

# A Dilemma in Engineering Class Design Project

---

Ruinian Jiang, Assistant Professor  
Sonya Cooper, Professor and Department Head  
Department of ET & SE, New Mexico State University

**Abstract:** Project design is a critical component in the success of higher level college engineering courses. Projects are ideal measures of student learning outcomes. The rapid development of commercial computer software has brought powerful tools for modern engineering education while creating new challenges for assuring student learning outcomes are met. Today, students may use commercial computer programs to solve almost any problem. A dilemma is created in that students might be able to solve their project problems using computer software without actually understanding the principles behind them; but it seems unreasonable to prohibit students from practicing and using the software. This paper discusses strategies used in solving this challenging problem based on authors' real teaching experiences.

## I. INTRODUCTION

The rapid development of commercial computer software has brought powerful tools for modern engineering education while creating new challenges for assuring student learning outcomes are met. Currently commercial computer programs are available for students to use in solving almost any problem; from structural analyses and 3-D drawings to very specific designs such as drainage system development. Students are able to "solve" their project problems using computer software without actually understanding the principles behind them. Engineering educators should be very concerned when they find mistakes in students' projects that should be recognized by common sense. The obvious reason is that the computer allows problems to be solved without the benefit of learning the steps in problem solving. This prompts the question of whether we want our students to be creative problem solvers or computer operators.

In elementary and middle schools and even in some high schools, calculators are prohibited in homework assignments so students may learn basic mathematical principles. In higher education, before commercial computer software, basic principles were learned from creative teaching along with homework and project work. Today, with powerful software tools available, it seems unreasonable to prohibit students from using them. Also, employers consider knowledge of software beneficial, since they use it in their businesses. Thus the dilemma: how to encourage students to use commercial software while making sure they have grasped basic principles to become independent thinking professionals. Another concern is that some students in a class know specific software well, finishing

assignments quickly and easily, while other students may not have the same proficiency and have to do the problem manually. This gives a perception of unfairness in that the assignment is structured such that students have an unequal advantage. In this paper the above concerns are discussed and the lessons learned from the authors' experiences are summarized with a roadway design example project.

## **II. PROBLEM DESCRIPTION**

For most civil engineering technology higher level classes at New Mexico State University, students are assigned a term project to be completed individually or in a team. Roadway design is a very basic and important skill that has many applications in highway engineering, and commercial and residential development. A simplified project assignment for ET 412, Highway Technology, is used here to illustrate the problem. The purpose of the project is to practice roadway design concepts. The assignment description follows:

*For the topography given in Figure 1, design a two-lane, two-way road to connect the three points A, B, and C. The design speed is 25 mph. The design includes a horizontal alignment, a longitudinal profile, and cross sections every 50 ft. Use the end-area method to calculate the earthwork (cut and fill). The steps to follow are: i) design and draw the horizontal alignment on the plan; ii) draw the existing profile of the horizontal alignment centerline and design a proposed profile; iii) draw a cross section every 50 ft; iv) calculate earthwork using the end-area method; and v) show all necessary curve and sight distance parameters.*

