INTRODUCTION

Welcome to Exploring Civil Engineering. This text is a very simple introduction to the world of civil engineering and an understanding to the impact it has on our every day lives. Exploring Civil Engineering provides a basic concept and simple principles to real life practices in civil engineering. You will be able to go through the text and gain an understanding of the oldest branch of engineering professions. The project will enable your students to become familiar with the design process that is utilized for an on site infrastructure project. Exploring Civil Engineering was created by employees at Dibble Engineering a very well known civil engineering firm in Phoenix, AZ. It was written with the intent to give students a beginning of civil engineering.

Exploring Civil Engineering uses the A+CAD software technology as the tool to draw the engineering plans for this project. A+CAD is a key component of The CAD Academy’s package to help educators prepare students to learn the same type of technology that they may be exposed to in industry. The A+CAD technology offers the industry standard compatibility with AutoCAD®-native DWG files, commands, applications, and command set as well as programming APIs, such as LISP and SDS (A+CAD’s application programming interface).

Student’s success in this course is directly related to his or her ability to understand how to proceed in traditional and non-traditional class settings. It is imperative for you to:

1. Read all material carefully. Reread the material several times for total understanding. DO NOT SKIM.

2. Understand the concept of an activity before you start entering commands on the keyboard.

3. The information you will type is presented in numbered sequence.
   Follow the steps carefully, watching the screen as you proceed.

4. Read the concepts again if you are having difficulty understanding a particular item.

5. Repeat the steps of an exercise over and over to develop mastery. Mastery means you are able to complete an exercise without looking at the book, and understand why you performed that particular function.

6. Ask questions if you do not understand or if you are having difficulty with the keystrokes.
IMPORTANT INFORMATION FOR INSTRUCTOR:

Exploring Civil Engineering resources are flexible and instructors should feel comfortable supplementing curriculum resources that they have found successful throughout the years. Instructors are encouraged to add any additional information to the teaching of this curriculum. The text and drawing files included are designed to be used together. The student folder contains files in their “raw” drawing state. The instructor folder contains the same drawings as the student, but also will include all completed drawings. The instructor folder also contains drawings which will be completed at various stages, depending on where the instructor is in the curriculum. The instructor then can put up the drawing in which he or she is talking about. Both the student and teacher folders will have the same file structure, containing three base files, component files and sheet files. It is recommended that the instructor sit through the text exercises and become familiar with the set up of the text material. It is the responsibility of the instructor to design their own quiz and testing material that they might deem necessary for their students and utilizing the text folders provided as well as any material they have added to this curriculum.

We welcome your suggestions, and hope that you will become a part of the collaborative effort in educating our future engineers.

ABOUT THE AUTHOR

Exploring Civil Engineering text was created by Dibble Engineering Inc. Dibble Engineering (Dibble) is an innovative and dynamic consulting engineering firm founded in Phoenix, Arizona in 1962. During the past four decades, Dibble has built an excellent reputation as a leader in the field of civil engineering, providing quality, timely, and value-priced engineering services to city, county, and state agencies, as well as a multitude of clients in the private sector. Dibble focuses in airport infrastructure, drain and flood control, site infrastructure, survey/GIS, transportation, and water resources.

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PREREQUISITES

Prerequisites for this course include basic mathematics, geometry, reading and writing skills, basic computer skills, and an understanding of Computer Aided Design (CAD) applications.

I. INTRODUCTION

1.1 General Introduction

Have you ever wondered how a bridge is designed and constructed? Or why recreational parks look like large holes? Or how a building gets water and sewer services? Civil engineers play an important role in the planning, design, and construction of these types of projects.

Civil engineers design the world’s infrastructure and shape the history of nations around the world. In fact most structures, large and small, require the help of a civil engineer whether in designing, planning, or construction management. It would be hard for most people to imagine life without the many contributions of civil engineers to their standard of living. Often you are not even aware of the impact that civil engineers play in our everyday life.

Civil engineering is the oldest branch of the engineering profession. In the ancient world, the pyramids, roadways, aqueducts, bridges, canals, and many other structures were the product of civil engineering. In early times, architects, adding to their responsibility not only the jobs of an architect, but also the jobs of a civil engineer. During the eighteenth century, men who dedicated themselves to the planning, construction, and maintaining public works began to call themselves “civilian engineers” or “civil engineers.”

