

Web-based Visualization Techniques for Structural Design Education

Mohammed E. Haque, Ph.D., P.E.

Texas A&M University

Abstract

With the advances in information technology over the last decade, the traditional teaching format of having an individual lecture to an audience has been supplemented, and in some cases, replaced by the rapid development and implementation of new distance learning methods. As technology rapidly changes, the importance of educating and training diverse populations of civil/construction engineering/science students becomes more critical. Traditional lecture format teaching methods sometimes fall short of conveying the complex analysis and design principles that need to be mastered in structural design. However when the theories are exemplified in a virtual environment with multimedia, animation, interaction, and manipulated image visualization techniques in a virtual reality environment, students' conceptual understanding are enhanced. The important advantages of the virtual reality environment over other computer-based design tools are that it enables the user to interact with the simulation to conceptualize relations that are not apparent from a less dynamic representation, and to visualize models that are difficult to understand in other ways. The interactive nature of virtual environments made it a natural extension to the 3-D graphics that enable students to visualize real life structures before actually building them. The main objective of this research was to create an innovative structural design concept visualization methodology on a web-based interactive virtual environment. The principal elements of the presented approach are: animation, user interaction, manipulated image visualization, and virtual navigation. The presented paper illustrates the design concept visualization techniques for flexural and shear behavior of reinforced concrete beams. It was created using mainly Java and Virtual Reality Modeling Languages (VRML). The presented teaching and learning methodology employed a generic architecture, which was discipline/course independent, and can be adapted to various other civil/construction engineering/science courses that will certainly promote and enhance students' subject visualization and conceptual understanding.

I. Introduction

Structural design concept visualization whether in reinforced concrete or steel structure is a subject that depends on geometric and physical perception, and every effort should be made by educators to enhance this ability. This makes it as an interesting challenge in an exciting area, requiring creativity and imagination as well as knowledge and systematic thinking. Traditional lecture format teaching methods sometimes fall short of conveying the complex analysis and

design principles of structural design courses. There is a range of problems in this method of instruction. Some of the problems experienced and cited^{1,2} are as following:

- Lack of teaching aid to vividly explain the intricacies of the structural design principles.
- Lack of time to teach whole detailed structural design.
- Inadequate visual learning environment.
- Inability of individualized tutoring due to increasing student numbers.
- Inability to excite students to study structural design concepts interactively.
- Difficulty in teaching students to make connection between theory and application of reinforced concrete design.
- Inability to address students who do not participate or view the traditional teaching as a chore.

Acknowledging the above problems, there is an identifiable need to establish alternative sources of information and modes of learning for students. It is in response to this need that the computer based interactive prototype courseware model was conceived^{1,2}. The interactive computer aided learning¹⁻⁵ allows the students to proceed at their own pace, motivated by a curiosity about “what happens” interactivity and “the need to know” the design principles. Although the classroom environment in Engineering and Construction Science is highly structured by the instructor, teaching students to be critical thinkers is essential in the virtual classroom of the future. The teacher-centered classroom denies the student the opportunity to more self-directed, autonomous, and creative. Often a virtual educational delivery system is used to facilitate distance learning rather than the age-old method of correspondence course curriculum. These virtual delivery systems⁶⁻⁸ have similarities around the globe. These virtual delivery systems hold student autonomy and creativity as essential attributes.

The development of the World Wide Web (WWW) has led to unprecedented growth over the last decade in access to information over the Internet. The Web-based learning environment offers many advantages including ease of use, quick access, low cost, available without the limitations of time or location, computer platform independent, and flexible in allowing students to control their learning pace. This paper demonstrates various web-based design concept visualization techniques, which are valuable for teaching and learning structural design.

II. Visualization Techniques

The principal element of the proposed approach is to assimilate the students' learning knowledge and behavior by providing individualized guidance and assessment tool. This includes^{1,2} -

- Structuring of the reinforced concrete design course material with respect to content.
- Presenting, modularizing and tailoring the presentation according to each student's level of competence.
- Identifying and utilizing the teaching strategies involved in the learning process. This involves the use of multimedia to enhance learning experience leading to increased motivation and better visualization and more learner participation.
- Accommodating a flexible interactive reinforced concrete design and step-by-step navigation.

