Computer Assisted Practices for Learning Concepts of Deflection in Transversely Loaded Beams

Alamgir A. Choudhury

Department of Industrial and Manufacturing Engineering
Western Michigan University
Kalamazoo, MI 49008-5336

Abstract

Learning deflection concepts for transversely loaded beam elements in engineering mechanics is essential for practicing engineering design and analysis. But the analytical nature and computational requirements limit the effectiveness of the traditional teaching methodology. This paper presents a computer-assisted tool that students can use to formulate and solve problems practiced in the class and simulate different "what if" scenarios. Visualizing effects of various parameters on the behavior of the physical system allows students to relate the system behavior to the theoretical concepts. The graphical simulation of the solution generates students' interest, engages them in problem solving and eventually leads to comprehending the underlying theoretical concepts.

1. Introduction

The subject of beam deflection [1,2] in engineering mechanics is taught in both traditional undergraduate mechanical and civil engineering programs as well as two and four year engineering technology programs. Generally engineering programs utilize analytical methods to teach the concepts first and then practice problem solving to reinforce the learning. With the understanding of the fundamental concepts, students formulate and solve deflection problems in a variety of applications, e.g. design of a new product or system component. On the other hand, in the engineering technology programs, students learn the subject through problem solving and applications without the detail study of the theoretical concepts. Therefore, in the curriculum, the emphasis is on mastering routine problems solving techniques for modification and improvement of an existing system. But without the theoretical foundation, such techniques alone cannot ensure effective learning of the subject and successful practice in the field. Because of the expectation of application-driven learning in the technology programs, students tend to avoid topics involving detailed theoretical concepts. Therefore, in these programs, teaching beam deflection in the traditional manner is a difficult and time-consuming task.

In most engineering technology programs, the subject of beam deflection is taught using two theoretical methods, namely, moment-area and superposition [1]. While the moment-area method uses properties of the bending moment diagram area, the superposition method requires combined use of deflection formulations of standard beam elements. The moment-area method can be utilized to solve the deflection problem in general, but due to the mathematical computation involved, average students find it more difficult to use. In the superposition method, the deflection problem is divided into several standard sub-problems and overall deflection is computed by combining the results of the sub-problems. Deflection equations of these problems are available in

standard texts or charts [1]. Experience in the classroom indicates that for average students, the superposition method is preferable to moment-area method.

Due to ubiquitous use of computer in industry, during the past few decades, Computer Assisted Practices (CAP) have become common to mathematics, science and engineering problem solving. As a result, problem solving requiring extensive computation have been increasingly integrated in the curriculum. Generally, computer based instruction and learning results in higher interest in the subject, increased participation in course work and improved learning outcomes [3,4]. In the undergraduate engineering mechanics area, a large number of computer-assisted tools [5,6] are available to help students formulate a problem, solve, and even test their understanding of the subject. Most of these tools present the solution in both numeric and graphic form. Philpot [5] showed the use of commercially available MDSolids system for developing and solving a variety of mechanics of materials problems. Ressler [6] developed "Visual Stress Transformer," a Visual Basic program to animate stress transformation for engineering mechanics classes. Others [7,8] used available commercial software such as Working Model [9] and Spreadsheet either to enhance student learning or to teach students computer applications for solving technical problems. Each of these tools has some novel feature that can be beneficial in a specific situation, but requires specific student background for their proper use. In general, these application tools can be classified in two categories, (a) adaptation of commercially available software programs and (b) application programs developed in-house. The commercial software programs are versatile in nature and can be used to solve a variety of problems in general. Many of them are also referred in textbooks along with instructions. But they are expensive and require time to get acquainted with. Though they may provide elegant solution of a problem, students cannot easily relate the theory with the problem solving method. On the other hand, the in-house tools may be less expensive to develop and simpler to use, which means the students can learn the system faster. Also, since these tools directly apply the related theoretical concepts to the solution of a problem, students can easily relate to those concepts and learn the subject more effectively. But these in-house tools are not generalized in nature and can be used only for the solution of a specific type of problem.

2. Objective

The objective of the tool presented is to provide a cost-effective alternative for computer-assisted problem solving that utilizes the same theoretical formulations taught in the class. Since Visual Basic [10] is a commonly used programming language for many engineering and technology programs, and this application program was developed entirely in Visual Basic. Other objective was to keep the overall application program simple and within the grasp of average students so that the learning of the theory, problem solving and application development can be achieved by the same practice.

