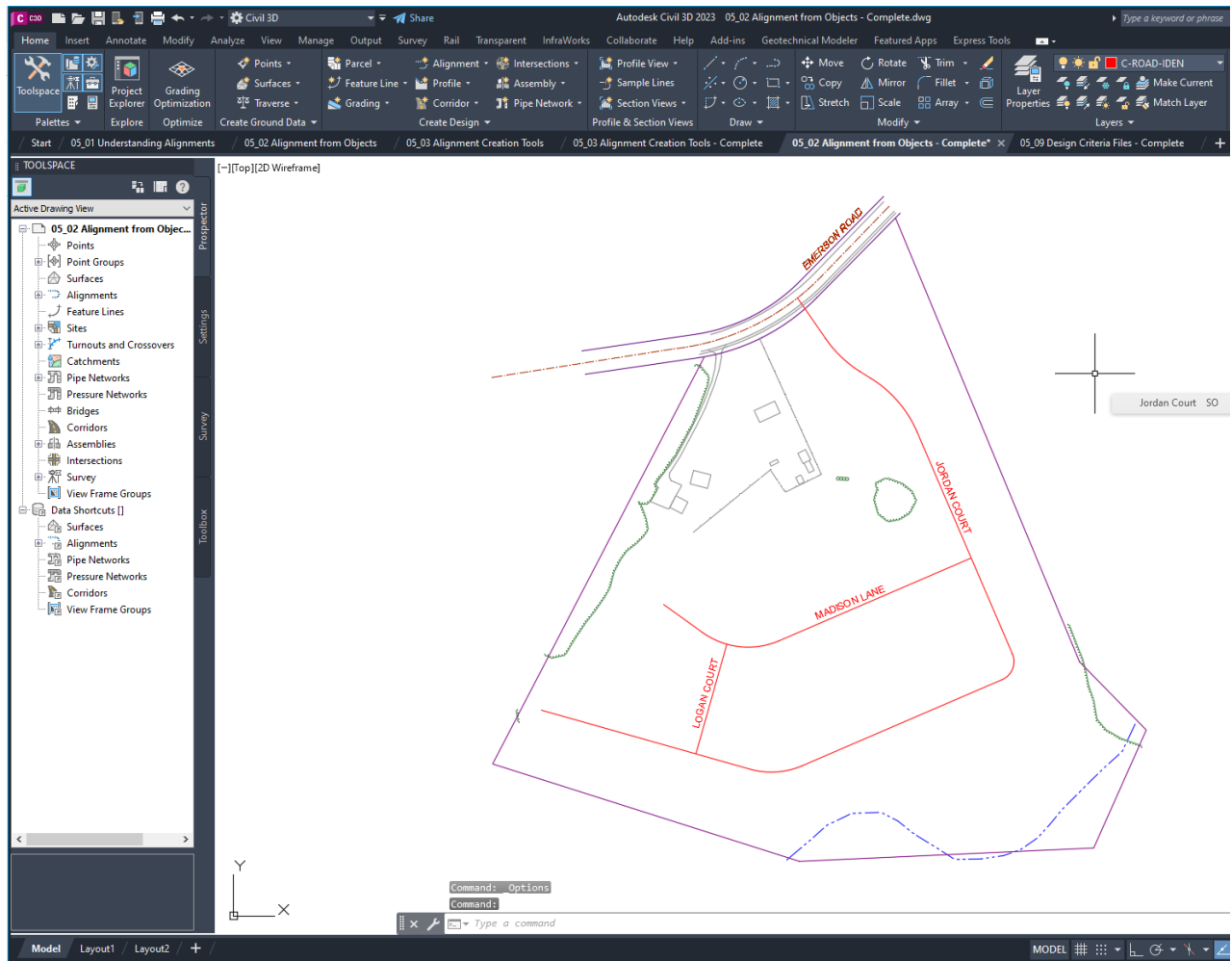


Figure 1. Horizontal Alignments Created Using Civil 3D

VERTICAL ALIGNMENT

A vertical alignment consists of the crest and sag curves and the straight-line segments that connect them. It specifies the elevation of points along a roadway. Vertical alignment in two dimension is viewed from a profile view. The following items associated with vertical alignment are taught in Civil 3D,

- Creating existing ground profile
- Creating a design profile
- Editing profiles
- Design check set and design criteria check for profiles.

