MicroStation® Applications for Highway and Transportation Structures Design as Part of the Software Series in Civil Engineering Technology Independent Learning Program at Fairmont State College

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Abstract

The authors developed a series of computer aided drawing instructional modules utilizing MicroStation® software as part of the Software Series in Civil Engineering Technology Independent Learning Experiment at Fairmont State College - Track 3: Design. These modules, which are customized to utilize transportation and transportation structures projects, serve as enhancements to the Design Track in the CET program, specifically enhancing instructional objectives in Structures (CIV 290), Structural Design (CIV 440), Advanced Structural Analysis (CIV 410), Surveying II (CIV 240), and Highway Design (CIV 400). Using transportation projects throughout the scheduling modules provides an experience integrating aspects of the transportation, structural, and water system tracks within the program. The series is comprised of Three modules: Module 1, Introduction to MicroStation®; Module 2, MicroStation® Applications for Bridge Design; Module 3, MicroStation® Applications for Highway Design; In each module, students are required to complete exercises based on example projects created by the authors. The examples utilized in the modules are actual transportation projects, which have been constructed and are in use. The utilization of built projects allows the students to gain additional experience with proven construction plans followed by visits to the actual sites to see the constructed product illustrated in the plans. Final projects are employed to bring together learning activities from each of the modules. This summative final project approach serves to reinforce the "real world" experience.

Introduction

In recent years, Fairmont State College has been teaching AutoCAD® as the primary computer aided drafting software package for all engineering technology disciplines. In response to suggestions from Fairmont State College's Civil Engineering Technology Industrial Advisory Committee, MicroStation® was purchased for use in the CET program. However, the Advisory Committee did not wish for AutoCAD® instruction to be eliminated. Therefore, the program needed to find a way to deliver instruction in both platforms. In order to address the need for instruction in both platforms, it was decided that students would continue to receive instruction in AutoCAD® in the freshman year. MicroStation® would be implemented as part of the Software Series in Civil Engineering Technology Independent Learning Program,[1] which was

implemented by Brizendine in 1998. The program utilized software commonly found in industry in a semi-self-paced environment to achieve an increase in student learning. The program was initiated to address the fact that "technology has changed many engineering methods and work today is almost entirely computer driven"[3] and to provide a mechanism for software inclusion in a curriculum that was already stretched for credit hours.

The Software Series in Civil Engineering Technology Independent Learning Program[1], is a series of one- and two-credit special topics software courses offered at Fairmont State College in six identified disciplinary tracks, namely: Surveying, Graphics, and Transportation; Construction; Hydraulics and Hydrology; Environmental; Geotechnical; and Structural. This program resulted from industry input requesting more applications software skills. The underlying precept of the Software Series in Civil Engineering Technology Independent Learning Program is to expose students to software packages in more detail than normally would be feasible in respective classes without sacrificing content lecture time. Baccalaureate students are required to take core courses in all six tracks at Fairmont State College.[1]

In addition to serving the Civil Engineering Technology Program, these courses are in demand from the Certificate and Associate of Applied Science in Technical Studies: Transportation/Highway Technician Programs[3] and in the form of training modules for Industry.

Instructional Facilities[4]
The facility used for the MicroStation® instruction consists of twenty-five IBM Pentium III computer stations with seventeen-inch monitors. Instruction involves two computer projectors; one projector is used for displaying a Microsoft PowerPoint® presentation[8], and the other projector is used to project the instructor's MicroStation® software application onto a "smart board." The smart board uses TeamBoard® software[9] to convert the white board into a touch computer screen. This process has proven to be a very effective tool in illustrating the processes and commands required to execute schedule functions in MicroStation®.