3. Application modules

The tool is comprised of two modules. In Module I, the students define the parameters of a deflection problem and see the solution in both numeric and graphic forms. By comparing the computer solution with that produced by the analytical methods, students are able to identify the source of any mistake in learning. It also allows students

to experiment with different "what if" scenarios to see the behavior of a physical system due to changes in system parameters. The module also provides graphical simulation of these scenarios, therefore, generates student interest and eventual learning of the subject. In Module II, a programming template leads the students through a step-by-step development of an application program of their own. Utilizing this programming template they are able to simulate the deflection of beam problems practiced in the class.

3.1 Module I - Beam deflection problem solving tool

This Visual Basic application program is made available to the students through the web as a VB executable file. Therefore, use of this module does not require prior programming experience. It is simple enough for students to become familiar with the tool themselves. After accessing the system, students simply set the parameters of a deflection problem and obtain both the numerical and graphical solutions.

In this module, one starts by selecting the type of beam, e.g. simply supported, cantilever, or overhanging beam. Based on this selection, an appropriate dialog box appears for the specification of the beam geometry, loading, and deflection parameters. These parameters are beam length, moment of inertia of cross section, modulus of elasticity of material, magnitude and locations of concentrated and distributed loads, and external moment. The input for system specification and output with deflection result of simply supported, cantilever, and overhanging beams are shown in Figures 1-4. In each of these cases, deflection is calculated using the same equations students use in their theoretical solution. During solution of a specific problem, deflection due to each force at individual nodes along the length of the beam is calculated. Then they are added to compute the net deflection at each node. Using a VB line function and the distance versus deflection data, a deflection curve is generated. To solve the problem, students simply specify the beam geometry and loading parameters and run the program. To assist with the comprehension of the problem, a graphical rendering of the solution appears interactively. If the analytical solution produced by the student differs from the computer solution, the student can locate the source of error in his/her solution and rectify them until the two solutions are in agreement.

Students can also experiment with modulus of elasticity of the material, moment of inertia of the section, and magnitude and location of loads to investigate their effects on the nature of the deflection curve. This practice helps them to develop an insight on the effect of these parameters on the deflection and eventual understanding of the theory. In the absence of such tools this learning would be achieved only after prolonged practices.

3.2 Module II – Application development practice

After the use of Module I, students can be easily taught how to develop their own application programs to solve similar deflection problems. In Module II, a VB application program template is used to guide students through the steps to develop their own problem solving program. Prior to using Module II, students are expected to have gained sufficient experience with the beam deflection theory and familiarity with the module I. This tool works the best when it is integrated with the regular schedule of an engineering mechanics class.
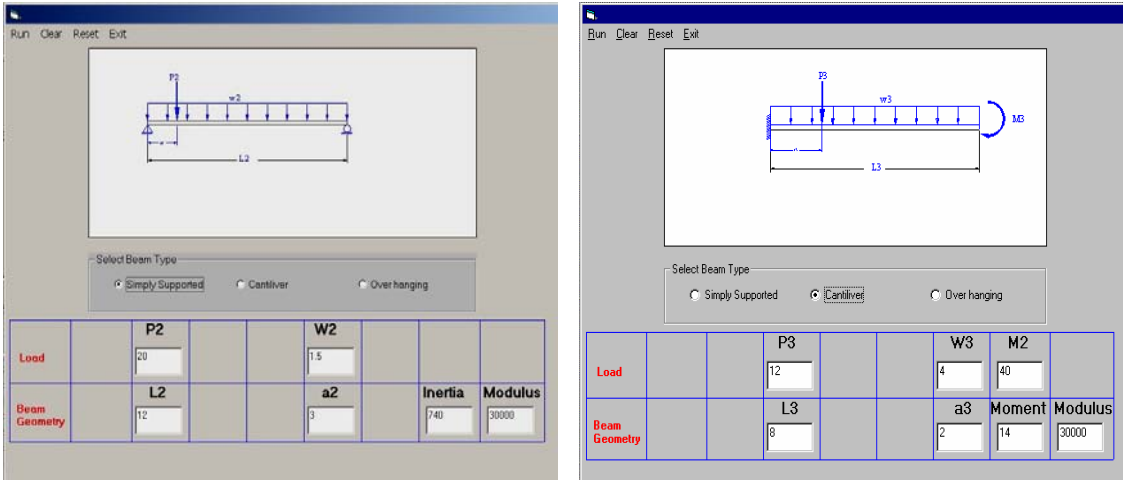
Figure 1. User input for simply supported and cantilever beam problems