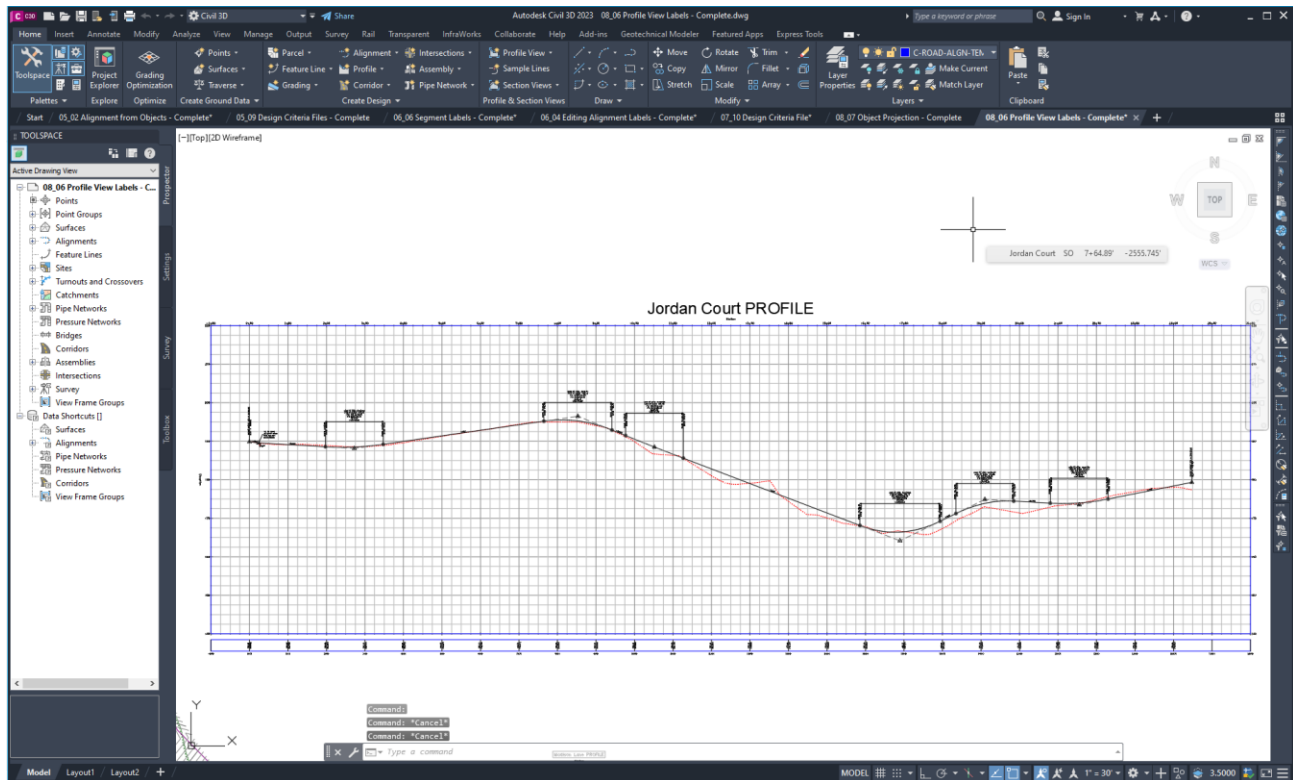


Figure 2. Vertical Alignment of a Roadway Created Using Civil 3D

Figure 2 shows the profile view of an alignment as created using Civil 3D. The design check set and design criteria check for a vertical alignment would check for design speed, passing distance, rate of curvature etc. Civil 3D drastically reduces the time needed to perform these checks if they were done manually. Also, using an existing ground profile and a design profile, working out the cut and fill calculations are made easy by Civil 3D.