Module Development
CET graduates of Fairmont State College primarily acquire employment in the transportation, construction and consulting industries of West Virginia and surrounding states with a large percentage accepting employment with companies doing business in West Virginia. The WV Department of Highways requires consultants to submit plans digitally in MicroStation® format. MicroStation® is the principal drafting/design tool utilized in the local transportation industry to develop Highway and Bridge Plans. Therefore, the decision was made to model the class to conform to the development of these types of transportation projects. Modeling the natural progression of bridge and highway construction, the course manifested itself to be comprised of three primary modules. The first module is an introduction to the program, the second is comprised of bridge applications, and the third presents highway applications.

Course Manual
The authors developed a 200-plus-page course manual, comprised of 18 chapters divided into three modules[9] and two appendices. The first module, Chapters 1 through 10, illustrate the basic commands and the MicroStation® environment. The second module, Chapters 11 through 14 and Appendix A, present the application of MicroStation® in bridge design. The third module,

Chapters 15 through 18 and Appendix B, present the use of MicroStation as it pertains to highway design. Appendix A houses the bridge project plans which are used for Module 2, likewise, Appendix B houses the highway project plans used for Module 3.

Exercises Utilized in the Modules

In order to facilitate an understanding of the material e.g. "learn-by-doing", each chapter has class exercises and chapter review questions. The exercise's intent is to reinforce practically what was discussed during the chapter. Exercises are constructed to provide a building block approach to a finished product. Students may work together but ultimately each student submits independent work. The exercises, which are a continuation, from chapter to chapter also prepare the student to complete the final project which is independent of the building block chapter project. The final project affords an opportunity for the student to develop a project from the ground up, providing a simulated "on-the-job" practice experience while serving as an evaluation and assessment tool.

According to Schroeder, "… new students, compared to their more traditional predecessors, prefer a high degree of personalism. Because they are often unsure of themselves, they want a great deal of feedback from their teachers. They adapt quite well to group activities and collaborative learning.[5]" Independent learners can thrive in this learning environment. Indeed, the active learning process empowers the student. Blackmore states, "Once students are actively engaged in their own learning process they begin to feel empowered and their personal achievement and self-direction levels rise.[7]"

Module 1: Introduction to MicroStation®

The first module, Module I: Introduction to MicroStation® gives the students a basic understanding of the software platform and the commands used in the program. Since all students have a working knowledge of AutoCAD® upon entry, this segment familiarizes them with corresponding MicroStation® commands. The manual begins by giving the student a quick background in the Windows 95/2000/NT® environment. Chapter 1 presents the MicroStation® file manager environment to the students: creating a new file, opening existing files, and closing existing files. After the student is comfortable with the file manager, the manual proceeds to introduce the student to the MicroStation® interface. The student is then taken through the various commands MicroStation® utilizes to input data as well as the multiple ways MicroStation® will accept data input. The following is an example from the first module explaining the different procedures for entering data into the program.

> MicroStation® uses three main procedures for inputting data into the program. First, the pull down menus located at the top of the interface can be used to place characters into the program, which is illustrated in Figure 1. The tool bars, which are common with most programs, can also be seen in Figure 1. Command based direct input is the third option for data entry.

Figure 1. Illustration of Pull Down Menu

The focus of the final chapters in the first module deal with the functions widely used in project creation within the WV Department of Highways such as referencing files into the existing file; using leveling as a layering tool; inserting and creating cells; and MDL add-ins. Referencing files is accented due to the multi functionality of the process. Referencing files allows the user to bring in previously drawn sheets to an existing sheet to create a final drawing. An example would be that the MicroStation® user would create a utilities drawing, a topographical drawing, and a highway alignment, respectively, and then reference all three into one drawing to create a finished drawing. The user also has the ability to turn the referenced files off and on to view only the data needed.