Simply Supported Beam

X1	Delta1	X2	Delta2	X3	Delta3	X4	Delta4
001	0.001722	037	0.055033	073	0.069893	109	.045905
002	0.003443	038	0.056046	074	0.069701	110	.044812
003	0.005162	039	0.057023	075	0.069479	111	.043700
004	0.006877	040	0.057965	076	0.069226	112	.042571
005	0.008588	041	0.058872	077	0.068944	113	.041424
006	0.010294	042	0.059744	078	0.068632	114	.040260
007	0.011994	043	0.060581	079	0.068291	115	.039080
008	0.013686	044	0.061383	080	0.067921	116	.037885
009	0.015370	045	0.062150	081	0.067522	117	.036673
010	0.017044	046	0.062882	082	0.067094	118	.035447
011	0.018707	047	0.063579	083	0.066638	119	.034206
012	0.020359	048	0.064242	084	0.066154	120	.032951
013	0.021999	049	0.064870	085	0.065642	121	.031683
014	0.023625	050	0.065464	086	0.065103	122	.030402
015	0.025236	051	0.066023	087	0.064537	123	.029108
016	0.026832	052	0.066548	088	0.063944	124	.027802
017	0.028411	053	0.067039	089	0.063325	125	.026485
018	0.029973	054	0.067495	090	0.062679	126	.025157
019	0.031516	055	0.067918	091	0.062008	127	.023818
020	0.033039	056	0.068307	092	0.061311	128	.022469
021	0.034542	057	0.068662	093	0.060589	129	.021111
022	0.036024	058	0.068984	094	0.059842	130	.019744
023	0.037483	059	0.069272	095	0.059070	131	.018369
024	0.038919	060	0.069527	096	0.058275	132	.016986
025	0.040330	061	0.069749	097	0.057455	133	.015597
026	0.041717	062	0.069938	098	0.056612	134	.014200
027	0.043077	063	0.070094	099	0.055747	135	.012797
028	0.044409	064	0.070217	100	0.054858	136	.011389
029	0.045714	065	0.070308	101	0.053947	137	.009976
030	0.046990	066	0.070367	102	0.053014	138	.008559

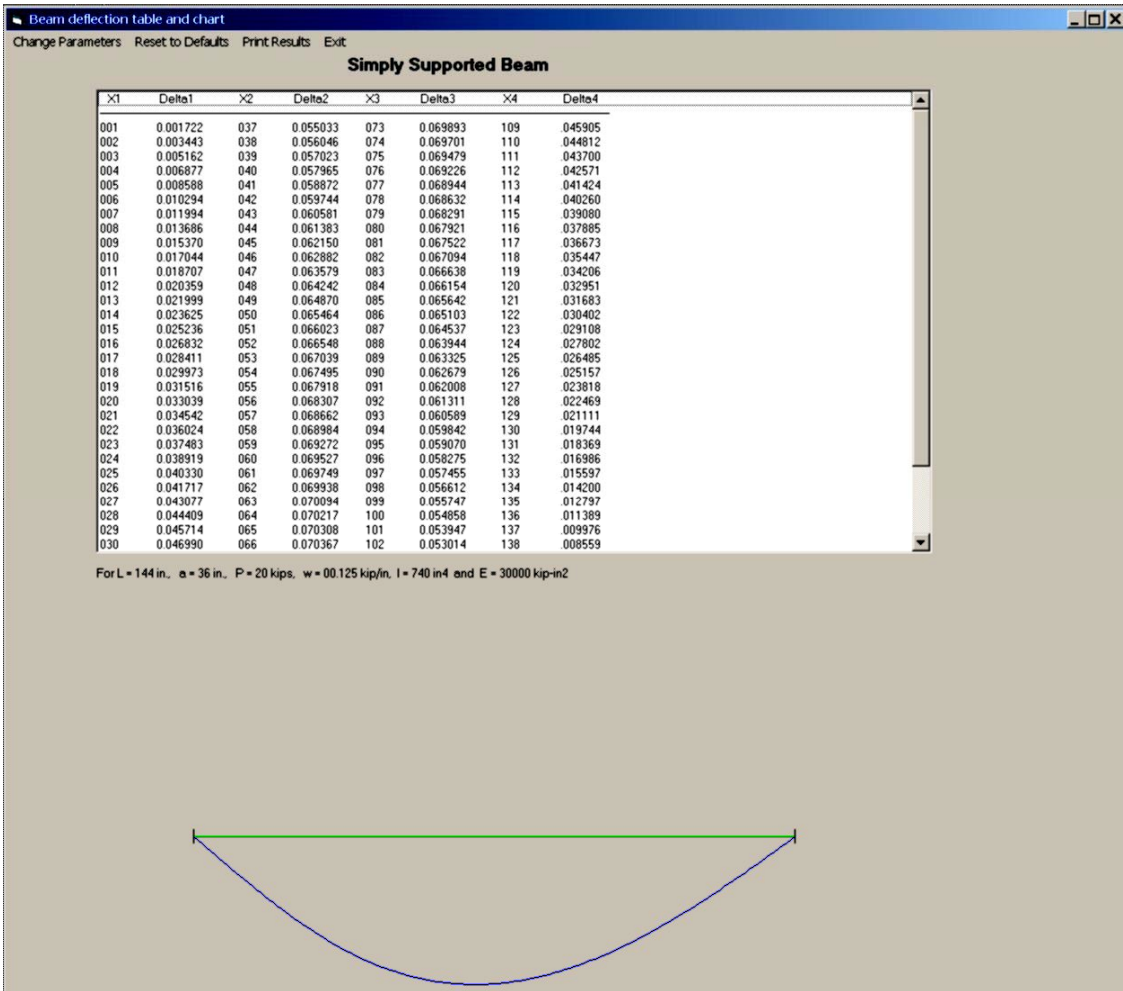For L = 144 in., a = 36 in., P = 20 kips, w = 00.125 kip/in, I = 740 in4 and E = 30000 kip-in2