The visualization techniques consist of five individual modules (Figure 1), which are:

1. Lecture Presentation
2. Image Visualization/Animation
3. Annotated/Manipulated Image Visualization
4. Interactive Design Animation, and
5. Virtual Design Navigation

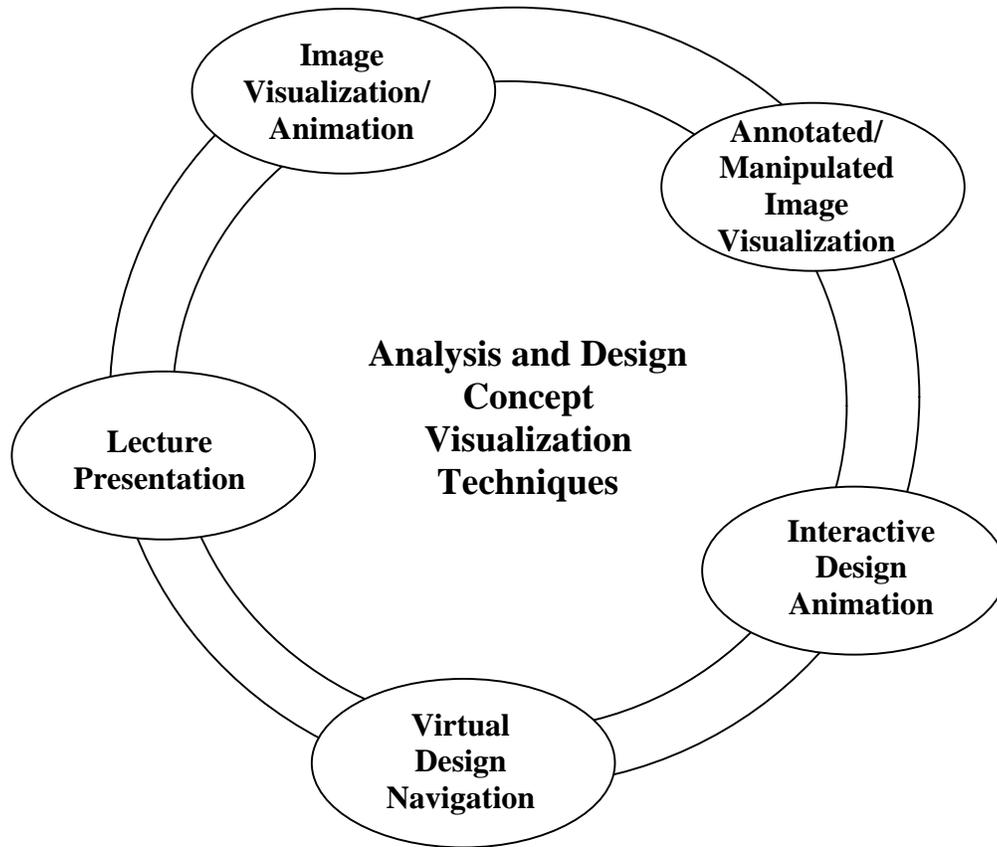


Figure 1 Analysis and Design Concept Visualization Technique Wheel

Lecture Presentation: The intent of this module is to teach analysis and design concepts by providing an individualized guided and interactive personalized tailored course materials using PowerPoint slide presentation converted to HyperText Markup Language (HTML) and linked to other HTML files containing 3D diagrams (Figure 2). HTML is the basic vehicle that delivers text information over the Internet. Authors have used various Web pages developing visual editor including Microsoft's FrontPage2000, Word2000, and Macromedia Dreamweaver.

Image Visualization/Animation: This module provides students with a variety of scaffolding visual techniques, such as digital images, 3D graphics, and animation. The authors have created several GIF (Geographical Interchange Format) animations for beam flexure and shear. In GIF animation, several frames are displayed in a rapid succession, which creates the illusion of movement. Figure 3 shows a few GIF frames of shear failure animation. GIF is the most important tool for bringing animation to the Web. The GIF animation files are small, do not require any special plug-ins, and are easy to create. There are many software available for GIF animation, such as GIFmation, GifBuilder, GIF Construction, and ImageReady. The Authors also have used Adobe Photoshop, Macromedia Flash and Freehand for creating images and animations. To open a Flash Player movie or animation in a browser, user must first open an HTML document, which in turn activates the Flash Player and runs the movie.