Module 2: Applications for Bridge Design
A number of our constituent employers, namely, consulting engineers, contractors, and the West Virginia Department of Transportation employ MicroStation® to develop bridge plans. Therefore, the goal of the second module is to provide the student an introductory background in bridge design and construction and the utilization of MicroStation® as a bridge design tool. While, bridge design is very complicated and not often taught to CET students at the undergraduate level, the authors believe that a rudimentary introduction is appropriate and necessary. The Module begins with the general organization of bridge plans, types of sheets, and bridge engineering definitions and terminology. Upon completion of the introduction, the student is then guided into the creation of specific sheets in the project plans.

The remaining chapters of Module 2 present the plan sheets used in bridge plan development. The first section deals with general sheets as follows: Title Page, Notes and Quantities, Layout, and Situation. Chapter 13 deals with the bridge substructure and is presented in this order to follow the construction sequence, i.e. one builds from the ground up. In this chapter, it should be noted that specific West Virginia Department of Highway practices are followed. For example, the treatment of reinforcing bars used in the project includes the numbering, reinforcing schedule, and quantity calculation of reinforcing bars. The reinforcing bars section provides a discussion of why steel reinforcing is required in concrete construction and the procedures for labeling the reinforcing bars.   The following section, a sample from the reinforcing section, is provided as Exhibit 1.

Exhibit 1. Excerpt from Reinforcing Section of Module 2

Rebar Numbering Conventions and Process

Reinforcing bars must be referenced from the construction plans to the reinforcing list sheet. This allows the contractor to be able to match lengths and type to the structural element, in other words, which bar goes where. The West

Virginia Department of Transportation uses between four and seven characters as a numbering convention for reinforcing steel. The numbering convention on the construction plan sheets begins with the first letter of the structural element, e.g. if the rebar is going to be used in an abutment then the first character will be the letter A. Likewise, if the structural element is a pier the first letter will be P. The following list illustrates typical beginning letters:

- ❑ *Abutment / Wingwalls = A*
- ❑ *Pier = P*
- ❑ *Deck (Slab) = S*
- ❑ *Diaphragms = D*
- ❑ *Parapets and End Posts = EP*

The next character in the reinforcing bar numbering convention is the size of the rebar to be used at that location. The bar size is then followed by a number used to designate each individual rebar based on where it is located, size, and the length of the rebar. The first rebar number will be one, and it is located at the lowest elevation for the structural element. The next rebar will be two and is located at the next lowest elevation and so on. Finally, the last character will be "E" if it is epoxy coated as discussed previously. An example, shown as Figure 3.6 below, of the numbering convention is given below for an epoxy coated, number 10 reinforcing bar located at the lowest elevation in the abutment.

Figure 3.6. Reinforcing Bar Convention
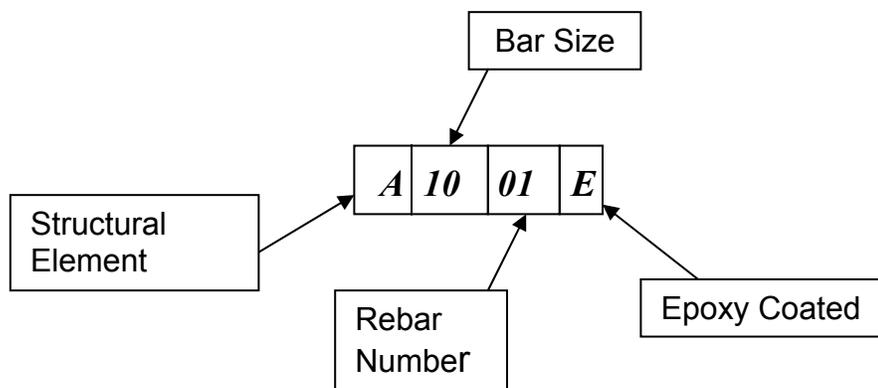
4. Reinforcing Bar List (Schedule) Sheet

The reinforcing bar list contains all of the rebar to be used on the project. Additionally, notes pertaining to the rebar and rebar types and dimensions are listed on the sheet.

A. Typical Rebar Sheet Notes

Notes typically found on the rebar list sheet are as follows: (It should be noted that each project may require the addition or omission of notes to the ones listed here.)

