Contemporary Techniques to Teach Reinforced Concrete Design

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Abstract

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, 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. The contemporary information technology allows us to develop student-centered virtual design studios that can be reached to a large student population via the web. The student-centered distance learning archetype includes dynamic demonstration of theoretical engineering models allowing students to manipulate, experiment, and translate theories into real-world applications. The traditional lecture format teaching methods sometimes fall short of conveying the complex analysis and design principles that need to be mastered in structural design. The textbooks available in structural design are mostly prepared for engineering students, and do an excellent job, but the associated rigorous theories make it an uninteresting academic hurdle for many below mediocre students. However when the theories are exemplified in a virtual environment with multimedia, animation, interaction, virtual walk-through, and manipulated image visualization techniques, students' conceptual understanding are enhanced. This paper demonstrates various design concept visualization techniques for reinforced concrete design, and their developing means and methodologies. These visualization techniques 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.

Introduction

Contemporary information technology allows us to develop learner-centered virtual design studios that can be reached to a large student population via the web. The student-centered distance-learning archetype should include dynamic demonstration of theoretical engineering models allowing students to manipulate, experiment, and translate theories into real-world applications. Visualization is an important factor in modern education. Traditional teaching falls

short of this aspect. Design concept visualization in reinforced concrete is a subject that depends on geometric and physical perception, and every effort should be made by educators to enhance this ability [1]. This makes it 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 that need to be mastered in reinforced concrete design course. One of the methods of reducing this short fall is to use simple animated virtual models, which demonstrate basic structural design concepts that can be used to enhance the students understanding. The interactive computer aided learning [1-5] allows students to proceed at their own pace, motivated by a curiosity about "what happens" interactivity and "the need to know" the design/ analysis principles.

The objective of this paper is to demonstrate various design concept visualization techniques for reinforced concrete design, and their developing means and methodologies. These visualization techniques 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.

Visualization Techniques

The visualization techniques that are discussed here are broadly classified under the following categories:

1. Image visualization/Animation
2. Digital Image Manipulation
3. Interactive Design Animation (Java-VRML based)
4. Walk-through Virtual Navigation

Image Visualization/Animation- The image visualization and animations are powerful tools for teaching design courses. If a student has a difficulty with a structural analysis and design problem, the animations of the structural response to loads explicitly show the foundations of the design mechanics by showing the connectivity between cause and effect. The author has created several GIF (Graphical Interchange Format) animations for beam flexure and shear. Figure 1 depicts a beam flexural failure animation creation using Adobe Image-Ready. It has animations of load increments, bending moment and beam deflection increments, tension crack growths and final collapse. In GIF animation, several frames are displayed in a rapid succession, which creates the illusion of movement. 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 other programs available for GIF animation, such as GIFmation, GifBuilder, GIF-Construction, Adobe Photoshop-ImageReady, Macromedia Flash, and Freehand. 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.

Digital Image Manipulation - The manipulated digital 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 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. For example, Figure 2 shows the arrow notation used by the model to explain the shear failure modes in a reinforced concrete structures [1,3]. 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. And they become ready to visualize the design mechanics (Figure 3) and theories [3].
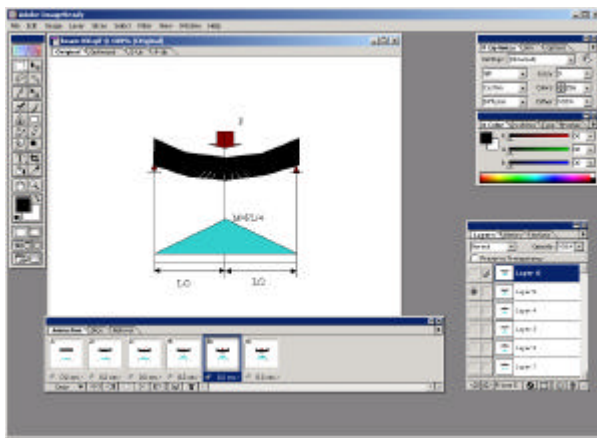

Figure 1: Beam flexural failure animation creation using Adobe Image-Ready
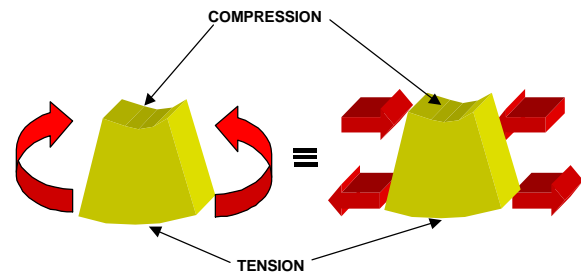

Figure 2: Manipulated Image visualization for flexural failure.
(Digital image from Northridge Collection, Earthquake Engineering Research Center, University of California, Berkeley)

Interactive Design Animation (Java-VRML based) - The dynamic virtual models can promote and support the professor led motivational lectures as well as self-directed experiential learning activities. Figure 4 shows Java model screens, where the user is allowed to define the load and beam geometry values [2]. 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. As the load is increased moment, deflection and shear forces increase. The conceptual principle adopted here 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.