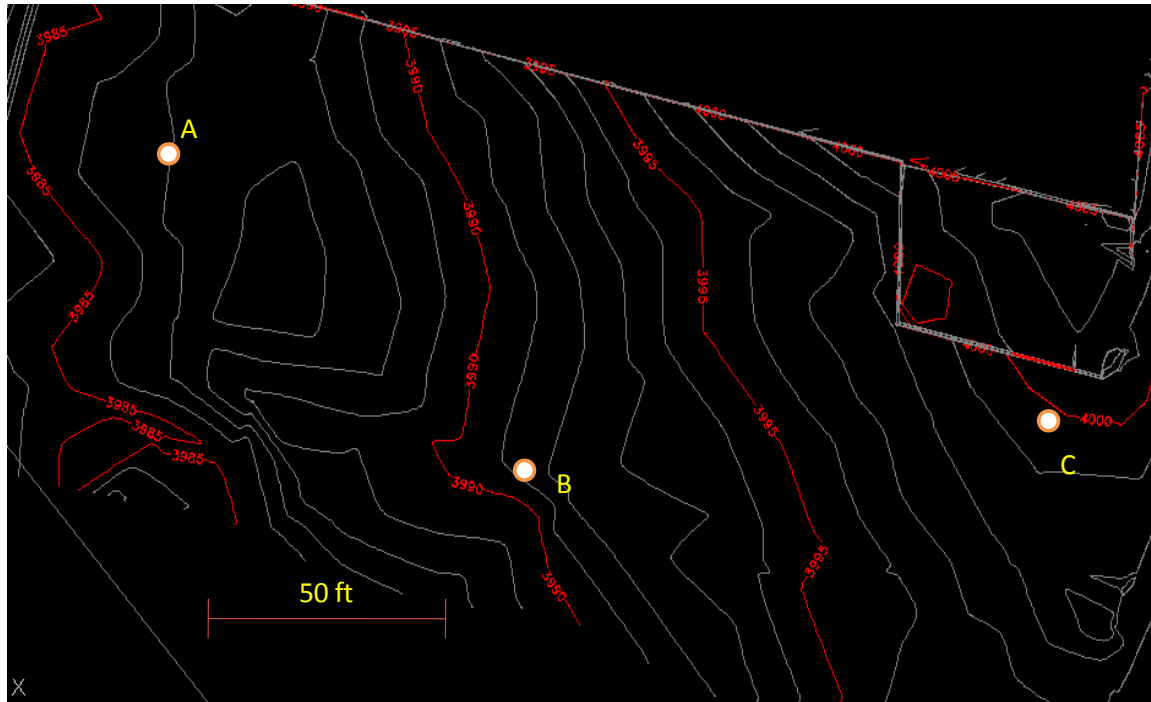


Figure 1 Topography used for roadway design, courtesy of Summit Engineering, NM.

Learning outcomes for this assignment are the following:

- To visually interpret topography from a plan view for initial horizontal alignment
- To apply circular curve geometry to highway superelevation principles, centerline alignment, and sight distance measurements
- To translate contours to a profile coordinate system
- To apply parabolic relationships to highway centerline profiles and sight distance principles
- To understand how to manipulate horizontal and vertical alignments for best cut/fill results.

This assignment begins as an individual project and is later used for the preparation of a more complex team project that requires 2 to 3 weeks of work. For this project assignment, less than 1/3 of the students did the assignment manually. They used scaled paper to draw the profile and cross sections, and used a calculator to calculate the cut and fill areas from the cross sections. More than 1/3 of the students finished the assignment partially using AutoCAD. They scanned the figure and input it into AutoCAD, designed a horizontal alignment with AutoCAD, and used polyline to calculate the cut and fill areas. The remaining 1/3 of the students did the project entirely automatically. They input the figure into Civil 3-D or AutoCAD Land Development Desktop (LDD), traced the contour lines, designed the profile and calculated cut and fill earthwork automatically using the software. The feedback from these three categories of students is quite different.

The students who did the project manually mentioned that they did so because they forgot how to use AutoCAD; they took an AutoCAD class more than 1 year ago and have not used it since. They said they spent a lot of time on the project (some more than 2 weeks); however they did learn a lot on the basic principles of roadway design by completing the project manually. They complained that they spent too much time on the project since they had to do it manually. (Of course they only knew the time was long because they compared their effort to the ones who finished quickly using the computer.)

The students who did the project using AutoCAD 3-D or LDD claimed the project was very easy. Some spent less than 1 day to finish it. These students generally worked part time with engineering companies and knew computer drafting very well. Unfortunately they learned very little on the principles of roadway design from this project assignment.

The students who did the project partially using AutoCAD said they first thought about design methodology and then used the computer to help them with the drafting and calculations. For example, they read the elevations of points manually from the plan and used the polyline function to calculate the cut and fill areas. This group of students felt fine with the project since they practiced and learned highway principles and did not spend too much time on the project.

Based on feedback from the students it was realized that improvements should be made for the project assignment. The assignment should guide students in such a way that they can practice the basic principles and at the same time use computer software to avoid laboring work. It was also realized that the collaboration between students should be encouraged in such projects since some of them know the principles well and the others know the computer software well.

### **III.IMPROVEMENT OF THE PROJECT ASSIGNMENT**

A roadway is a long and narrow structure. The 3-D design of a roadway is very different from that of other civil engineering structures. The coordinate system used for the roadway design is thus different from that of building structures. In roadway design, two 2-D coordinate systems are used.

