2   3-D Visualization and Animation Techniques in Structural Design Education

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Abstract

As technology rapidly changes, the importance of educating and training diverse populations of civil/construction engineering/science students becomes more critical. 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. 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, 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 approach adopted in this research was to create the interactive learning environment using Java and Virtual Reality Modeling Languages (VRML). VRML was the primary language used to create a virtual environment and 3-D simulation, and Java applets were created for interactive analysis, design and structural behavior animation over the World Wide Web (WWW). The presented paper illustrates the design concept visualization techniques for reinforced concrete structure analysis and design.

Keywords: *reinforced concrete design, virtual reality model, visualization, animation, distance learning, Java, VRML, WWW, 3-D*

INTRODUCTION:

The development of the World Wide Web (WWW) has led us to an unprecedented growth for the last ten years 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. The current information technology allows us to develop student-centered virtual design studio that can be reached to a large student population via the web. The student-centered distance learning archetype include dynamic demonstration of theoretical engineering models allowing students to manipulate, experiment, and translate theories into real-world applications. According to Menn (Mann 1993) evaluation of the impact of different instructional media on student retention of subject matter, it was found 90% of students remember, if they do the experiments themselves even if only as a simulation. In other words, guided tutoring and computer simulations through studios/labs that are properly designed and implemented could revolutionize technological education. The computer-based simulation software enables students to experiment interactively with the fundamental theories and apply them using electronic devices. It provides instant and reliable feedback. According to Gokhale (Gokhale 1996), in situations where the objective of instruction is to learn the facts without application or transfer, method of instruction is not a significant factor. However, if the educational goal is for students to transfer and apply the knowledge to real-world problems, then simulation integration into the class structure is an effective learning strategy.

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 an interesting challenge in an exciting area, requiring creativity and imagination as well as knowledge and systematic thinking. 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 (Martin and Haque 2001). The workplace is not systematic and concise, but rather it is filled with ambiguous situations. The teacher-centered classroom denies the student the opportunity to more self-directed, autonomous, and creative. The distance-learning archetype can be best described as a dynamic creative autonomous learning environment. 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 systems (Hiebert 1999; Long et al. 2000; Murphee 1999; Phillips 1998) have similarities around the globe. These virtual delivery systems hold student autonomy and creativity as essential attributes. This paper demonstrates various web-based visualization techniques including virtual animation, simulation and navigation, which are valuables for teaching structural designs.

CONCEPT VISUALIZATION TECHNIQUES:

The focal point of the structural design concept visualization approach is to assimilate the students' learning knowledge and behavior by providing individualized guidance and assessment tool. This includes (Haque et al. 2000):

- Structuring of the 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 virtual design and navigation.

This paper demonstrates five concept visualization techniques/approaches and their developing means and methodologies that are used in reinforced concrete design course via the web, which are:

1. HTML Presentation
2. 3-D Visualization and Animation
3. Annotated versions of manipulated images
4. Interactive Animation/Simulation, and
5. Virtual Navigation

HTML 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 various modes, such as PowerPoint slide presentation converted to HyperText Markup Language (HTML), and linked to other HTML files containing 2D/3D diagrams (Figure 1). The HyperText Markup Language (HTML) is the basic vehicle that delivers text information over the Internet. The author used various Web pages developing visual editors, including Microsoft's FrontPage2000, Word2000, and Macromedia Dreamweaver.
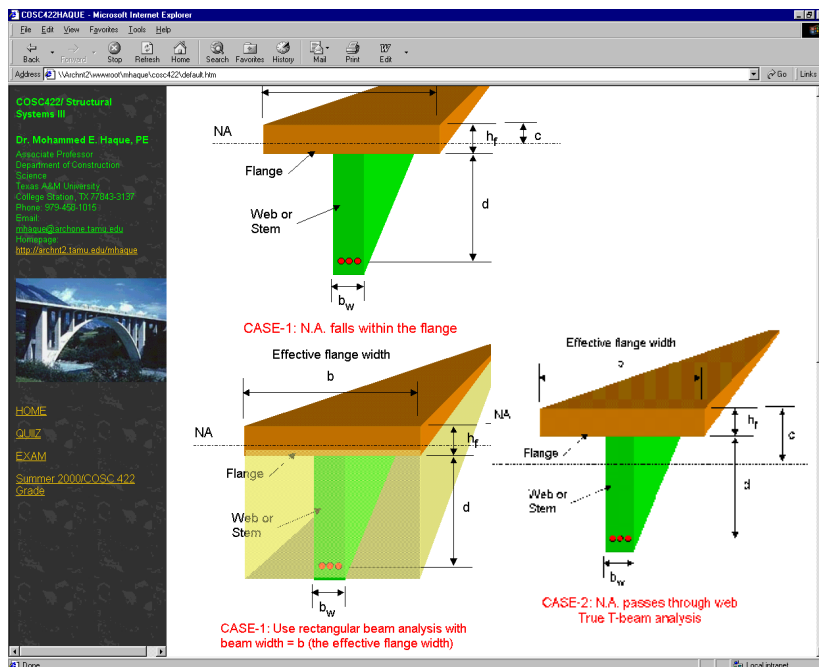
2.1.1   Figure 1 A lecture note: T-Beam Design Principles in 3-D Visualization

