DEVELOPING LEARNING MODULES ON STRUCTURAL ENGINEERING USING COMMERCIAL SOFTWARE

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ABSTRACT. Specialized software in structural analysis and design are now commercially available and may be adopted in schools to teach students on the use of state-of-the-art software. However, learning to use the software should not be the main objective when these software are integrated in the classroom. Methods on how these software be used to generate “new knowledge” and deepen the understanding on structural engineering concepts should be the primary goal. To effectively use these advanced computer tools, teaching and learning materials must be developed. This paper describes a learning and instructional material in the modeling and analysis of structures in 2D, developed using a commercially structural analysis software as a learning tool. The learning module is appropriate in a classroom environment where the “learning by doing” teaching approach is adopted.

1. INTRODUCTION

The rapid development of fast, powerful and affordable microcomputers has resulted in the professional engineers’ extensive use of sophisticated computer software in the solution of large, complex and sometimes even common problems. Specialized software for various civil engineering applications have now become a useful and necessary tool in the industry these days. The increasing reliance of engineers on computer software in the performance of their tasks requires that civil engineering students, the future professional engineers, must be knowledgeable of sound engineering concepts, updated on the latest computer technology used in the industry and aware of the limitations and capabilities of the computer in solving engineering problems.

Specialized software in structural analysis and design are now extensively used in the professional practice. These software are now available – some expensive, others reasonably priced especially for educational institutions and others available for free in the internet. Popular structural engineering related software include comprehensive structural analysis and design software such as STAAD, ETABS and SAP2000; structural analysis software such as BATS for 3D and GRASP for 2D; general purpose finite element analysis software such as STRAND7, steel and reinforced concrete design software such as GEAR, SAFE, CSI-COL and CSI Section Builder. These state-of-the-art software may be used in civil engineering schools to enhance the learning and teaching process. However, teaching the students on how to use the software should not be the main objective when these software are integrated in the classroom. Methods on how these software be used to generate “new knowledge” and deepen the understanding on structural engineering concepts should be the primary goal. To effectively use these advanced computer tools, teaching and learning materials must be developed. This paper
illustrates how a commercial software may be used to write and develop a learning and teaching module on structural analysis.

2. USING COMPUTER SOFTWARE IN THE CLASSROOM

Civil Engineering schools may integrate the use of software in the civil engineering curriculum to enhance the teaching and learning process. The computer software may be introduced to students in specialized courses in Structural Analysis, Reinforced Concrete Design and Steel Design and/or a separate computer-oriented course may be offered. An advantage of using software in the classroom is that more complex and larger structures may be analyzed and designed by the students, which is not possible by manual calculations or a calculator. This increases the student’s “feel” to real life problems. Another advantage of using these software, especially those with graphics, is that students can visualize the behavior of complex systems. By using a software, a student may follow a “cause and effect” type of activity wherein parameters are varied and the effect on the system is observed. By interpreting the graphical results visually and comparing numerical results, the student learns new insights and discovers new knowledge, which will expand his understanding on the implications of various parameters to structural analysis and design.

The danger of using sophisticated software, however, should also be recognized. Students using powerful software can suffer from the “black box” syndrome. As the program becomes more complex, it becomes increasingly likely that the student will not understand the internal workings of the program and the possibility of “garbage in, garbage out” becomes most likely where the student cannot detect the errors. Engineers should understand the logic, algorithm, capability and limitations of the computer software. The saying that “knowing how to run a program is not the same as knowing how a program runs” must be emphasized. The engineer, as the design professional, has the responsibility for the design of the civil engineering systems, which were derived using computer software. Although commercial software developers have a moral and ethical responsibility to produce software reasonably free of programming and technical errors, they have no control over how or by whom the software is used. It is thus imperative that users of computer software must be equipped with the proper background of engineering concepts and tools and must use sound engineering judgment and common sense. It is thus important that before exposing the students to specialized software, they should have a solid background on the theory of structures. Learning to use the software is not the end and main objective of the course. But what must be developed in the students is their ability to make sound judgment based on results obtained from the software (Oreta 2001).

The computer and the specialized software are now easily accessible to both teacher and student. Reference and users manuals are useful guides on the capability and features of a software but are not designed specifically for educational purposes. Educators must address the issue of how these computer tools be used effectively in the classroom specifically the use of the computer should focus on the following learning objectives: (a) how to deepen the student’s understanding of engineering concepts, and (b) how “new
knowledge” can be generated. The “missing link” – learning and teaching materials - between the learner (teacher and student) and the computer technology (hardware and software) for effective learning needs to be developed.

3. DEVELOPING LEARNING MODULES FOR 2D STRUCTURAL ANALYSIS

Structural analysis is an integral part of any structural engineering project. Its main objective is to determine the stresses or stress resultants in the members and the deflections at various points of the structure. The results of the structural analysis are used in the structural design of members, which must satisfy the safety and serviceability requirements of the design codes. If the code requirements are not satisfied, then the member sizes are revised and a re-analysis of the model of the structure is carried out until all safety and serviceability requirements are satisfied.