The American Society of Civil Engineers explains that “Civil engineering is the profession in which a knowledge of the mathematical and physical sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the progressive well-being of humanity in creating, improving, and protecting the environment, in providing facilities for community living, industry and transportation, and in providing structures for the use of humanity.”

Within the field of civil engineering, students can specialize in one of several areas, namely, Transportation, Water Resources, Environmental, Geotechnical, Structural, etc. A typical project team consists of a project manager, project engineer, designer, and a CAD technician. The project manager is in charge of coordinating with the owner and the other sub consultants involved with the project and making sure that the design team is staying on schedule. The project engineer assists the project manager with his tasks and is in charge of the day to day design and plan preparation. The project engineer also writes design reports. The designer assists the project engineer with the day to day design tasks and plan preparation. In most cases, the designer has CAD experience and ensures that the appropriate CAD standards are utilized in the preparation of the construction plans. The CAD technician assists the team with preparing and maintaining the electronic construction plans.

1.2 Project Overview & Objectives

Site infrastructure’s projects incorporate a combination of many civil engineering disciplines for the development of a specific project site. A “site” is defined as an area of land that has legal boundaries recorded with the appropriate local authority.

The site for this example project is a 1.1 acre undeveloped lot adjacent to a three lane roadway. The owner of the site wanted to develop the site with the construction of a two story building with a parking lot. The owner hired an architect to design the new two story building. A civil engineer was retained to design the remaining portion of the site including new water and sewer utility connections. The site must store the 100 year, 2 hour storm event including the runoff from the half street. The building must have an ADA accessible path from the main entrance to the accessible parking spaces in the parking lot.

One of the objectives of this example project is to teach the design process that civil engineers utilize on a site infrastructure project and the role that CAD plays in the design and preparation of construction plans. The software design tool that will be used for this project is A+ CAD.
3.2 CIVIL DESIGN - GRADING & DRAINAGE

It might be necessary on some site projects to do some sort of grading, which would actually reshaping the ground surface to specific elevation grades that have be determined by a civil engineer. The engineer would review the survey, evaluation and layout of the project to best determine the elevation grade necessary to get the best use of the surface ground. Grading of the land helps control soil erosion, sedimentation and surface runoff during and after construction on any project site.

Grading will happen at most project and construction sites. It will require the planning of an engineer or landscape architect to incorporate storm water and erosion and sediment control. It is not unusual for a project site to have additional dirt added to the site, this is considered fill, to meet the necessary requirements based on the guidelines of the local municipality. Each municipality, either it city, state, or county will have a set of standards in which the project manager and civil engineer must abide by depending on the location of the site project. It is also not unusual to have dirt removed from the project site that might not be needed for the grading of the site, this is considered cut. It is cost effective to have the cut and fill requirements of the project site to be as close to zero as possible.

In figure 3.2.1 below you can see an example of a subdivision that the grading has been prepared. You are able to identify the layout of the new streets and lots for the future homes.

In figure 3.2.2 you are able to identify the sediment protection and equipment that might be used on any grading project site.
Now that the parking lot is laid out, elevations need to be determined for all of the site components. There are general rules to follow to ensure a proper grading design. The two main categories of these rules are; designing the site to drain during a rainfall event, and to make the site ADA accessible.

For ADA accessibility, locations that a handicapped person might travel must meet the following rules:

1. The slope in the direction of travel must not exceed 5%.
2. The slope perpendicular to the direction of travel must not exceed 2%.
3. Ramps must have a maximum slope of 12H:1V.
4. There must be a path from the ADA parking stall to the building entrance with no stairs or steps.

For proper drainage, the following rules apply:

1. The minimum design slope in the direction of flow on asphalt pavement is 1%.
2. The minimum design slope in the direction of flow on concrete pavement is 0.5%.
3. Areas that drain against curb must have curb and gutter section.
4. A path must be provided for storm water to reach on site retention basins.
5. All storm water that falls on the site during the 100-year 2 hour event must be retained on site.

This list of rules will each be explained in greater detail later.

### 3.2.1 GRADING

Let’s start the grading design by opening the “Civil.dwg” file. Insert the “Grading.dwg”, which is located in the “CAD\Design Components” folder into our current drawing. Insert it with a base point of 0,0,0, scale factor of 1 for x, y and z and a 0 rotation angle. Choose to explode this drawing once which will enable us to use the drawing objects. This exercise will become the basic grading design for the site. As a general rule, grading of parking lots is done in planes so that it is constructible. These planes are defined by a specific slope in two perpendicular directions as shown in figure 3.2.3.