As shown in Figure 2 (Mannering et al., 2005), the first 2-D coordinate system is the plan view, which is the horizontal cast of a roadway on a plan. The second 2-D coordinate system is the vertical profile, which is the elevation change along the centerline of the road. The X-axis of the profile (the second 2-D coordinate) is actually made by stretching the centerline of a roadway into a straight line (actually it has curves). It was found that it is difficult for students to develop a clear 3-D image of roadways in their mind without performing exercises to construct a vertical profile from a plan and cross sections from the plan and the profile.

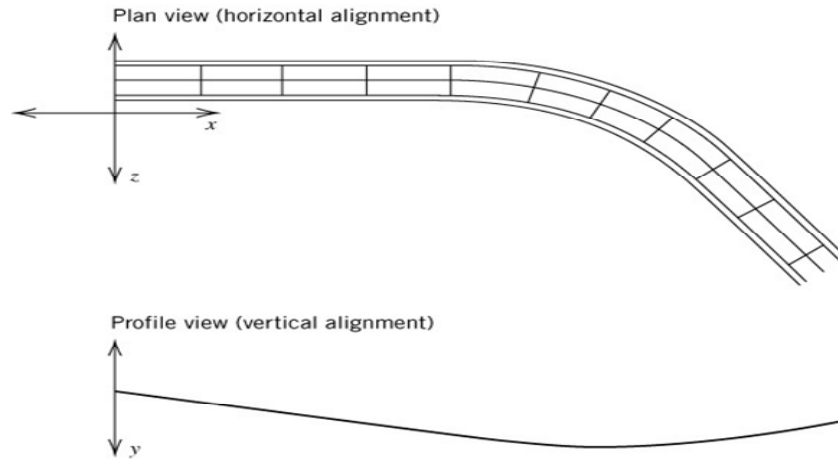


Figure 2 Coordinate systems used of roadway design (Mannering et al., 2005)

The exercises are provided through a modified project assignment as described below. This project is assigned to a team of two to three students, with one student proficient at AutoCAD. The project requires students to design the roadway manually first.

As illustrated in Figure 3, students first design a horizontal alignment to connect the three points A, B, and C. They may do this in different ways as long as they connect the three points and check the safety standard of the minimum radius against the design speed. One solution is to draw tangents and apply curves using curve geometry as shown in Figure 3.

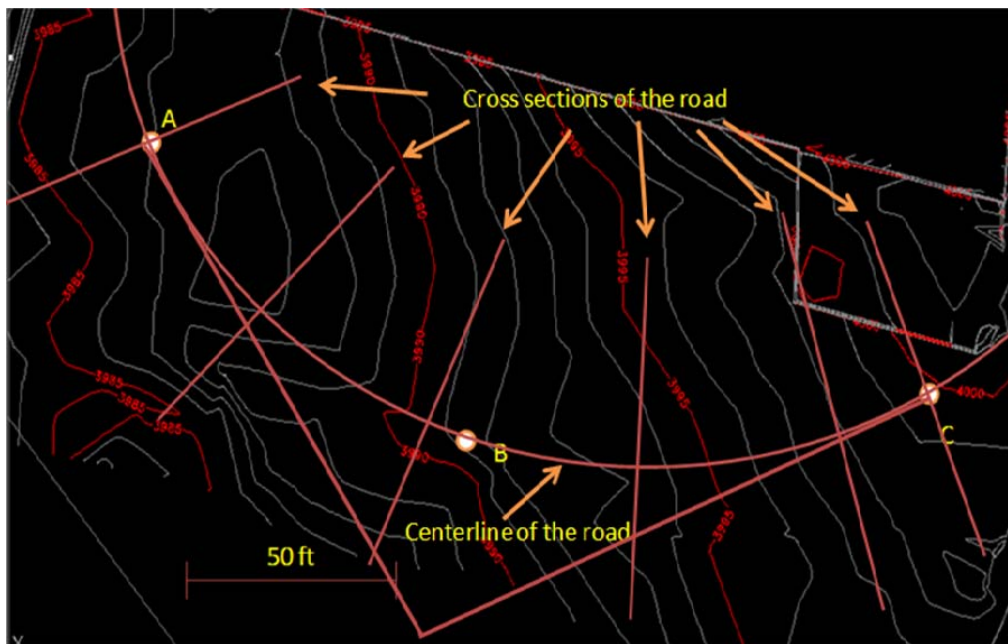


Figure 3 Plan view of the roadway

The second task is to read the elevations along the centerline ABC and draw a profile of the existing terrain. Next, the students design a proposed road profile using parabolic (vertical curve) relationships and following the existing terrain as close as possible. Students may use an Excel spreadsheet to do this. Figure 4 shows the profile of the existing terrain along the centerline of the road.