3-D Visualization and Animation: This module provides students with a variety of visual techniques, such as digital images, 3D graphics, and animation. The author has created several Geographical Interchange Format (GIF) animations for beam flexure and shear. In GIF animation, several frames are displayed in a rapid succession, which creates the illusion of movement. Figure 2 shows a few GIF frames for shear failure animation. A series of frames were created and displayed in a rapid succession (using 0.25 to 0.5 second intervals) to create the illusion of beam shear crack propagation. This shear failure animation helps students to understand the theory behind the use of shear reinforcement (stirrups) in a reinforced concrete beam (Figure 3). GIF is the most important tool for bringing animation to the Web. The GIF animation files are small, which 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 author also 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.
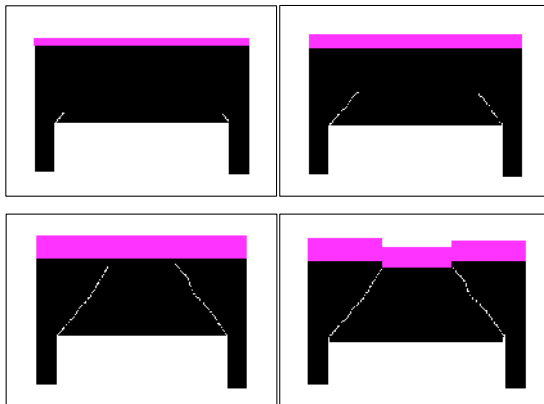

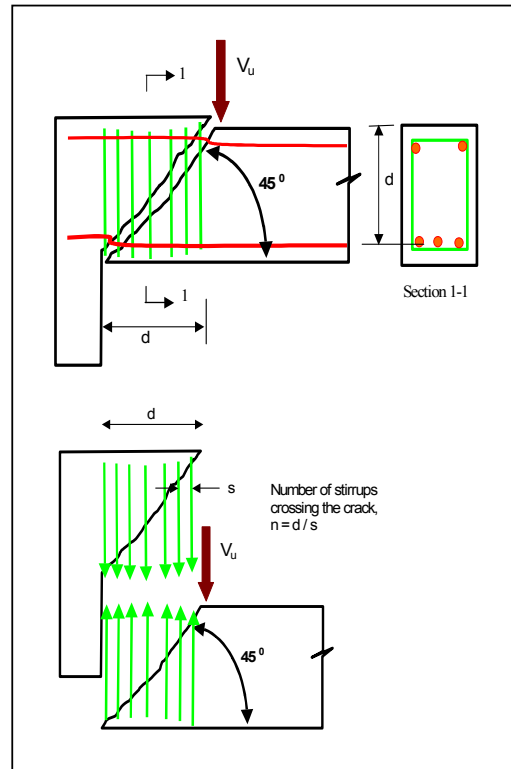*Figure 2 A Few GIF Frames of Concrete Beam Shear Failure Animation*

Figure 3 Theory behind the shear reinfo
(Digital image from Northridge Collection, Earthquake Engineering Research Center,