Recognizing the importance of structural analysis in the tasks of a civil engineer, the undergraduate civil engineering curriculum requires subjects related to structural analysis, which includes Engineering Mechanics - Statics and Dynamics, Strength of Materials, Structural Analysis. In these courses, the student learns the fundamentals of modeling and analyzing structures both two-dimensional and three-dimensional structures - trusses, frames and beams - from the determination of support reactions, computation of internal forces to prediction of displacements using various methods such as double integration method, moment-area method, Castigliano’s method, method of virtual work or conjugate beam method. Classical methods of analysis of statically determinate and indeterminate structures such as Moment Distribution Method, Slope Deflection Method, Method of Consistent Deformation and the Matrix Direct Stiffness Method are discussed. A student who understands the theory and techniques discussed in these courses is equipped with the tools and background needed in structural design.
There is still room for improvement in the teaching of structural analysis by introducing the computer and commercial software in the classroom. The rapid development of computer technologies, which include powerful and affordable microcomputers and reliable and user-friendly software in structural analysis, has started to change the delivery of instruction in higher education. Computers have greatly increased the ability of students to perform calculations and to process large amount of data. As a result, the type and nature of problems and mathematical techniques taught in school should adopt to new technology and maximize the usefulness of the computer in the teaching-learning process. In what way can computer usage be introduced in the curriculum? How can we increase the awareness of students on the importance of computers in the solution of various problems in civil engineering? One approach is to introduce the computer software in a structural analysis course to explain concepts and to illustrate structural behavior. An advantage of using a structural analysis software in the classroom is that more complex and larger structures may be analyzed and designed by the students, which is not possible in the regular class in structural analysis where the calculator or general math solvers (e.g. spreadsheets) are used by students in their calculations. Another advantage of using these software, especially those with graphics, is that students can visualize the behavior of complex systems. The software can be used to simulate a variety of structural and loading configurations and to determine cause and effect relationships between loading and various structural parameters, thereby enhancing the students’ understanding on the behavior of structures. This increases the student’s “feel” to real life problems.

Software for structural analysis are now available commercially – from simple to more sophisticated software and affordable to expensive ones (e.g. MicroFEAP, GRASP, BATS, STAAD, ETABS, SAP2000). Some textbooks in structural analysis (e.g., Kassimali 1999, Hibbeler 2002) also contain CD-ROM with software.

This paper presents a learning and teaching material developed using a commercially available software, GRASP - a user-friendly software is introduced for two-dimensional analysis of framed structures. Any 2D structural analysis software may be used to develop a similar learning material. GRASP was used here due to several reasons: (a) it is affordable; (b) it uses the Windows operating system, which is common in most microcomputers; and (c) it uses a graphics user interface (GUI).

4. INTRODUCING GRASP

GRASP which stand for Graphical Rapid Analysis of Structures Program is a user-friendly software for two dimensional analysis of framed structures which includes beams, trusses and rigid frames. Especially developed for the Windows, GRASP provides an interactive, easy to use, graphical environment for modeling and analysis. The major features of GRASP include:

- Modeling and analysis of multiple models in one file
- Presetting of default load cases and load factors
• Internal and automatic tracking of node numbers and member incidences
• Display the structural model at all times on the screen during analysis and superimposition of the analysis results on the model after analysis
• A Structure Wizard provides a step-by-step guideline for the generation of multistory structural models (Fig. 1)
• Supports SI, US and metric units and use of mixed units (Fig. 2)
• Apply loads on nodes and on members in multiple load cases (Fig. 3)
• Various restraint conditions including spring supports (Fig. 4)
• Eight pre-defined types of cross-sections (Fig. 5)
• Diagram of results with values and tables (Fig. 6)
• View and print the analysis results for the full structure up to 20 sections for a member

GRASP allows the user to select different member cross-sections, material properties and restraint conditions from its library. Member cross-sections may be any of the eight pre-defined types. Material properties are defined by the user. Support restraints can be specified by on-screen selection from several pre-defined cross-sections and restraint identification in GRASP is in a graphical manner. GRASP is ideally suited for rapid and easy analysis of simple structures and can also be used as an educational tool. GRASP is primarily based on a graphical means of interaction with the user and can provide direct feedback and effect of modifications.

5. LEARNING MODULES IN 2D STRUCTURAL ANALYSIS

“Understanding 2D Structural Analysis : Learning Modules in the Modeling and Analysis of Framed Structures” is an exploratory-type of instructional and learning material consisting of ten modules about modeling and analysis of framed structures in 2D was developed using the user-friendly 2D structural analysis software, GRASP. Each module focuses on a specific issue on structural modeling and analysis, which is discussed with the aid of graphical and tabular results obtained from GRASP. The set of learning modules is not a substitute to a textbook on structural analysis. The theory is not presented. No derivations or equations can be found. The student or reader must refer to the textbooks for definitions, equations and techniques. The material consists of ten chapters:

1. Understanding Structural Analysis
2. A Tour of GRASP
3. Loading Continuous Beams
4. Pattern Loading in Multistory Frames
5. Lateral Forces in Buildings
6. Pinned and Fixed Support Conditions
7. Soil Effects on Foundations
8. Support Settlements
9. Truss Analysis
10. Special Modeling Issues
Each chapter begins with background information and a “case study”. The reader explores the issues raised in the case study through the “Things to Do” activities or by simply reading, observing and analyzing the “Observation” and graphical and tabular results presented in the module. Included in the modules are “Things to Try” exercises and “Things to Ponder” comments on the analysis and design of structures. Using the set of learning modules, the reader or student with the aid of structural analysis software like GRASP discovers important insights on the response and behavior of structures due to variations in the parameters of the model and configurations of the structure, changes in member and material properties, and also changes in the restraint and loading conditions. Through the graphical results, the student can visualize the phenomena and this would accelerate his understanding of concepts through the experience of seeing and interpreting solutions to various structural modeling and analysis problems. The implication and relevance of the case study to the safe and reliable design of structures are also discussed. Each chapter ends with a set of references and reading materials related to the issue presented in the module. The student is encouraged to perform the “Things to Try” exercises that are related to the case study. Since GRASP provides direct feedback graphically and numerically, the student can explore and have fun by simple modification of the configuration of the structural model or loading condition and will expand his knowledge and understanding about modeling, analysis and design of framed structures.

The learning modules in 2D structural analysis (Fig. 7 shows a typical chapter) may be appropriately used in a computer laboratory class where an active learning approach or “learn by doing” strategy is used. The basic responsibility of the faculty in a “learning by doing” strategy is to design an appropriate learning environment wherein (a) the students are personally involved in the learning task, and b) knowledge or information must be discovered by the students themselves.

Among the issues addressed by the learning modules are:
(a) **Pattern Loading**: How should the live loads be placed so that the maximum internal forces at critical points of the frame can be determined? The individual members of a building frame must be designed for the worst combination of loads that can be expected to occur during its useful life. Live loads such as floor loads from human occupancy can be placed in various ways, some of which will result in larger effects than others. For this issue, the live loading can be placed on the beam or frame in a great variety of different schemes (e.g. Fig. 8).

(b) **Lateral Loads in Plane Frames**: What is the effect of lateral loads due to earthquake or wind on the internal forces of a building frame? A case study where two frames, one without lateral loads and another frame with lateral loads can be presented and their internal forces compared (e.g., Fig. 9). A discussion of the seismic design of structural members will also be appropriate in this chapter.

(c) **RestRAINT Conditions**: How do support conditions affect the behavior of a structure? Support restraints can be specified by on-screen selection easily in GRASP. The use of spring elements to model footings resting in soft soil can also be done. Fig. 10 compares the bending moment of two frames different support conditions.

(d) **Wind Loads on Roof Trusses**: How does wind direction affect the member axial forces and deflection of a roof truss? Wind pressures acting on the windward and leeward sides of the roof of a frame can be applied. Wind pressures acting towards the surfaces are positive, while negative pressures, called suction, act away from the surfaces of the structures. Fig. 11 shows an example of the deflection of a truss.

Other modules addressing issues on modeling of structures such as strengthening of frames using diagonal braces, modeling of shear walls, hinges at connections, semi-rigid connections, offset connections, symmetric structures, modeling of foundations etc. can be also be developed. These issues are not discussed in detail in a regular structural analysis class due to time constraints and limitations in the size and complexity of structures that can be solved in class. Exploring and understanding these issues with the aid of a computer is an approach that the teacher may adopt.

Similar learning modules may be developed using available state-of-the-art software. Concepts on modeling and analysis of structures in three-dimensions can be presented using STAAD, ETABS, STRAND7 or SAP2000. Stress analysis on cross-sections of different shapes can be presented using CSI Section Builder. The effect of section and load parameters in reinforced concrete and steel design of beams and columns may be explored using GEAR.
6. CONCLUSION

The university has a role in properly training engineering students to become competent professional engineers – updating them on the latest computer tools and technology used in the industry and providing them the necessary background and skills about engineering. The author believes that through the use of a computer software in structural engineering classes, students will deepen their understanding of structural engineering concepts and will discover the implications of various parameters in carrying-out the safe design of structures. However, the first step in the effective use of the computer in the classroom is to develop teaching and learning materials or modules. Any commercially available software on structural analysis and design may be used to develop learning modules focusing specific issues related to structural modeling, analysis and design. Knowing how to use the software should not be end and main objective when software is integrated in the classroom. The ultimate goal of engineering educators is “to explore how students can learn and discover new knowledge from new technologies.”

REFERENCES


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ABOUT THE LEARNING MODULE

If you want to receive an electronic copy in pdf format “Understanding 2D Structural Analysis”, send an email to the author at andyoreta@yahoo.com.
Fig. 7. A Typical Chapter of Understanding 2D Structural Analysis
Fig. 8 Effect of Placement of Live Loads in a Beam

Fig. 9 Effect of Lateral Loads on Bending Moment of a Building Frame
Fig. 10 Effect of Type of Supports on the Bending Moment (a) Pinned; (b) Fixed

Fig. 11. Deflection of a Roof Truss due to Wind Load