Figure 4.1 Typical Rebar Sheet Notes

- SEE ACI DETAILING MANUAL FOR STANDARD HOOK DIMENSIONS. ALL DIMENSIONS ARE OUT TO OUT.

- FIGURES IN CIRCLES SHOW TYPES.

- "." DIMENSION ON 180° HOOKS TO BE SHOWN ONLY WHERE NECESSARY TO RESTRICT HOOK SIZE, OTHERWISE STANDARD HOOKS ARE TO BE USED.

- "E" - INDICATES EPOXY COATED REBARS.

MINIMUM LAP SPLICES UNLESS OTHERWISE NOTED:

#4	1'-8"	#8	4'-11"
#5	1'-11"	#9	6'-3"
#6	2'-9"	#10	7'-11"
#7	3'-9"		

B. Types of Rebar

The standard rebar sheet includes some typical, widely used rebar shapes. Each shape has the dimensions labeled i.e. A, B, C etc., as can be seen in figure 3.7. The dimension labels are assigned values in the rebar list as illustrated in Table 3.2. For example, rebar P501 is a type 19. The "A" dimension is the shape diameter of 4'-8", while the "B" dimension is the lap length of 2'-0". The "R" dimension is the radius of the shape, and can also be the bend radius for other shapes such as a type 17.

Figure 3.7. Typical shapes of reinforcing bars
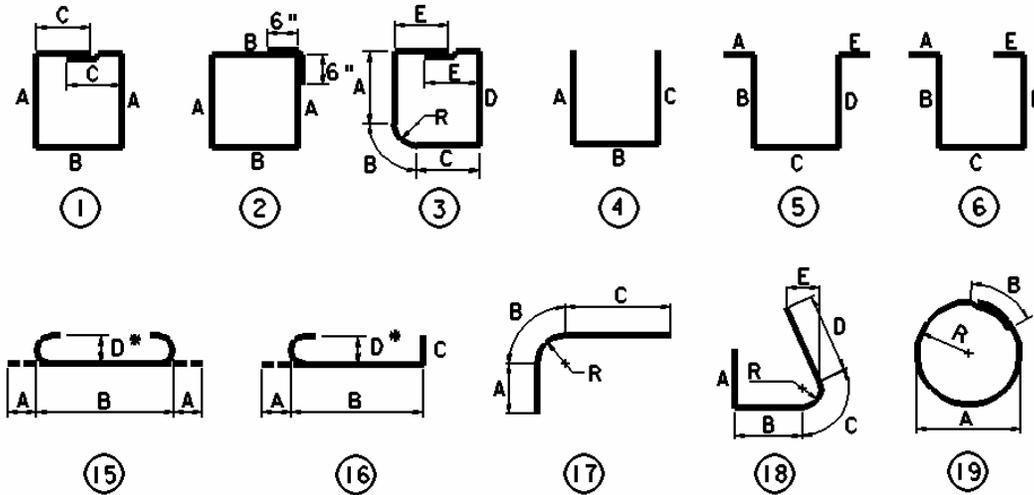
The project often requires types that are not listed in the sheet. In this instance, a type will have to be created for each "special" rebar shape required. Figure 3.8 illustrates some examples of project specific rebar types.

Table 3.2. Reinforcing Bar List

MARK	TYPE	NUMBER	LENGTH	A	B	C	D	E	R
			PEIR 1						
P501	19	32	16'-8"	4'-8"	2'-0"				2'-4"
P502	STR	2	5'-1"						
P503	STR	8	10'-10"						
P504	STR	2	9'-9"						
P505	STR	2	14'-4"						
P506	STR	2	19'-0"						
P507	STR	2	23'-8"						
P508	STR	4	24'-8"						
P509			8'-4"	2'-5"	3'-6"	2'-5"			
THRU	4	76	THRU						
P527			12'-2	4'-4"	3'-6"	4'-4"			
P528	4	10	12'-4"	4'-4"	3'-8"	4'-4"			
P529	4	6	7'-2"	2'-0"	3'-2"	2'-0"			
P530	25	8	4'-7"	2'-0"	5"	5'	3"	1'-9"	
P531	4	2	6'-3"	2'-6"	1'-3"	2'-6"			
P601	STR	92	11'-8"						
P901	10	30	35'-10"	2'-8"	33'-2"				
P1001	STR	8	24'-8"						