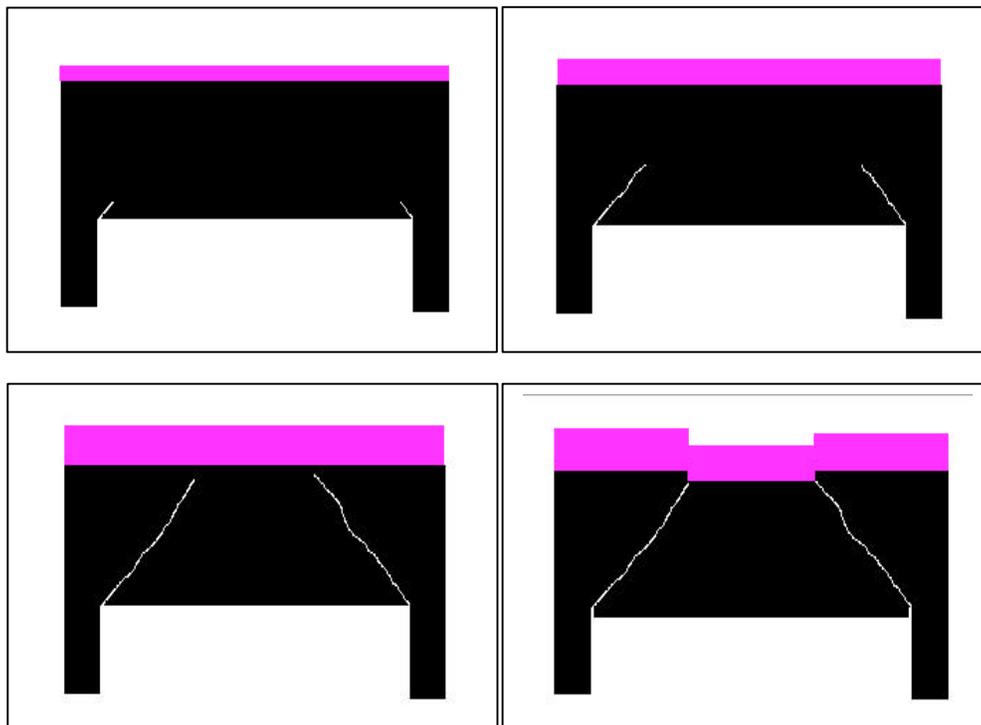


Figure 3 A Few GIF Frames of Concrete Beam Shear Failure Animation

Annotated/Manipulated Image Visualization: In order to aid students in attaining procedural skills, this model provides a variety of scaffolding visual techniques. Each design topic is composed of various sub skills, which themselves are topics. Before a topic is presented in its abstract form, students are shown a concrete representation of the problem. For example, when demonstrating the mode of reinforced concrete failure behavior, this will show appropriate digital manipulated images with power point subject presentation. The manipulated images are powerful tools for teaching design courses. With digital images, it is possible to add text, symbols, transparent overlays, guidelines and other annotation to highlight, explain, and analyze important features in an image⁹. If a student has difficulty with a complex problem, these

annotated versions of manipulated images explicitly show the foundations of the design mechanics by breaking up problems into their natural components, and showing the connectivity between those components. For example, Figure 4 shows the arrow notations used by the model to explain the flexural/beam failure in a reinforced concrete structures.