Annotated versions of manipulated images: The manipulated images are powerful tools for teaching design courses. If a student has a difficulty with a complex problem, these annotated versions of manipulated images explicitly show the foundations of the design mechanics by breaking up the problem into their natural components, and showing the connectivity between those components. Before a subject topic is presented in its abstract form, students are shown a concrete representation of the problem. In order to demonstrate the mode of reinforced concrete failure behavior, digital annotated versions of manipulated images with power point subject presentation are appropriate. On top of a digital photograph, semi-transparent arrow signs, rotation signs, deformation signs, etc. can be easily added using Microsoft Word Draw commands, Adobe Photoshop software, and others. For examples, the arrow notations used in Figures 4-6 explain the shear failure and flexural/bending failures in a reinforced concrete structures respectively. Once the students see the real structural failures and try to understand the mechanics behind the failures with the help of manipulated images, their interest to learn the theories of structural designs grow many folds.
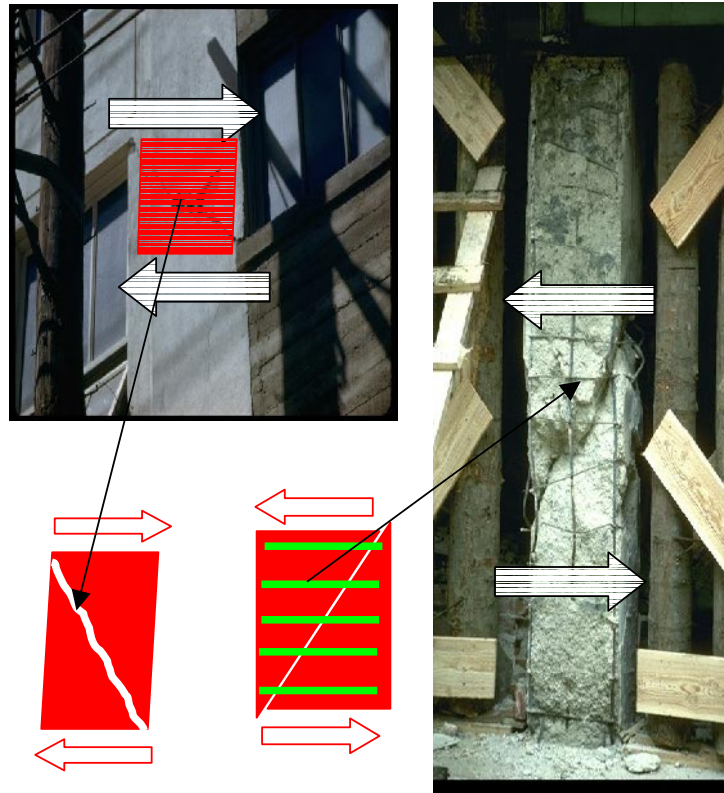
Figure 4 Manipulated Image visualization for shear failure.
(Digital images from Steinbrugge Collection, Earthquake Engineering Research Center, University of California, Berkeley)
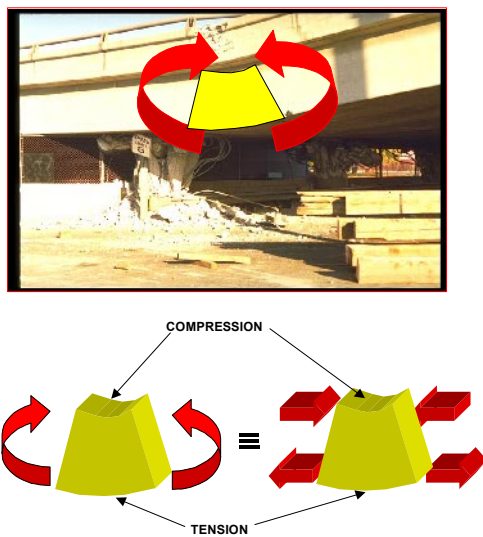

Figure 5. Manipulated Image visualization for flexural failure.
(Digital image from Northridge Collection, Earthquake Engineering Research Center, University of California, Berkeley)
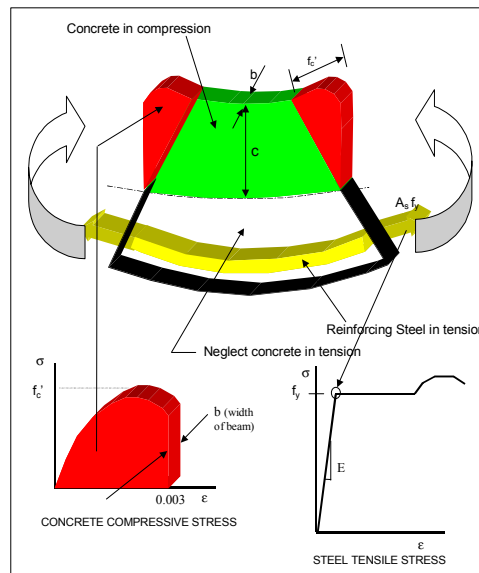