Figure 3.8. Project Specific Reinforcing Bar Types
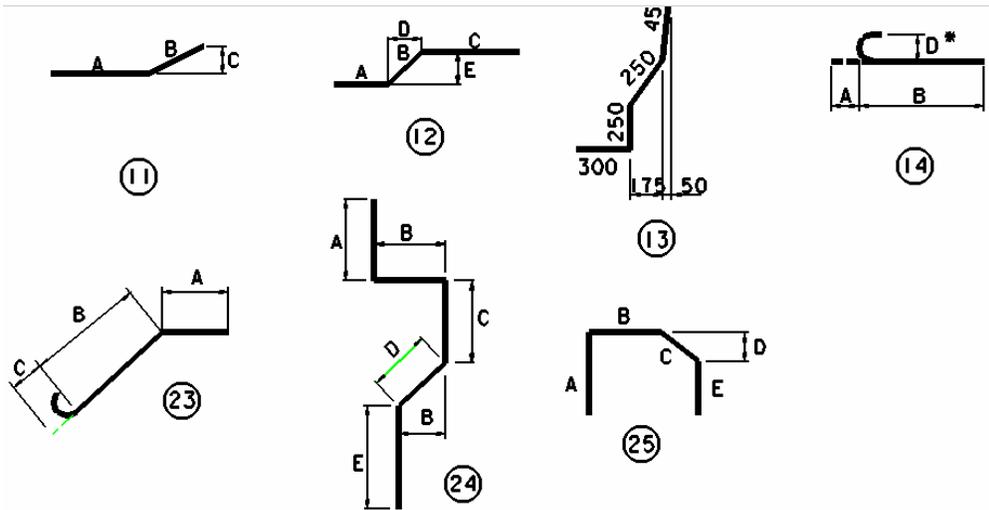
The file naming conventions used by the West Virginia Department of Transportation are also covered. The module also covers bridge abutment sheets, pier sheets, core-boring sheets, and wingwall sheets. For each sheet, the manual describes the details that should be displayed on each sheet and the information required for each detail. An extract from a typical wingwall sheet developed by students is provided as Figure 2.