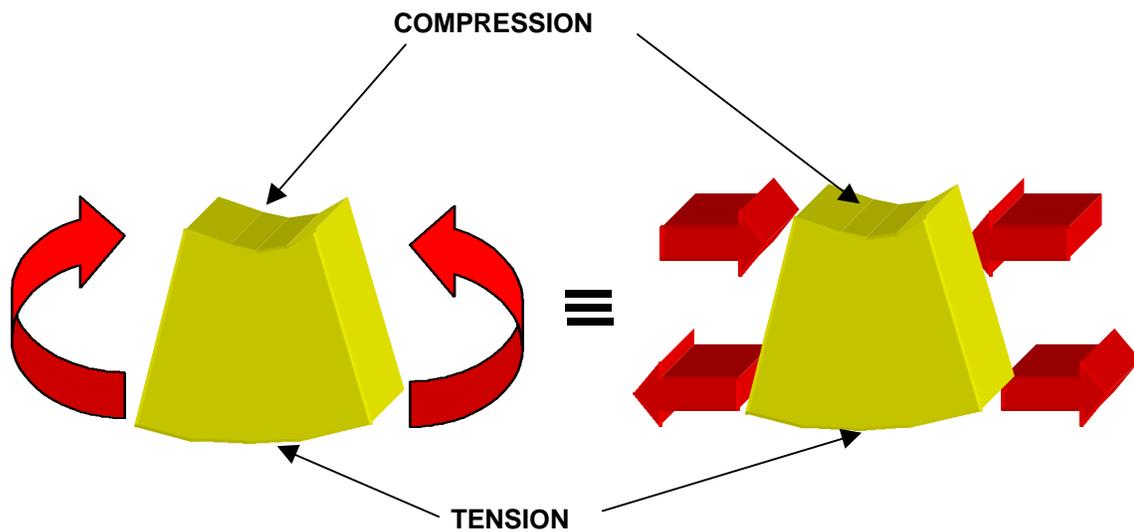


Figure 4 Manipulated Image visualization for flexural failure.
(Digital image from Northridge Collection, Earthquake Engineering Research Center, University of California, Berkeley)

Interactive Design Animation: Design based users are considered potentially powerful design tools by their ability to generate sets of designs adhering to user specified constraints. The conceptual principle adopted here is to reinforce students understanding of the behavior of concrete beams with the aid of simple structure such as a simply supported beam with a point load at the center of the beam. As the load is increased moment, deflection and shear forces increase. Figure 5 shows Java model screens ^{1,2} where user is allowed to define the load and beam geometry values. Next the user can interact with the beam by varying the structural load using up and down arrow keys. Once the designed critical moment values are exceeded, animation sound of concrete cracking with message box and calculated stresses are displayed. Results such as beam deflection, bending moment and shear force values are also shown on each user interaction with loads. This critique feature is used to confirm user understanding of design loading. For running this model on a PC needs Java plug-ins, which are freely available in many web sites. In this module, to deliver the interactive content on the web, Java programming language was used because of its platform and operating system independence. Various analysis and design problem based Java applications are developed using WebGAIN's Visual Cafe 4.0, and embedded in HTML documents as applets, which can be run over the web. Visual Cafe is a visual Rapid Application Development (RAD) tool designed exclusively for Java programming language. It is a complete form-based development environment that provides a rich set of What-You-See-Is-What-You-Get (WYSIWYG) tools and components that enable the program developer to develop, debug, and deploy high-performance Web applets and stand-alone Java applications.