CROSS SECTION

A cross section of an alignment consists of width of the roadway, shoulder, side slope and other cross sectional elements. The width of the roadway corresponds to the number of lanes, while each lane is usually 12 ft wide. Shoulder refers to the area that is to the side of and adjacent to the pavement. Side slope refers to the slope of ground beyond the shoulder and this may be a cut slope or a fill slope depending on the terrain. In Figure 3, the cross sectional elements are shown in the top right window. The left window shows the horizontal alignment and the bottom right window shows a three dimensional view of an alignment.

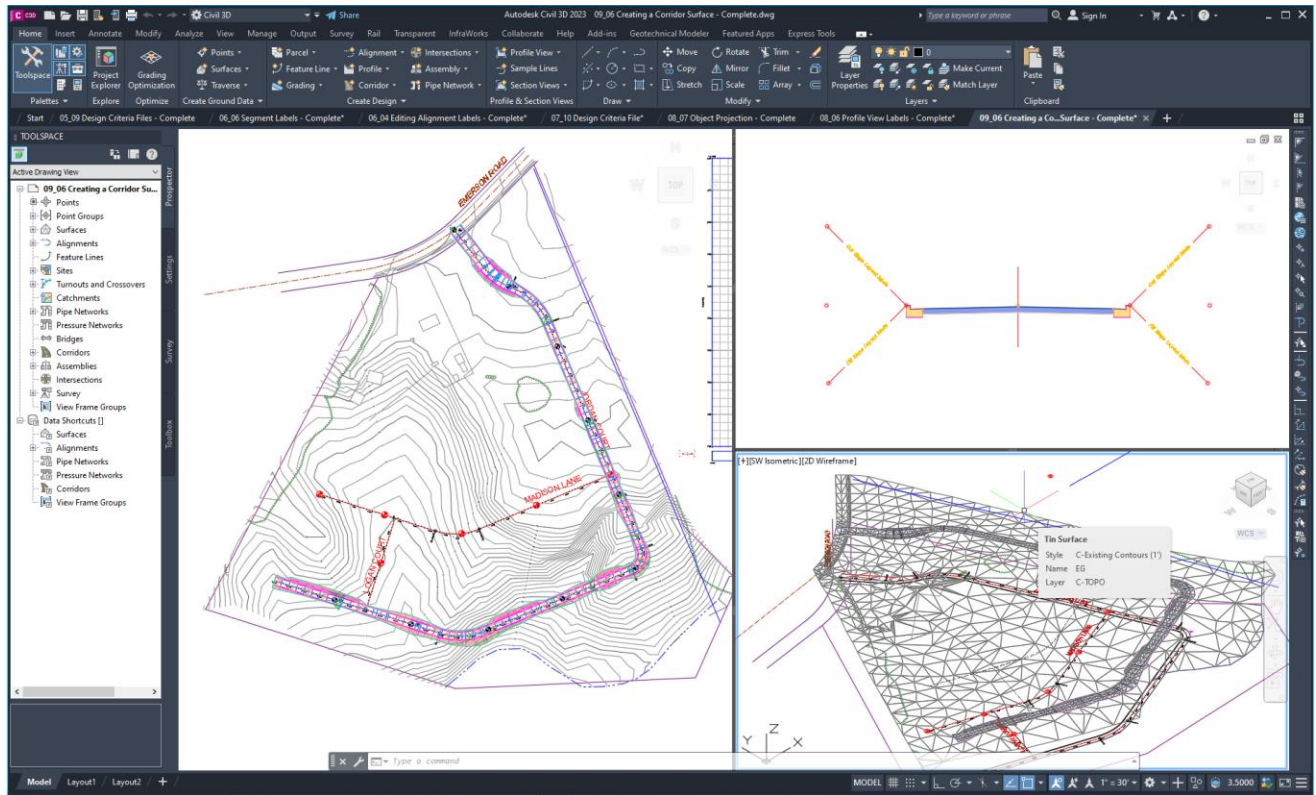


Figure 3. Cross Section and 3D View of an Alignment.

The three-dimensional rendition of the roadway and projection of plan view and profile view in two dimension helped students understand various elements of the roadway. Students were able to easily relate the lab work with topics taught during the highway design lecture.