Figure 2. Solution of the simply supported deflection problem
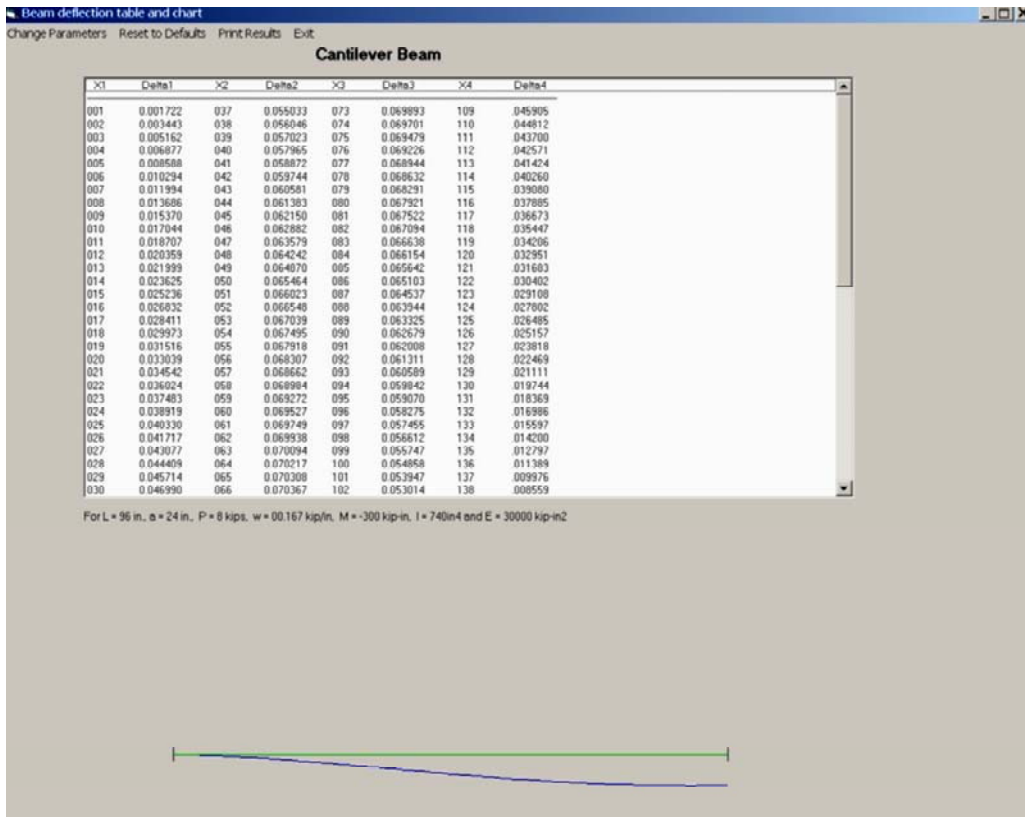
Figure 3. Solution of the cantilever deflection problem

Before introducing this module, example problems are analyzed in the class by using both moment-area and the superposition methods [1,2]. Based on the deflection equations of the example problems, the step-by-step procedure for creating a simple Visual Basic problem solving program is presented in the class. The example of a typical laboratory problem and its solution are shown in Figures 5 and 6. This example shows an overhanging beam partially loaded with a distributed force, a concentrated force and a moment. Using the template of the Visual Basic program students develop the complete program to solve the problem. It was found that the method is most effective when students are required to formally present their computer aided solution in the class. Experience in the class room showed that after sufficient exposure to Module I, generally students can develop their own application program in about a week.