Figure 2. Wingwall Sheet
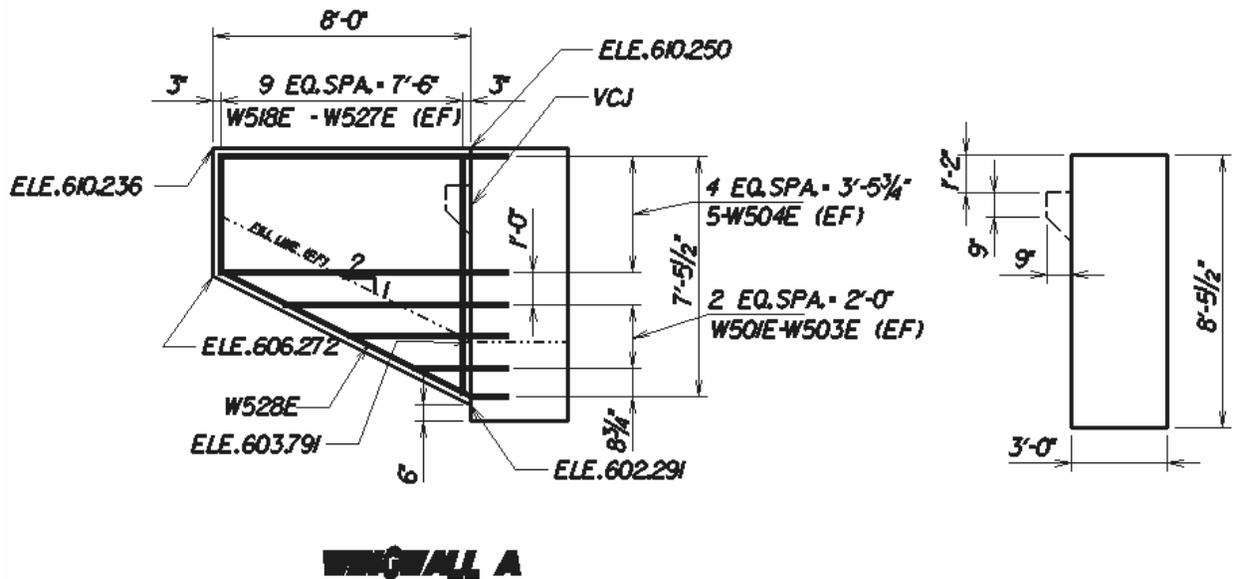
The final chapter in Module 2 deals with the development of superstructure plans: framing plan sheet, beam sheet, diaphragm sheet, and deflection sheet. Each sheet is broken down to illustrate the required details and the information displayed on each detail that is needed for construction of the project. An extract from a typical framing plan sheet developed by students is provided as Figure 3.

Figure 3. Framing Plan Sheet
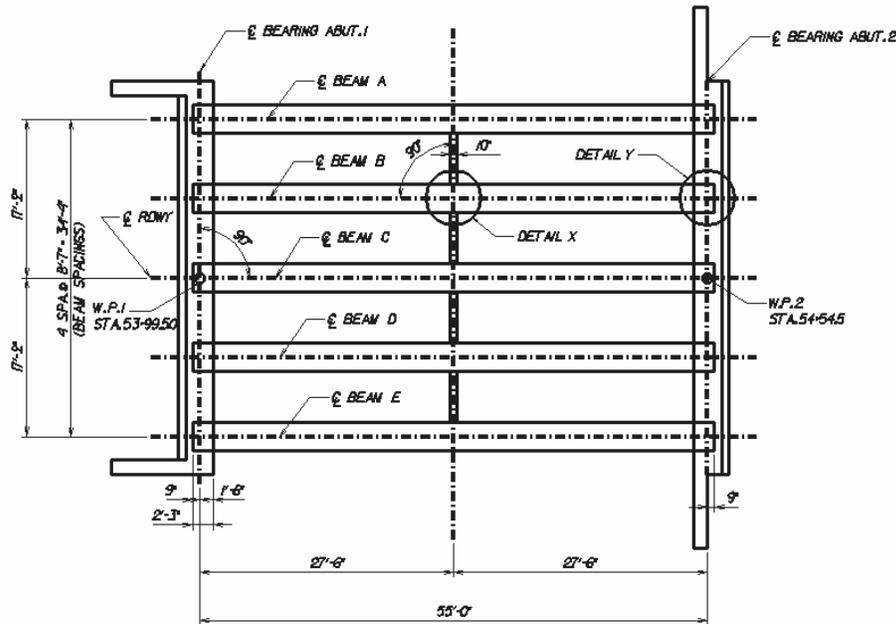
Module 3: Applications for Highway Design

The objective of Module 3 is to introduce the student to the development of highway project plans and their development. It should be noted that in highway design, the West Virginia Department of Transportation uses MicroStation® in conjunction with InRoads®. InRoads® is a software design aid, which can perform automated topographical generation; cross-section generation; and cut and fill tables, just to name a few of the software's capabilities. Separate training is provided for the InRoads® package. Module 3 focused on generating the details used in highway design using only MicroStation® as a stand-alone package since many consultants do not utilize the InRoads® package.