Figure 6. Structure's moment strength mechanism

Interactive Animation/Simulation: The dynamic virtual models can promote and support professor led motivational lectures as well as self-directed experiential learning activities. The conceptual principle adopted here for an example, is to reinforce students understanding of the behavior of concrete beams with the aid of simple structure such as simply supported beam with a point load on center of the beam. As the load is increased moment, deflection and shear forces changed. Figure 7 shows Java model screens (Haque, et al. 2000) where student 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, animated 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. The author has developed various analyses and design problems based Java applications using WebGAIN's Visual Cafe 4.0, and embedded them 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.
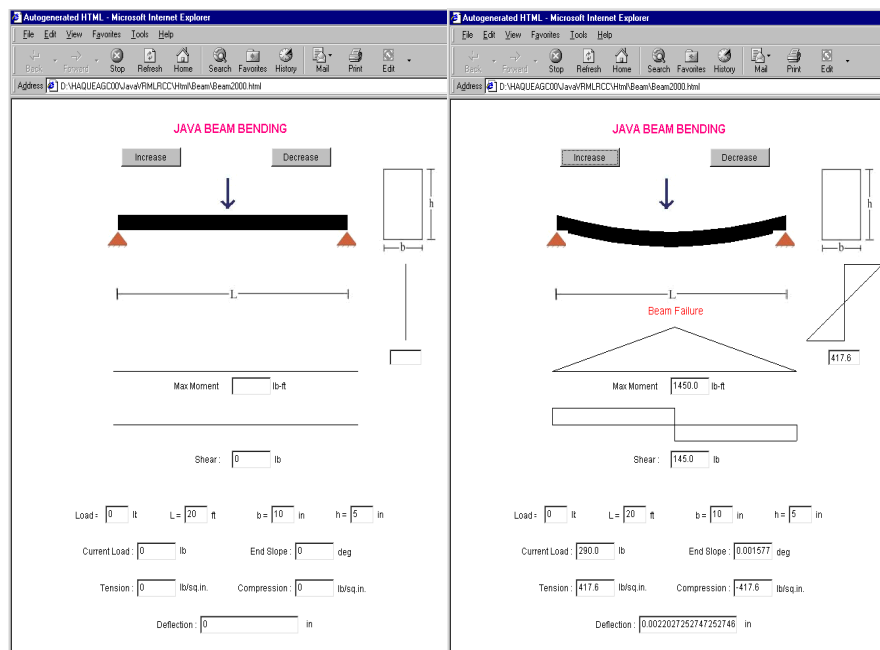

Figure 7 Java based Interactive Beam Analysis Animation

Virtual Navigation: It is found that many of the current internet-based educational applications do not present 3D objects even though 3D visualization is essential in teaching most engineering design principles. The author strongly believes 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 topics. For example, the capabilities of VRML Model (Figure 8) include calculating number of reinforcing steels for simple structures such as rectangular beam and T-beam, generating the position of this reinforcement 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 structures. 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 author used Silicon Graphics' Cosmo Worlds 2.0 to create the VRML files.
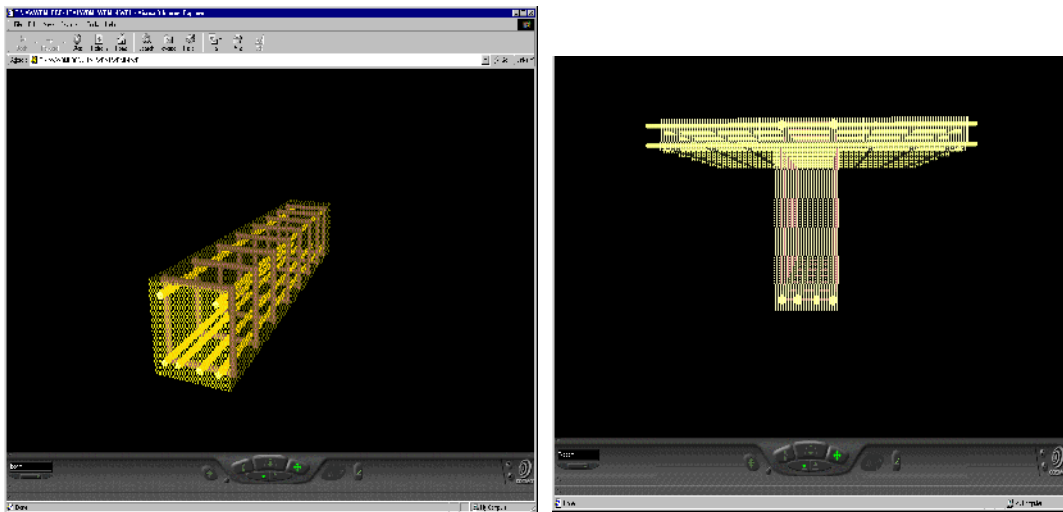

Figure 8 Virtual Design Navigation - Rectangular Beam (Top) and
T-Beam (Bottom)

CONCLUSIONS:

Various visualization techniques as discussed in this paper can be valuable aids not only in teaching design principles in the class room but also an effective self directed tool for open learning via the Web. The 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. 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. The 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.

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