4. Implementation and assessment
Module I is given to students in class as Visual Basic executable file. It was tested in a small class environment, and student response was very positive. Students were initially amused by the ability to check the accuracy of their analytical solutions. They also liked to simulate deflection by changing magnitude and location of loads.
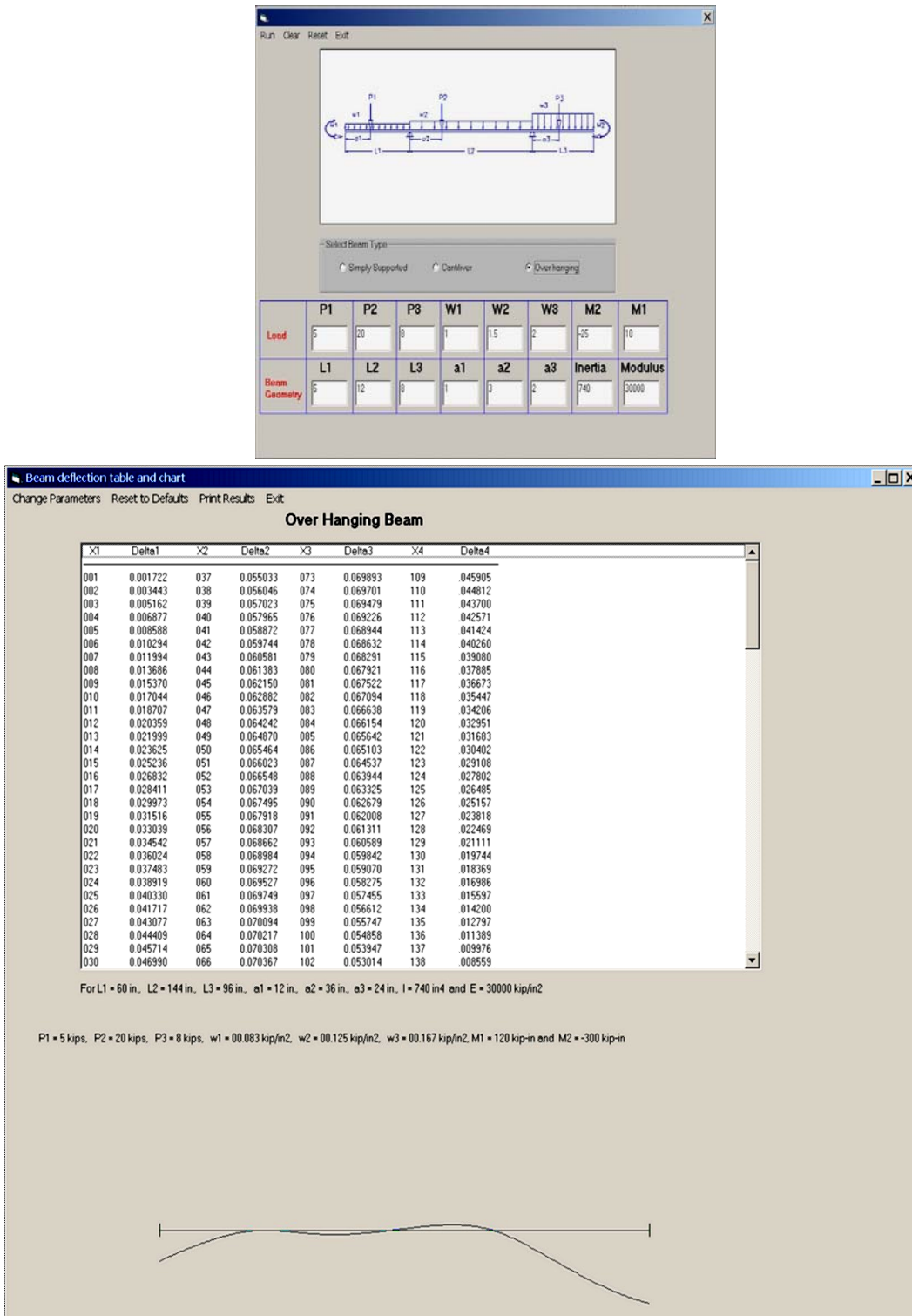
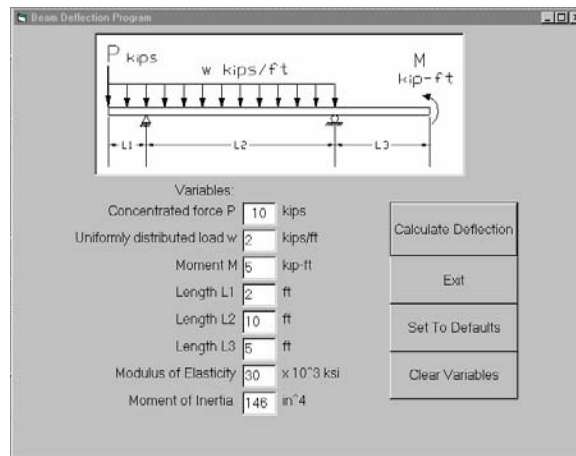Figure 4. An overhanging beam problem and its solution