As with Module 2, students are presented with highway design and geometry terminology to develop a rudimentary knowledge base. In Module 3, the West Virginia Department of Transportation's file naming conventions are also presented as they pertain to highway project plan design. This allows all users of these shared files to effectively manage files both internally and externally.

The design sheet sections begin with Chapter 12, which introduces the students to general sheets such as general notes sheet, title page, and quantity summaries. The student is taken through the process of placing pre-developed sheets and filling the tables using the text command. This same process is used for the title page and the general notes sheet. The student is then presented

with the generation of profiles, both existing and proposed. Even though InRoads® will create these details, the student is directed to manually create the profiles by using elevation data provided in the exercises. Pedagogically, it is believed this manual approach improves understanding. Creating cross-sections and typical sections are the final topics in Module 3. Again, cross-sections are created by InRoads® and typical sections can be found in the West Virginia Department of Transportation Databases, however, in order to understand the computer output, one must first gain "hands-on" experience. The following, Exhibit 2, presents an example of the description of normal crown and super elevated sections.

Exhibit 2. Description of of Normal Crown and Super-Elevated Sections.

Where a roadway is at NORMALCROWN, the cross slopes are just like those of any tangent segment of the roadway. The slope usually falls on each side of centerline, as shown in figure 13.

Normal Crown Centerline

Traffic Lanes
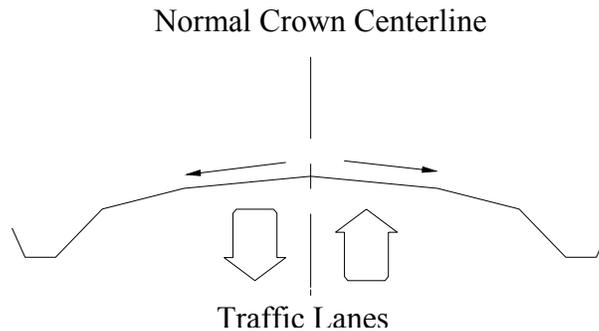
Figure 13

Where a roadway is SUPERELEVATED, the outside edge is higher than the inside edge. The roadway slopes down toward the inside of the curve as shown in figure 14.

Superelevated
Centerline

Traffic Lanes
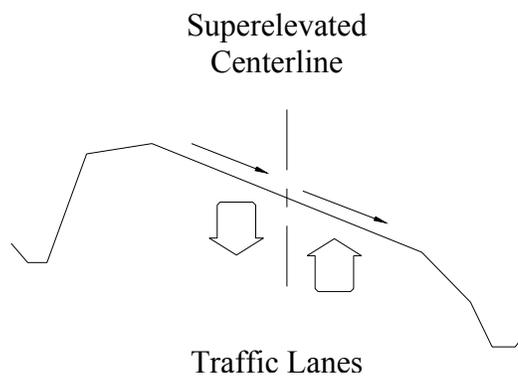
Figure 14

Final Project Development
Students utilize the skills learned in the module exercises to complete a final project, which is evaluated at the end of the course. An Active Learning model is utilized throughout these modules; students add new experiences to old knowledge in this environment. Each module uses a final project as a means of assessing the student as well as giving the student the confidence that they can use the software. For the first module, the final project is a layout of a basketball court. While this may seem non-technical, the project uses a number of the commands in MicroStation® program. The final project for Module 2 is the development of a bridge layout sheet. The bridge dimensions, elevations and existing topography are given to the student. Using information provided in the problem statement the student completes the layout sheet. For Module 3, the student is required to produce typical section details for a described project.