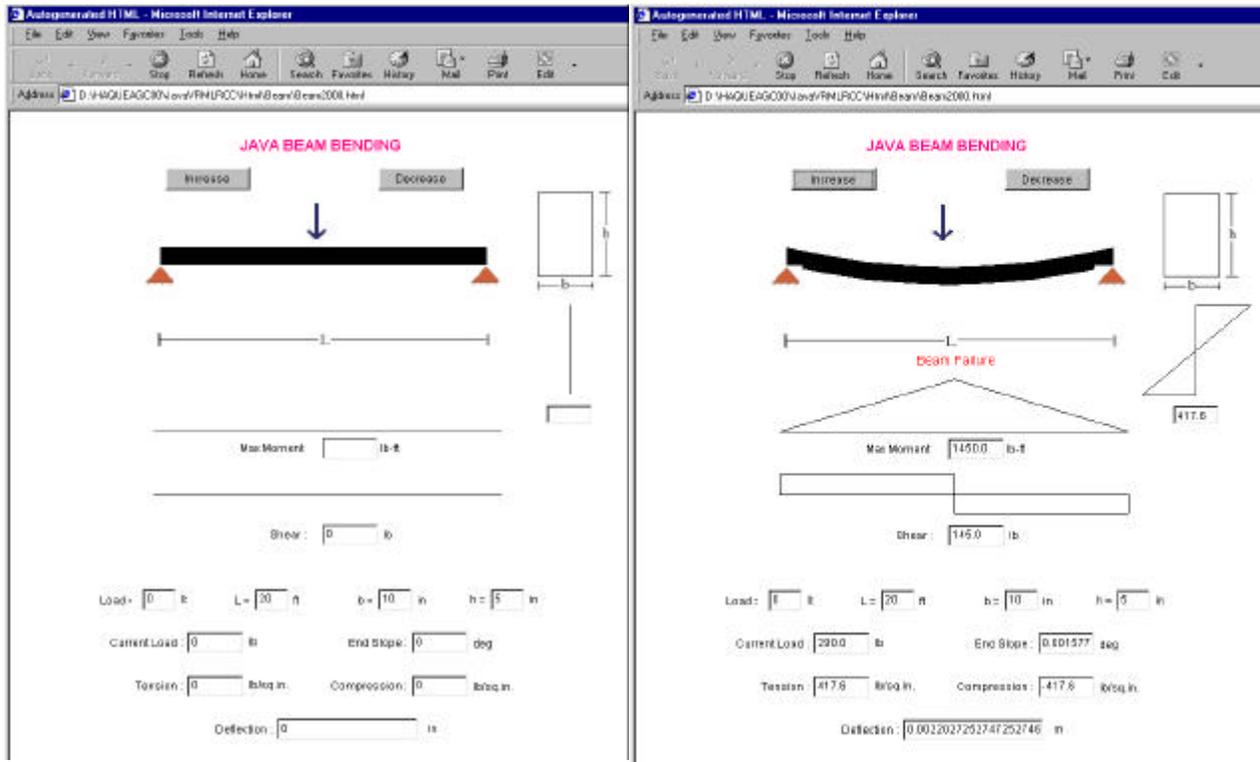


Figure 5 Java based Interactive Beam Analysis Animation

Virtual Design Navigation: It is found that most current internet-based educational applications do not present 3D objects even though 3D visualization is essential in teaching most engineering design principles. The authors strongly believe that if 3D objects can be presented on the Web and be interactively changed/navigated, it will be beneficial for the students' conceptual understanding on the domain topics. For example, the capabilities of VRML Model (Figure 6) include calculating number of reinforcement for simple structures such as rectangular beam and T-beam, generating the position of reinforcing steels, and plotting the 3-D navigational structures. Inputting beam dimensions and load information in a JavaScript based program, this generates the information in a VRML world file for view from any direction/angle and walk through the designed structure. It requires a web browser for interpreting standard html and JavaScript, such as Netscape or Internet Explorer, and a VRML browser such as Cosmo Player. In practice VRML is a text-based language, where objects are defined as geometries in this modeling language. The authors have used Silicon Graphics' Cosmo Worlds 2.0 to create the VRML files.

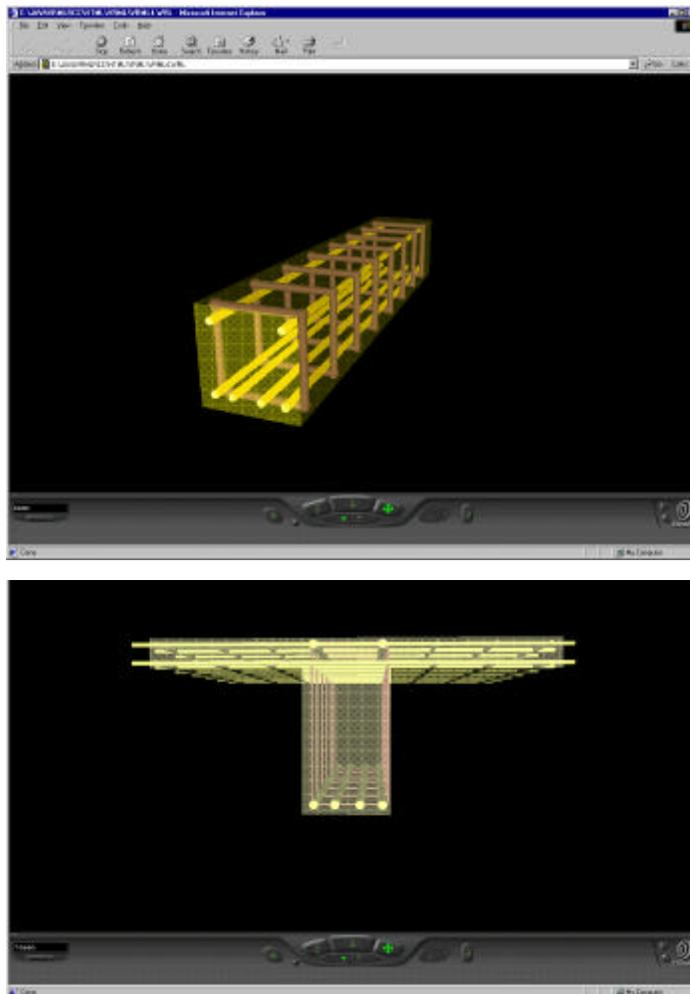


Figure 6 Virtual Design Navigation - Rectangular Beam (top) and T-Beam (bottom)