Figure 5. Input to a typical laboratory exercise problem

In general, the experience of teaching beam deflection with this tool was pleasant and semester end class survey showed enhanced student satisfaction in the class. Similar in house application development to assist traditional class practices can also be implemented in other areas of mechanics and eventually library of applications can be developed. Formal integration of CAP with class practice, homework and laboratory exercise can enhance student learning even further.
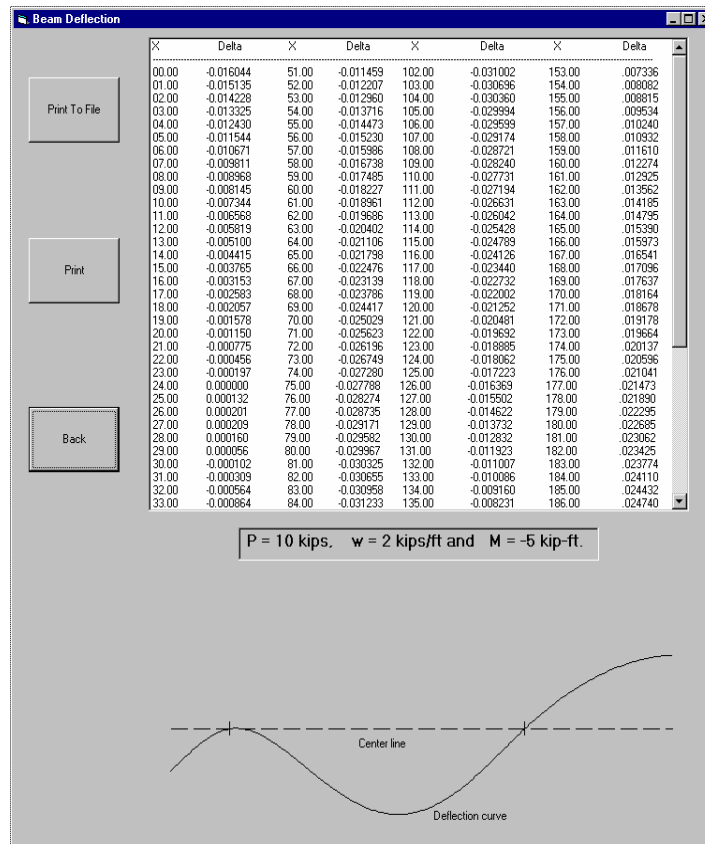

Figure 6. Output of the Visual Basic laboratory problem

5. Conclusion

The computer assisted practice tool presented here is designed to facilitate the learning of beam deflection theory in the mechanics class and build student confidence in the development and use of computer program for solving deflection problems. Instead of focusing on only the theory and the routine problem-solving techniques in the class, the introduction of beam deflection simulation and computer programming generates student interest in the subject. Visual input from the graphical simulation draws student attention to the underlying cause of deflection and eventual comprehension of the theory. By studying the effects of the beam parameters and loading characteristics on the nature of the deflection curve, students develop insight on this subject. The simultaneous study of deflection theory, the practice of exercise problems, and experimentation with deflection simulation is an effective method for enhancing student learning in the mechanics class.

6. Bibliography

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