Adaptation for Industry Training[4,13]
As previously stated, the West Virginia Division of Highways uses MicroStation® to develop project plans and to communicate with their consultants. Hence, there is an urgency for new hires to "get up to speed" with the software expressed by both the consultants and the West Virginia Department of Transportation. Additionally, continuing education of existing employees is necessary to these organizations to maintain competitive in the marketplace. To satisfy these needs, Fairmont State College adapted the academic course described in this paper to provide continuing education for the transportation industry.[13] Engineers and technicians earn continuing education units in the form of professional development hours (PDHs) or technician development hours (TDHs), respectively, upon successful completion of the training modules.

The authors recognize that there are numerous approaches in the treatment and development of bridge substructure plans; however, a preponderance of Fairmont State College CET graduates obtain employment with organizations that do business with the WVDOT so their methodologies and procedures were addressed. Further, many engineering consultants have availed themselves of this course in the continuing education adaptation.

The training program is structured to move the students through the training courses utilizing a typical DOH project for each class exercise, such that the trainee has a completed example project at the completion of the third training session. Training occurs in three two-day sessions spaced approximately one month apart. Each two-day session contains one of the three modules described previously. Trainees receive one section of the manual during each training course. At the end of the third training course the student has a complete manual including a detailed table of contents, a hard copy and diskette of the final projects completed in MicroStation®.

To optimize the learning experience and ensure that everyone learns the material, two instructors are utilized in each class. While the first instructor provides instruction and demonstrates the software, the second instructor monitors progress of participants, providing assistance where needed and keeping everyone on task so that no one is left behind. Instructors rotate periodically between teaching and assisting students.

Final projects are also utilized for the training programs. Completion of the final project results in increased confidence; students leave the training with two completed highway projects that attest to their ability to develop drawing using MicroStation®. At the end of each training

module, students are afforded the opportunity to sit for an exam to receive college credit (credit by exam) for the academic course. The college credit program was well received by the students, consultants, and the West Virginia Department of Transportation.

Conclusions and Observations
As previously stated, the Software Series in Civil Engineering Technology Independent Learning Program has been underway at Fairmont State College since 1998. To date, the Software Series is a popular program with students as well as with faculty. Students receive more software instruction than would otherwise be afforded in each program track which enhances the academic content instruction, and the faculty does not sacrifice valuable class time dealing with software issues. The acceptance of the program can be attributed to the added skill sets and marketability gained by the students.

As indicated by students, the semi-self-paced learning does have certain advantages. The class does meet once a week for an hour to provide continuity, lecture, and project updates; yet, by and large, the project work is done at the student's leisure. However, the instructors note that students communicate with the instructors outside of class more frequently than traditional classes. Diaz and Cartnal point out that independent students prefer independent study and self-paced instruction and would prefer to work alone rather than with other students on course projects. Dependent learners look to the teacher and to peers as a source of structure and guidance and prefer an authority figure to tell them what to do.[11] This method of instruction provides a framework where both types of students and their needs can be addressed. The independent learners move through the material quite quickly with little assistance while the instructors utilize the released lecture time to provide the individual attention needed by the dependent students, resulting in a positive learning experience for each student. In addition, the dependent learners are "stretched" to intermittently self-discover and thus move further along the path to independent learner.

It should be noted that student feedback for the program is outstanding. They like the semi-self paced approach, the integration of the West Virginia Department of Transportation standards into the course, and the project-based format of the course. Approximately 20 Fairmont State College CET students participate in an intern program between Fairmont State College and the West Virginia Department of Transportation each year with many others hired by consultants. As a result of the integration of WVDOT standards in the course, the students and their employers benefit by less on-the-job-training. Interns and graduates are immediately more productive, which is a win-win situation for all involved.

By design, the Software Series Independent Learning Program provides opportunities for elective credit to students committed to enhancing their overall engineering technology education. As a result of the success of the adapted MicroStation® Application Modules and based upon input from the CET Advisory Board, the Civil Engineering Technology program processed curricular change to integrate the content of these modules in a required sophomore level course, CIV 275 Civil Engineering Graphics, which subsequently has received excellent ratings by student participants.

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