III. Concluding Remarks

Animation/visualization techniques provide virtual experiential learning when combined with interactive design animation and virtual design navigation. These activities are self-directed, experiential, and personalized for the autonomous self-directed distance learner. Web based teaching and learning has potential advantages compared to traditional education since it is less expensive, easy-to-access, easy-to-update and platform independent. Although multimedia is generally considered as an individual pursuit, authors' study suggest that its use in classes with a large audience can be accommodated, provided that it is linked directly to the achievement of a specific group of learning objectives. In this sense the proposed design studio model is seen to act as a navigator rather than as an oracle or source of knowledge. One of the true benefits of the proposed courseware with five concept visualization modules as discussed in this paper is its flexibility of usage in design education. The informal feedback from students has been positive as being a useful self-learning mechanism. Although the presented approach is being applied to reinforced concrete design principles, it employs a generic programming architecture in visualization techniques, which is discipline independent and can be adapted to any other similar domain, which will certainly promote and enhance students' understanding.

Bibliography

1. Haque M.E., Vamadevan A., Duraimurugar S., and Gandlur Y. Java and VRML based Interactive Reinforced Concrete Design Course Studio. American Society for Engineering Education, *ASEE 2000 Annual Conference Proceeding, Section 1315 Use of Computer Technology to Enhance CE Education*, St. Louis, MO: (2000).
2. Haque M.E., Vamadevan A. and Rotsawatsuk, P. Java-VRML Based Studio for Reinforced Concrete Design Principles. American Society for Engineering Education, *2000 ASEE North Central Section Spring Conference Proceeding, Section 202*, East Lansing, MI: (2000)
3. Budhu M. On the Determination of the Stress State in the Simple Shear Apparatus. *Geotechnical Testing Journal*, ASTM, pp. 211-222 (1998)
4. Jain K. and Noble, D. An interactive Web-based teaching tool for simplified 3D analysis of solar rhythms. *Elsevier, Automation in Construction* No. 8 pp. 181-194 (1998)
5. Miller G. Visual Mechanics – Beams & Stress States. University of Washington, PWS Publishing, (1998).
6. Long, P., Tricker, T., Rangecroft, M., and Gilroy, P. Satisfaction with distance education: evaluation of a service template. *Total Quality Management*. 11 (4-6), pp. 530-537 (2000).
7. Phillips, V. Online universities teach knowledge beyond books. *HR Magazine*. 43 (8), pp. 120-128 (1998).
8. Murphee, V. Using the virtual classroom. *Occupational Health & Safety*. 68 (9), pp. 28-29 (1999).
9. Martini, K. Digital Images and Seismic Design - A new role for photographs in architecture and engineering. AIA Faculty Institute on Teaching Seismic Design, Berkeley, CA, <http://urban.arch.virginia.edu/~km6e/ACSA-96/> (1996)

MOHAMMED E. HAQUE

Mohammed E. Haque is an Associate Professor of the Department of Construction Science at Texas A&M University at College Station, Texas. He has over fifteen years of professional experience in analysis, design, and investigation of building, bridges and tunnel structural projects of various city and state governments and private sectors. Dr. Haque is a registered Professional Engineer in the states of New York, Pennsylvania and Michigan, and members of ASEE, ASCE, and ACI. Dr. Haque received a BSCE from Bangladesh University of Engineering and Technology, a MSCE and a Ph.D. in Civil/Structural Engineering from New Jersey Institute of Technology, Newark, New Jersey. His research interests include fracture mechanics of engineering materials, composite materials and advanced construction materials, computer applications in structural analysis and design, artificial neural network applications, knowledge based expert system developments, application based software developments, and buildings/ infrastructure/ bridges/tunnels inspection and database management systems.