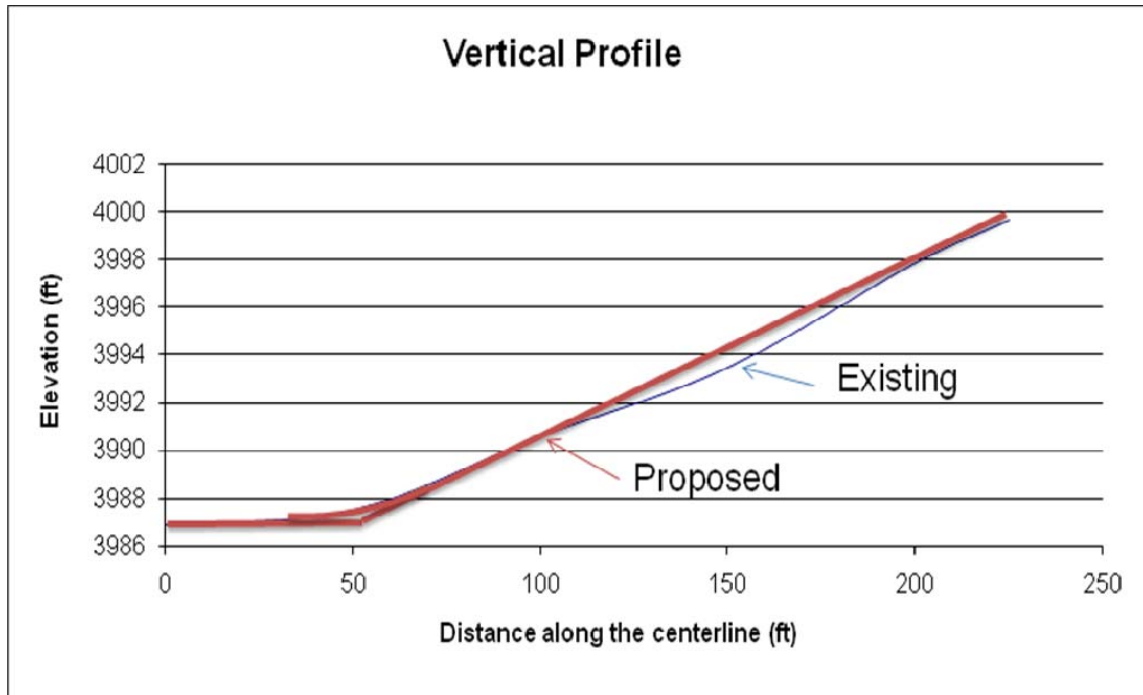


Figure 4 Vertical profile of the existing terrain along the centerline of the road

The third task is to draw cross sections for each 50-ft interval along the road; the cross section locations are shown in Figure 3. For a two-lane, two-way road, the existing and proposed elevations are shown for the centerline, edge of pavement, edge of shoulder and three or four points to the right-of-way. More points should be added if necessary. Figure 5 gives a typical cross section for a cut-fill section. Students are required to use the following formula to calculate cut and fill cross-sectional areas respectively (NCEES, 2007); the principle of the formula is illustrated in Figure 6.

$$Area = [X_A(Y_B - Y_N) + X_B(Y_C - Y_A) + X_C(Y_D - Y_B) + \dots + X_N(Y_A - Y_{N-1})] / 2$$

After calculating cut and fill section areas for each cross section, students then use the Average End Area Formula to calculate the earthwork:

$$V = L (A_1 + A_2) / 2$$

Finally, they use an Excel spreadsheet to calculate and summarize the net earthwork.