![Grading Planes Diagram](image)

**FIGURE 3.2.3 – GRADING PLANES**

Where two planes meet, the slope must be the same for each plane along this edge. For this project, the parking lot and driveway are composed of 3 planes, see figure 3.2.4.
FIGURE 3.2.4 – PROJECT GRADING PLANES
On construction plans, where two planes meet is either a flow line if it is a low point, or a grade break if it is a high point. The slopes for this site range from 1% to 1.5%, which are within the allowable range. The driveway has been graded for you but the parking area and sidewalk require grading elevations, see figure 3.2.5.
To determine the remaining elevations, start from the northeast corner which indicates an elevation of 87.84. Since the area is a plane with 1.5% in the east-west direction and 1% in the north-south direction, every foot to the south increases the elevation by 0.01 feet and every foot to the west increases the elevation by 0.015 feet. Remember that if you move diagonally, you are moving both in the north-south direction and in the east-west direction and so the elevation increases or decreases at the corresponding rate. Also, notice that the site is not exactly lined up north-south or east-west. It has a skew. The plane of the parking lot also has this skew. As you dimension, make sure that the dimensions are parallel or perpendicular to the angle of the parking lot, not just up and down across the screen. The equation for the elevation from the 87.84 point in the northeast corner of the parking lot is: 

\[ \text{Elevation} = 87.84 + 0.015 \times \text{distance East} + 0.01 \times \text{distance south} \]

Also, note that the elevations on the sidewalk are 6 inches higher than the elevations in the parking area, since the curb is 6 inches high. Using the equation, fill in the remaining elevations. Once this is done, use the elevations on the sidewalk in front of the building to determine the slope of the building entrances, see figure 3.2.6. Save and exit your drawing. You have completed the grading aspect of the site project.
3.2.2 DRAINAGE

Now that the parking area and driveway are graded, the next step is to determine which sides of the parking lot and entry drive require gutter adjacent to the curb. Gutter is required in places that water will flow against the curb during a rainfall event. Offset the curb in these areas by 1.5 feet toward the pavement area and trim the excess lines. Place the new line on the “C-PRKG-ASPH” layer. Next, determine where the low spot is in the parking area and on the driveway on the north side. The water that will pond in this area will need a place to drain. Make a 3 foot depressed section in the curb line to allow the water to leave the pavement in these areas, see figure 3.2.7.

The next step is to design the retention basins so that they can hold the 100-year, 2-hour storm event. This 2-hour storm event has a 1% probability of occurring at that location each year. The amount of rainfall for the 100-year event changes from region to region. For this site, the 100-year, 2-hour event is 2.6 inches, which is determined using drainage maps for the region. To determine how much storm water the site must retain, the equation is Volume = (Site Area) * (Rainfall Event) * (Runoff Coefficient). The runoff coefficient is a decimal value between 0.10 and 0.95 that varies depending on the surface that the rain falls upon. For example, rain that falls on pavement has a coefficient of 0.95 meaning 5% of the water is absorbed or evaporated before it reaches a retention basin, while grass has a coefficient of
0.35 meaning 65% of the water is absorbed by the grass and only 35% of the water reaches a retention basin. The actual coefficient used varies depending on the municipality. For this project, assume a weighted coefficient of 0.80, one that has been averaged based on the ratio of various surfaces throughout the site.

This project has an area of 48,415 square feet. So the total volume required to be retained for the site is equal to 48,415 * 0.80 * (2.6/12) or 8,392 cubic feet of water. To visualize a cubic foot of water, picture a 1 ft x 1 ft x 1 ft cube filled with water. This is also equal to 7.5 gallons. This site already has an existing retention basin on the south side of the site. To determine basin volumes, the “Retention Basin” tab of the spreadsheet “Civil Design.xls” in the main project folder will be used. Cells that require information are yellow, see figure 3.2.8.