STUDENT FEEDBACK

All course and teaching evaluations are done using Student Rating of Teaching Effectiveness (SRTE). Since the highway engineering course had a lecture and lab component. The SRTE evaluation was performed for lecture and lab separately. The table below shows the rating by students for the lab portion of the course. The numbers in each column correspond to the number of students who rated with the specific rating provided in column header. The mean values shown in the table are the weighted mean.

Table 2. Student Rating for the Lab and Instructor

Item	Rating by students (1 to 7)							Mean
	1	2	3	4	5	6	7	
Rate how well this course increased your understanding of the course topics.	-	-	1	1	3	8	7	4.8
Rate how well the instructor promoted a meaningful learning experience for you.	-	-	-	1	3	5	11	5.7

While the mean value of rating of the lab and the instructor are good, there is still a lot of room for improvement. The open-ended questions in SRTE provide a basis on where the improvement can be made. These open-ended questions attached in SRTE are shown below,

1. What aspects of this course helped you learn?
2. What changes to this course could improve your learning?

For the first open-ended question, some of the students' answers are listed below,

- The Lab portion was very useful for future applications in the field.
- Some sort of final CAD project would have been useful for learning the software.
- The labs were sometimes difficult to follow. Learning Civil 3D was a lot to handle in such little time.
- Real-world Applications: Connected course material to real-world examples and practical applications helped make the learning more meaningful and relevant for us students.

The following are some of the responses of the students for the second open-ended question.

- I feel the lab is fine the way it is.
- More focus on the basics would be appreciated. As someone who came from a Solid Works background switching to Civil 3D and CAD was a learning curve that was not accounted for in the class.
- Slowing down a little.
- I enjoyed the class so I wouldn't change anything.
- The labs were sometimes difficult to follow. Learning Civil 3D was a lot to handle in such little time.

CONCLUSION

This paper discussed how Civil 3D was integrated into Highway Engineering course for undergraduate students in Civil Engineering. It is apparent that Civil 3D helped students with visualizing highway design. Using the feedback received from students it can be concluded that the students found the software to be very useful, particularly for future applications in the highway engineering field. Students also felt that the lab connected course materials to real world examples and practical applications. This is a very important feedback because if the students believe that the lab connected course materials to real world examples and practical applications, it means that they are equipping themselves for a possible highway engineering career. The utilization of software like Civil 3D by highway/transportation engineering firms has been increasing for the past few years. Specifically, students will be well prepared for creating new highway alignments, performing design checks for the highway, and work out cut and fill calculations.

The students' feedback also provided useful information on improving the lab such as introducing a lab project, slowing down the pace of instruction, focusing on basics. This feedback will be taken into account to modify the lab before the next course offering. The authors are planning to collect more data from various terms and years and do a comparison study of how the modifications to lab would be received by the students. Apart from SRTE survey, efforts would also be made to come up with a questionnaire specifically designed for the lab to get additional feedback information.

REFERENCES

1. Deigert, M. J., & Behrouzi, A., & Brady, P. A. "Implementing Bluebeam Software in Architectural Engineering Design Courses" Paper presented at 2020 ASEE Virtual Annual Conference, June 2020.
2. Goncalves, J. and Santos, B. "Enhancing Civil Engineering teaching through 3D Computer Aided Design" IOP Conference Series: Materials Science and Engineering, 586, 2019.
3. Arriagada, M., & Zavala, G. "Students Perceptions on the Use of AutoCAD Activities in Courses of the Mining Engineering Program" Paper presented at 2022 ASEE Annual Conference & Exposition, Minneapolis, MN , August 2022.
4. Osakue, E. E. "Teaching Solid Modeling with Autocad" Paper presented at 2015 ASEE Annual Conference & Exposition, Seattle, Washington, June, 2015.
5. Zhang, Y., & Probst, D. "Blessing Or Curse, Teaching With Cad Software" Paper presented at 2010 Annual Conference & Exposition, Louisville, Kentucky, June, 2010.
6. Gaikawad, P. and Ghodmare, S. D. "A Review-Geometric Design of Highway with the Help of Autocad Civil 3D". International Journal for Research in Applied Science & Engineering Technology, Volume 8, Issue V, May 2020.
7. <https://www.linkedin.com/learning/autodesk-civil-3d-2022-essential-training/>