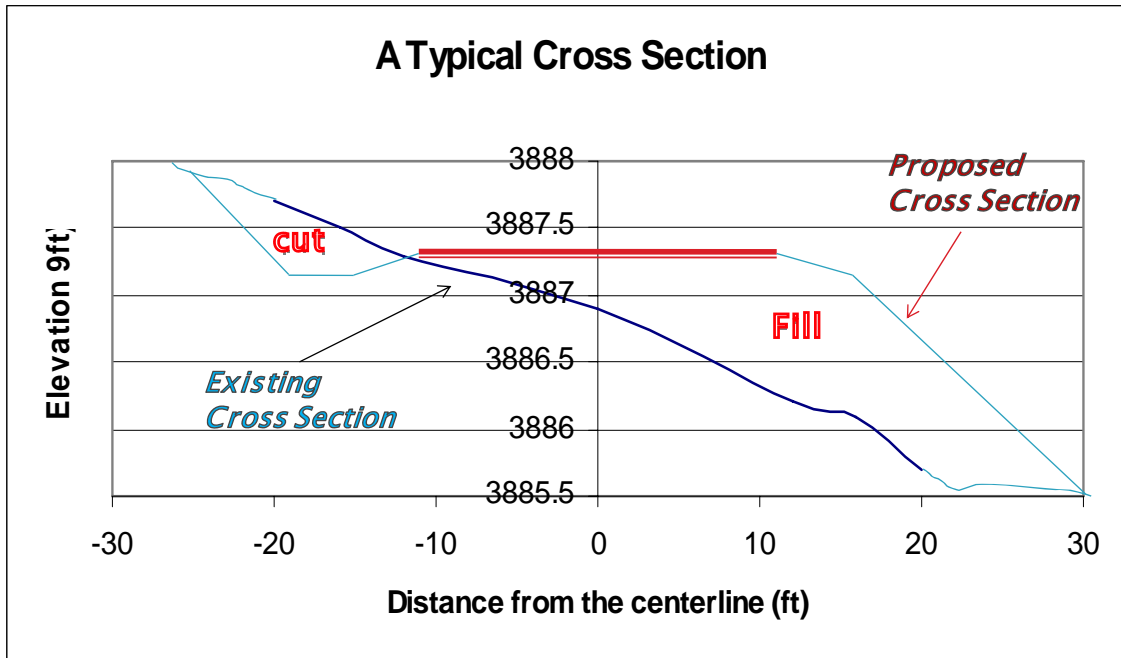


Figure 5 A typical cross section

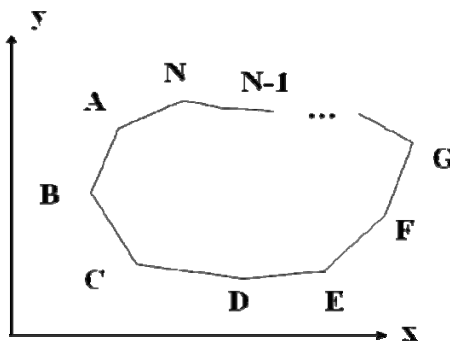


Figure 6 Area calculations using the coordinate method

With the above manual exercises, students are able to thoroughly understand the basic concepts of roadway design. Students are then required to do the same project using a computer software tool such as Civil 3-D or AutoCAD LDD. Then they are required to compare the results obtained from the manual and the computer method. After practicing with this project, students feel satisfied knowing the methodology behind the computer results and being relieved of tedious work.

#### **IV. CONCLUSION**

A good project design is critical to the success of engineering classes. In these project assignments, students should have both the opportunity to understand basic concepts and to practice computer software skills. Assistance in forming work teams should be provided so that students with different skills can be assigned to a team. For example; some students are good at concepts and some others are good at computer skills. A good combination of team members can encourage the team to work closely and effectively. More importantly, they feel good about the project because everyone had to follow the same procedures, setting an equal playing field for all. Cross training within a project team has also been achieved: the member with strength of computer drafting teaches other members on computer skills, and the one with analytical skills teaches others on application of basic principles and engineering analysis.

A simplified project that can be done manually may be used for students to practice basic concepts. This is essential to train students to be effective engineers and not only draftsmen or a computer operators. Assigning manual exercises is necessary since it is possible for students to finish a project totally using commercial computer software without grasping the basic concepts. If students are totally dependent on computers they will not be able to notice incorrect computer output. This may lead to some unpleasant results or even disasters in their future practice.

#### **V. REFERENCES**

Mannering, F.L., Kilareski, W.P., and S.S. Washburn, (2005), Principles of Highway Engineering and Traffic Analysis, John Wiley & Sons, Inc, pp 372.

NCEES, (2007), Fundamentals of Engineering Supplied-Reference Handbook, National Council of Examiners for Engineering and Surveying.