![ON-SITE RETENTION BASIN VOLUME CALCULATIONS](image)

**FIGURE 3.2.8 – DRAINAGE SPREADSHEET**

Start by opening the “Existing.dwg” file in the “CAD\Base Files\” folder and find the existing retention basin. See figure 3.2.9.
FIGURE 3.2.9 – EXISTING RETENTION BASIN

FIGURE 3.2.10 – EXISTING RETENTION BASIN
Select the 1188 elevation contour. Now right click on it and select “Properties.” In this window there is a dialogue box labeled “Area.” Enter this value into the corresponding cell in the spreadsheet. This is the cell under the “Existing Basin” section next to the “88” elevation. Repeat this for the 87 and 86 contours. See figure 3.2.10. The spreadsheet calculates the volume of water this retention basin can hold. The site requires approximately 5,000 cubic feet of additional retention volume. To accommodate this, a new retention basin will be designed on the north side of the site. Design the basin so that it takes on the water from the parking lot and connects to the existing basin with an equalizer pipe. This equalizer pipe keeps the water surface elevation between the basins equal so that one basin is not fuller than the other. Once you are finished with the “Existing.dwg”, choose to close it without saving any changes that you might have made.

To continue on with this tutorial, open the “Civil.dwg” file in the “CAD\Base Files\” folder. Now select the “C-TOPO-DEPR” layer and use the polyline command and draw a series of arcs that outline the new basin. It should look something like figure 3.2.11.

Once it is drawn, offset it by 4 feet three times. Since each contour is 1 foot deeper than the next, this makes the basin 3 feet deep. The maximum slope for retention basins is 4H:1V and the maximum depth is 3 feet. If there is more than one area with a bottom contour, delete the smaller ones. Only one low spot in the basin is desired. The retention basin should look something like figure 3.2.12.

FIGURE 3.2.11 – NEW RETENTION BASIN OUTLINE
Next, go back to the “Civil Design” spreadsheet and enter in the contour area values into the “New Basin” section. The top elevation of the new basin will match the top elevation of the existing basin. Notice that the total volume has been updated, see figure 3.2.13. If the combined volume of the two basins does not exceed the required site volume, then redraw the new basin again but this time larger. If the combined volume provides more than 2000 CF excess volume, redraw the new basin but this time smaller. Do this until your design meets these requirements.
FIGURE 3.2.13 – NEW RETENTION BASIN VOLUMES

Now that the basin is drawn, we will need to connect it to the existing basin. The two basins will be connected with a 12 inch diameter Reinforced Concrete Pipe (RCP). While in the “Civil.dwg” file, insert the “Pipe.dwg” file, which is located in the “CADDesign Components” folder into our current drawing. Insert it with a base point of 0,0,0, scale factor of 1 for x, y and z and a 0 rotation angle. Choose to explode this drawing once which will enable us to use the drawing objects. The pipe is composed of three lines and a headwall. Extend or trim the pipe’s lines to the bottom contour of your basin and then move the headwall to this location. It should look something like figure 3.2.14.
Next, switch back to the spreadsheet “Civil Design” in the “Basins” tab and look at the value under drain time, see figure 3.2.15. Municipalities require the water in retention basins to drain within 36 hours.
The water in a retention basin seeps through the soil and into the ground. This is called percolation. Civil engineers employ geotechnical engineers to perform a percolation test in which a specific size hole is dug and then filled with water to see how fast it drains. The rate at which the water drains is the percolation rate. In the yellow cell next to “Initial Perc Rate,” enter the value “0.0025” CF/Min/Ft², this means that for every square foot of area on the bottom contour of the retention basin, 0.0025 cubic feet drain every minute. See figure 3.2.16. A safety factor of 2 is applied to this value to account for clogging over time. Depending on how large of a basin you designed, the drain time will be around 50 hours. This exceeds the maximum of 36 hours to drain so we will need to put a drywell into the basin to help drain the water. See figure 3.2.17.
Drywells are shafts that are drilled deep into the ground that penetrate the more permeable ground layers. The type of drywell used for this project has two chambers. The first chamber helps clean the water before it reaches the second, deeper chamber. This helps prevent the deep chamber from clogging.

Switch back to the spreadsheet and enter a value of 1 for one drywell in the yellow cell under drywells, see figure 3.2.18. This should drop the drain time well under 36 hours. The next step is to place the drywell in the drawing.

While in the “Civil.dwg” file, insert the “Drywell.dwg” file, which is located in the “CAD\Design Components” folder into our current drawing. Insert it with a base point of 0,0,0, scale factor of 1 for x, y and z and a 0 rotation angle. Choose to explode this drawing once which will enable us to use the drawing objects. This should place the drywell in the bottom of the basin, see figure 3.2.19. If not, move the drywell so that it is in the bottom of the basin. The drainage design is now complete. Choose to save and exit your current drawing.
FIGURE 3.2.19 – DRYWELL LOCATION