To deliver the interactive content (Figure 4) on the web, Java programming language was used because of its platform and operating system independence. The WebGAIN's Visual Cafe 4.0 software was used to develop the Java applet. The 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. For running this model on a PC, one needs Java plug-ins, which are freely available on many web sites.
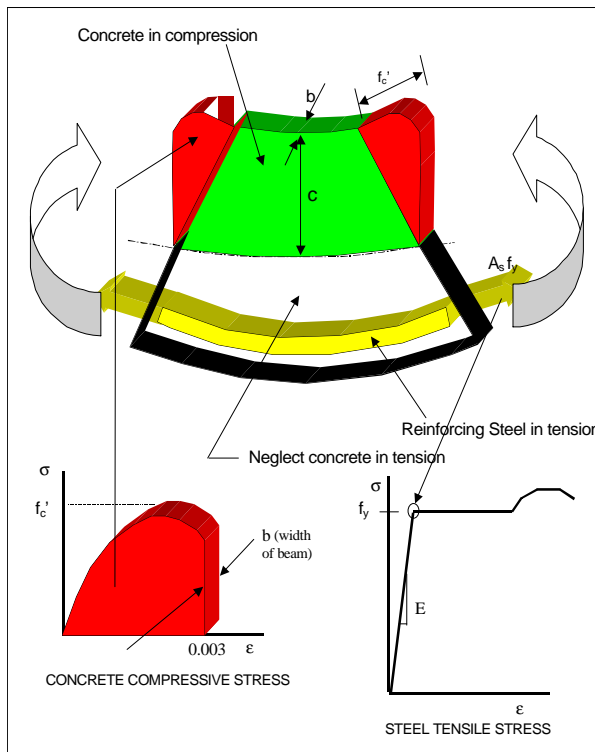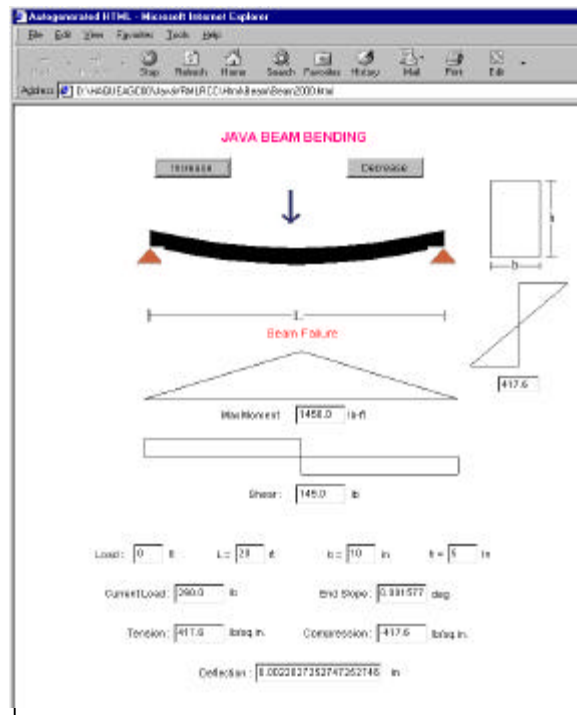

Figure 3: Structure's moment strength mechanism

Figure 4: Java based Interactive Beam Analysis Animation

Walk-through Virtual Navigation- It is found that most of the current internet-based educational applications do not resent 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 domain topics [1,3]. For example, the capabilities of VRML Model (Figure 5) include calculating number of reinforcement for simple structures such as rectangular beam and T-beam, generating the position of this reinforcement and plotting the 3-D navigational structure.

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 Silicon Graphic's Cosmo Worlds 2.0 was used to create the VRML files.

Nothing can be more convincing to a student than being walked-through a virtual model of a transparent concrete beam with reinforcement details (Figure 6). With a walk-through, things can be discovered, added or corrected before the actual construction begins. The 3D image and walkthrough animations was done using various functions of 3D-Max including photo-realistic lighting, camera matching, creating custom materials, volume lights, space warps, putting objects on paths, track view editor, skinning, etc.
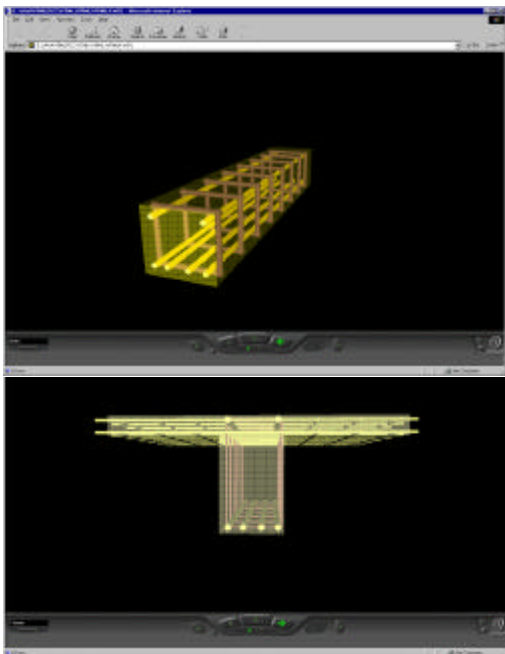

Figure 6: Walk-through within a transparent reinforced concrete beam

Figure 5: Virtual Design Navigation - Rectangular Beam and T-Beam

Animations involving just camera motion through a static scene or around a static object are adequate for many different applications. Using only camera motion, the viewer can see what it would be like to walk through a transparent concrete beam, which exists only as a computer model. This walkthrough is an excellent way to show the students the reinforcement details. Instead of 3D-Max, Maya can be used which is a very high quality 3D modeling, animation, and rendering software. It is used primarily to produce models and 3D graphics for movies, computer games, TV shows, and commercials. It is also used in industrial design applications to provide dynamic/animated visualizations. A person can create a model, animate it, and render it completely in Maya.

Conclusions

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. This paper describes with examples various visualization techniques that can be valuable aids not only in teaching design principles of reinforced concrete structures in the class room, but also effective self directed tools for open learning via the web. Web based teaching and learning has potential advantages compared to traditional education since it is less expensive, easy-to-access, easy-to-update, platform independent, and flexibility of usage in design education. The informal feedback from students has been positive as being a useful self-learning mechanism. All the techniques as discussed in this paper employ a generic programming architecture, which is discipline independent and can be adapted to any other similar domain, which will certainly promote and enhance students' understanding.

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